Virginia Erosion and Sediment Control Handbook

Third Edition

1992

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Much credit must be given to the "Commission Technical Staff," the "Erosion and Sediment Control Advisory Board" and the "Technical Advisors" who prepared or provided guidance for the previous edition of this handbook. The 1980 edition presented "state of the art" information and a solid framework which has become part of other technical publications and remains part of this handbook.

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FOREWARD

Regulatory authority for the Erosion & Sediment Control Program was transferred to the Department of Environmental Quality on July 1, 2013. Anywhere in the handbook where the Department of Conservation or DCR are referenced, the reference should be replaced; respectively, with the Department of Environmental Quality or DEQ. Additionally, anywhere Soil and Water Conservation Board or "Board" are reference in the handbook, the reference should be replaced with State Water Control Board.

This handbook replaces the 1980 Virginia Erosion and Sediment Control Handbook and establishes new standards and guidelines for the control of soil erosion and sedimentation on "land-disturbing activities" (as defined in Section 62.1-44.15:51, Code of Virginia). The authority for the Department of Environmental Quality to undertake this handbook revision is provided under Section 62.1-44.15:52 of the Code.

This handbook is intended to serve as a technical guide in the effort to meet the requirements dictated by the Virginia Erosion and Sediment Control Law and the Virginia Erosion and Sediment Control Regulations *(9VAC25-840; previously 4VAC50-30)*. The use of the words such as "shall," "will," and "must" within the design standards in Chapter 3 is meant to emphasize the directions which will ensure that the control measure or design procedure will serve its intended purpose. The remaining chapters and sections of this handbook contain guidelines and support materials to assist users in the implementation of the technical standards in accordance with the provisions of the law and regulations.

Any questions or comments concerning this handbook or the Virginia Erosion and Sediment Control Program in general may be directed to the Virginia Department of Environmental Quality.

CHAPTER 1

Introduction

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INTRODUCTION

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CHAPTER 1

INTRODUCTION

While all lands erode, not all land can be considered a source of sediment pollution. There has always been a certain amount of erosion that occurs naturally. However, major problems can occur when large amounts of sediment enter our waterways. This accelerated erosion is most often caused by surface mining, poorly managed croplands, construction sites, urban/suburban stream banks, and logging roads.

This publication focuses on one specific sediment pollution source: construction sites. The typical construction site erodes at a rate of up to 100,000 tons per square mile per year. This rate is 200 times greater than erosion from cropland and 2000 times greater than erosion from woodland (48).

The successful mitigation of soil losses on urban construction sites results in the reduction of on-site and off-site environmental damage and substantial savings to developers and their subcontractors. When implemented properly, erosion and sediment control (E&S) measures can control soil movement to a point where there is only minimal loss of this very precious resource; no appreciable damage to off-site receiving channels; enhanced project aesthetics before, during and after development; and fewer complaints from concerned government agencies and citizens. Notably, there is a state law and regulation which dictate the use of such measures.

A function of the Virginia Erosion and Sediment Control Handbook (hereafter referred to as "handbook") is to establish minimum design and implementation standards for these measures in the effort to control erosion and sedimentation from land-disturbing activities in Virginia. (The term "land-disturbing activity" in this book refers to the definition found in Section 10.1-560 in the Virginia Erosion and Sediment Control Law (VESCL) located in Chapter 8). The other function of the handbook is to provide guidelines for the implementation of those standards in accordance with the VESCL and the Virginia Erosion and Sediment Control Regulations (VESCR).

At the time the original handbook was developed in 1974, the emphasis was on local program establishment. That document served as a basis for the development and adoption of local E&S programs throughout the state. Once the program establishment phase had been completed, the emphasis was shifted to program implementation.

The handbook was revised in 1980 to improve the effectiveness of the statewide E&S program. This latest revision provides updated information on E&S measures, engineering methods, law and regulation changes and stresses proper program implementation to further enhance the state and local attempts to mitigate sediment loss as a result of urban construction.

HANDBOOK OBJECTIVES

* Revised Standards and Specifications: New conservation practices and methods have been introduced as well as improved criteria for designing and implementing existing practices. Site planners and engineers need to be aware of the most recent technological developments in the field to improve the effectiveness of their erosion and sediment control design.

* Present an Acceptable Level of Control: The handbook contains assistance for site planners and plan reviewers on the selection of conservation practices in order to achieve an acceptable level of control on a project. Specific guidance is also provided in the application of conservation practices.

* Address Stormwater Management: The handbook addresses post-development stormwater considerations associated with runoff from regulated activities. The design of a stormwater management system should receive high priority in site planning. Requirements for designing such systems which minimize adverse downstream effects of increased runoff are contained in the VESCR in Minimum Standard (MS) #19, and methods for meeting those requirements are contained within. Off-site erosion, flooding and nonpoint source pollution due to urban development in a watershed have become significant statewide problems which must be addressed.

* Compliance with Section 319 of the Clean Water Act of 1987 and the Virginia Nonpoint Source Pollution (NPS) Management Program: Since the development of the original handbook, Section 319 of the Federal Clean Water Act was created and dictated the creation of a Virginia NPS Management Program. The Virginia NPS Management Program identifies statewide programs designed to quantify, control and limit the detrimental effects of nonpoint source pollution. The state's Erosion and Sediment Control Program has been placed under the category of urban nonpoint source pollution control and will strive to meet the goals noted in the program. The Virginia Erosion and Sediment Control Handbook is one of three proposed urban nonpoint source pollution control manuals. The other two volumes will be developed in the near future.

* Make the Handbook More Usable: It is extremely important that the people who administer the VESCL be provided with useful information which is written in terms they can easily understand and pass on to those responsible for design or those involved in site implementation of E&S. While a certain amount of technical expertise is required to adequately prepare or review E&S plans and specifications, technical material which is presented in a manner which is more understandable tends to be more readily accepted and adhered to by the public.

* Provide Revised Information: Amendments to the VESCL have required the replacement of outdated and obsolete guidelines.

MAJOR CHANGES

The 1992 revision of the handbook is intended to incorporate changes in the VESCL that have been made in the last decade. In September of 1990, the VESCR were adopted and took the place of the 14 "General Criteria" which appeared in the 1980 edition. The format and style of the handbook have been maintained; however, an effort has been made to refine each chapter and include language that accurately reflects the parameters set forth by the VESCR.

EFFECT OF HANDBOOK REVISION ON LOCAL PROGRAMS

Local programs should benefit from the introduction of the VESCR into the handbook. The VESCR contain the "Minimum Standards" that more clearly define the intent of the VESCL and provide the framework for greater consistency among local programs in terms of administration, implementation and enforcement.

CHANGES IN CONSERVATION PRACTICES

Technical advances of the past decade have prompted the addition of new practices for the control of erosion and sedimentation and the refinement of existing practices. Also, improvements to some of the engineering methods used in the previous handbook have resulted in changes when appropriate.

HOW TO USE THIS HANDBOOK

This handbook is intended to serve as a technical guide in the effort to meet the requirements dictated by the VESCL and the VESCR. The use of words such as "shall," "will," and "must" within design or implementation standards (notably in Chapter 3) is meant to emphasize the directions which will ensure that the control measure or design procedure will serve its intended purpose. Innovative modifications to the control measures or design procedures are acceptable and encouraged, especially if they improve upon sediment-loss mitigation. However, designers and plan reviewers should be sure that the modified practice or procedure will be at least as successful as those noted in this handbook in meeting the intent of the VESCL and the VESCR.

ABBREVIATIONS/ACRONYMS

The following terms are abbreviated or appear as acronyms in the handbook:

Abbreviation/ Acronym	Term	Abbreviation/ Acronym	Term
approx.	approximate	N.C.	North Carolina
A.S.T.M.	American Society for Testing and Materials	pt.	point
avg.	average	R/W	right-of-way
cfs	cubic feet per second	sq.	square
csm/in.	cubic feet per second, per square mile, per inch	spec.	specification
corp.	corporation	std.	standard
cu.	cubic	tol.	tolerance
dept.	department	typ.	typical
dia.	diameter	USDA-SCS	U.S. Department of Agriculture, Soil Conservation Service
ed.	edition	USDI	U.S. Department of the Interior
elev.	elevation	Va. DSWC	Virginia Division of Soil and Water Conservation
E&S	erosion and sediment control	VCIA	Virginia Crop Improvement Association
fps	feet per second	VDOT	Virginia Department of Transportation
gal.	gallon	VESCL	Virginia Erosion and Sediment Control Law
inc.	incorporated	VESCR	Virginia Erosion and Sediment Control Regulations
lbs.	pounds	VHTRC	Virginia Highway and Transportation Research Council
max.	maximum	vol.	volume
min.	minimum	VPI&SU	Virginia Polytechnic Institute and State University
min	minute	VTM	Virginia Testing Methods
mm.	milimeter	yd.	yard
N/A	not applicable	yr.	year

FUTURE UPDATES

It is envisioned that modifications to the handbook will be necessary from time to time. The handbook has been designed to accommodate inclusion of information as needed.

CHAPTER 2

Erosion and Sediment Control Principles, Practices and Costs

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EROSION AND SEDIMENT CONTROL
PRINCIPLES, PRACTICES AND COSTS

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CHAPTER 2

EROSION AND SEDIMENT CONTROL PRINCIPLES, PRACTICES AND COSTS

This chapter contains basic information on the principles, practices and costs of erosion and sediment control on urban land-disturbing projects. It is divided into three parts.

PART I - EROSION AND SEDIMENT CONTROL PRINCIPLES: Information on the causes and effects of erosion and sedimentation is presented along with a discussion of basic conservation principles for effectively controlling the problem.

PART II - OVERVIEW OF PRACTICES: The nature, purpose and distinguishing features of erosion and sediment control practices are briefly summarized to provide users with a quick reference and broad basis of comparison.

PART III - COSTS: Information on estimating the cost of implementing various vegetative and structural erosion and sediment control practices is provided.

WALL CHART: A large, folded wall chart is contained in a pocket at the end of this chapter to provide users with a single-sheet reference to all of the erosion and sediment control practices found within. This chart consolidates relevant information concerning the selection and application of the practices and presents a unified coding system for designers who will specify the practices on erosion and sediment control plans.

PART I

EROSION AND SEDIMENT CONTROL PRINCIPLES

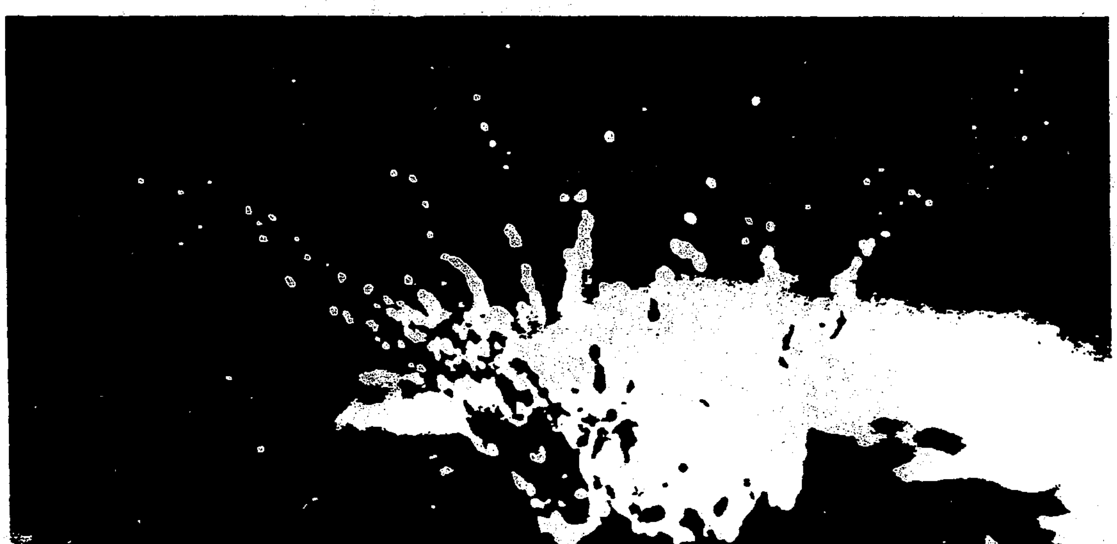
THE EROSION PROCESS

Soil erosion is the process by which the land's surface is worn away by the action of wind, water, ice and gravity. Natural, or geologic erosion has been occurring at a relatively slow rate since the earth was formed, and is a tremendous factor in creating the earth as we know it today. The picturesque mountains of the west, the rolling farmlands of the Piedmont, and the productive estuaries of the Coastal Zone are all products of geologic erosion and sedimentation in Virginia. Except for some cases of shoreline and stream channel erosion, natural erosion occurs at a very slow and uniform rate and remains a vital factor in maintaining environmental balance.

Water-generated erosion is unquestionably the most severe type of erosion, particularly in developing areas; it is, therefore, the problem to which this handbook is primarily addressed. It is helpful to think of the erosive action of water as the effects of the energy developed by rain as it falls, or as the energy derived from its motion as it runs off the land surface. The force of falling raindrops is applied vertically, and force of flowing water is applied horizontally. Although the direction of the forces created is different, they both perform work in detaching and moving soil particles.

Water-generated erosion can be broken down into the following types:

Raindrop erosion is the first effect of a rainstorm on the soil. Raindrop impact dislodges soil particles and splashes them into the air (see picture below). These detached particles are then vulnerable to the next type of erosion.



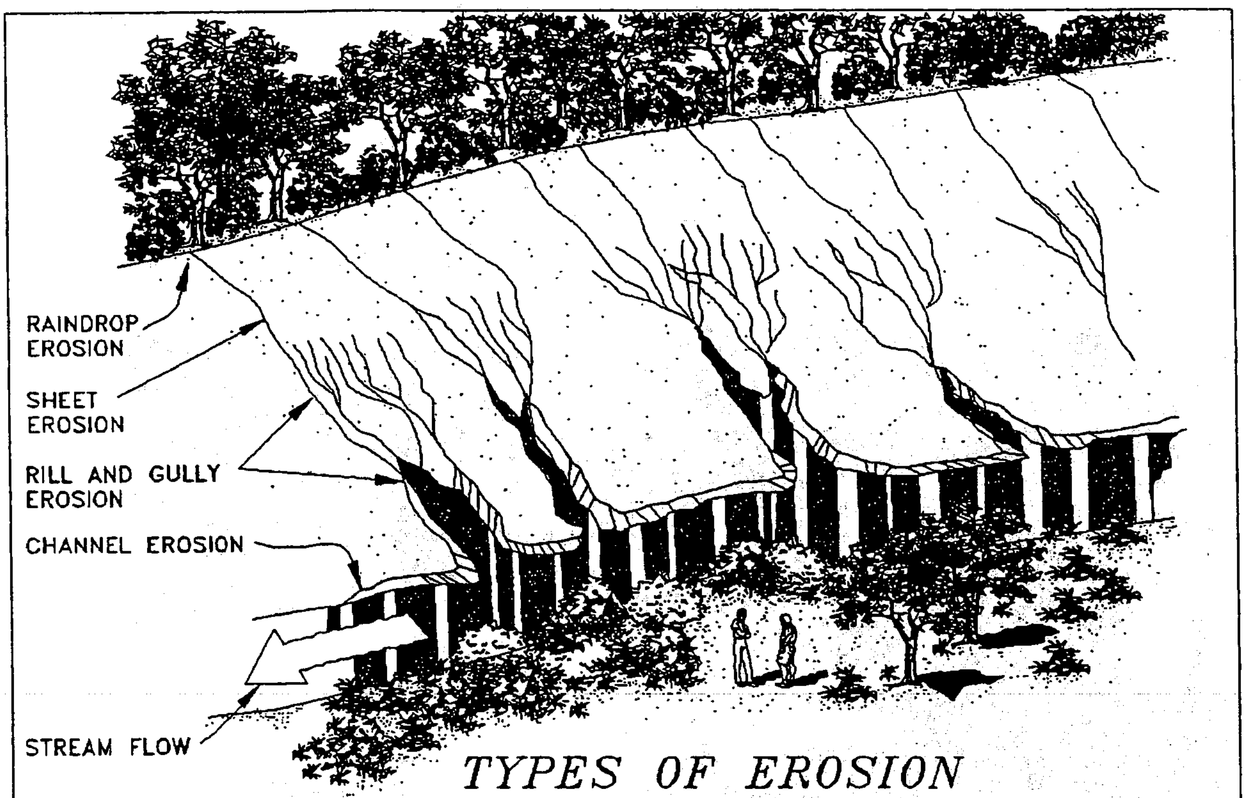
Source: Soil Conservation Society of America

Sheet erosion is the erosion caused by the shallow flow of water as it runs off the land. These very shallow moving sheets of water are seldom the detaching agent, but the flow transports soil particles which are detached by raindrop impact and splash. The shallow surface flow rarely moves as a uniform sheet for more than a few feet on land surfaces before concentrating in the surface irregularities.

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

Gully erosion occurs as the flow in rills comes together in larger and larger channels. The major difference between gully and rill erosion is a matter of magnitude. Gullies are too large to be repaired with conventional tillage equipment and usually require heavy equipment and special techniques for stabilization.

Channel erosion occurs as the volume and velocity of flow causes movement of the stream bed and bank materials. Plate 2-1 illustrates the five stages of erosion.



Source: Michigan Soil Erosion and Sedimentation Guidebook   Plate 2-1

FACTORS INFLUENCING EROSION

The erosion potential of any area is determined by four principal factors: the characteristics of its soil, its vegetative cover, its topography and its climate. Although each of these factors is discussed separately herein, they are inter-related in determining erosion potential.

Soil characteristics which influence the potential for erosion by rainfall and runoff are those properties which affect the infiltration capacity of a soil and those which affect the resistance of the soil to detachment and being carried away by falling or flowing water. The following four factors are important in determining soil erodibility:

1. Soil texture (particle size and gradation)
2. Percentage of organic content
3. Soil structure
4. 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. Soils high in organic matter have a more stable structure which improves their permeability. Such soils resist raindrop detachment and infiltrate more rainwater. Clear, well-drained and well-graded gravel and gravel-sand mixtures are usually the least erodible soils. Soils with high infiltration rates and permeabilities either prevent or delay and reduce the amount of runoff.

Vegetative cover plays an extremely important role in controlling erosion as it provides the following five benefits:

1. Shields the soil surface from raindrop impact
2. Root systems hold soil particles in place
3. Maintains the soil's capacity to absorb water
4. Slows the velocity of runoff
5. Removes subsurface water between rainfalls through the process of evapo-transpiration

By limiting and staging the removal of existing vegetation and by decreasing the area and duration of exposure, soil erosion and sedimentation can be significantly reduced. 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, drainageways, and the banks of streams.

Topography. The size, shape, and slope characteristics of a watershed influence the amount and rate of runoff. As both slope length and gradient increase, the rate of runoff increases and the potential for erosion is magnified. Slope orientation can also be a factor in determining erosion potential. For example, a slope that faces south and contains droughty soils may have such poor growing conditions that vegetative cover will be difficult to re-establish.

Climate. The frequency, intensity, and duration of rainfall are fundamental factors in determining the amounts of runoff produced in a given area. As both the volume and velocity of runoff increases, the capacity of runoff to detach and transport soil particles also increases. Where storms are frequent, intense, or of long duration, erosion risks are high. Seasonal changes in temperature, as well as variations in rainfall, help to define the high erosion risk period of the year. When precipitation falls as snow, no erosion will take place. However, when the temperature rises, melting snow adds to runoff, and erosion hazards are high. Because the ground is still partially frozen, its absorptive capacity is reduced. Frozen soils are relatively erosion-resistant. However, soils with high moisture content are subject to uplift by freezing action and are usually very easily eroded upon thawing.

SEDIMENTATION

Normally, runoff builds up rapidly to a peak and then diminishes. Excessive quantities of sediment are derived by erosion, principally during the higher flows. During lower flows, as the velocity of runoff decreases, the transported materials are deposited to be picked up by later peak flows. In this way, sediments are carried downslope, or downstream, intermittently and progressively from their source or point of origin. A study of sedimentation due to highway construction and land development in Virginia, for instance, indicated that 99 percent of the sediment discharge occurred during periods of high flow which took place during only three percent of the period of measurement (77).

SEDIMENT POLLUTION AND DAMAGE

Sediment pollution is soil out of place. It is a product of the activities of man which lead to severe soil loss. When these large quantities of soil enter our waters, then sediment pollution occurs.

Over four billion tons of sediment are estimated to reach the ponds, rivers, and lakes of our country each year, and approximately one billion tons of this sediment is actually carried all the way to the ocean. Approximately 10 percent of this amount is contributed by erosion from land undergoing highway construction or land development (73). Although these latter quantities may appear to be small compared to the total, they could represent more than one-half of the sediment load carried by many streams draining small subwatersheds which are undergoing development (81).

Excessive quantities of sediment cause costly damage to waters and to private and public lands. Obstruction of stream channels and navigable rivers by masses of deposited sediment reduces their hydraulic capacity which, in turn, causes an increase in subsequent flood crests and a consequent increase in the frequency of damaging storm events.

Sediment fills drainage channels, especially along highways and railroads, and plugs culverts and storm drainage systems, thus necessitating frequent and costly maintenance. Municipal and industrial water supply reservoirs lose storage capacity, the usefulness of recreational impoundments is impaired or destroyed, navigable channels must be continually dredged and the cost of filtering muddy water preparatory to domestic or industrial use becomes excessive - and sometimes exorbitant. The added expense of water purification in the United States, because of sedimentation, amounts to millions of dollars each year.

In an aquatic environment, the general effect of fine-graded sediments such as clays, silts, and fine sands is to reduce drastically both the kinds and the amounts of organisms present. Sediments alter the existing aquatic environment by screening out sunlight and by changing the rate and the amount of heat radiation. Particles of silt settling on stream and lake bottoms form a blanket which creates a hostile environment for the organisms living there and literally smothers many of them and their eggs. The disastrous effect (upon commercially valuable finfish and shellfish populations) of excessive amounts of silt entering estuarine waters was widely publicized in the case of the Chesapeake Bay following flooding of its main tributary, the Susquehanna River, caused by Hurricane "Agnes" in 1972.

Coarser-grained materials also blanket bottom areas to suppress aquatic life found in these areas. Where currents are sufficiently strong to move the bedload, the abrasive action of these materials in motion accelerates channel scour and has an even more severely deleterious effect upon aquatic life. The aesthetic attraction of many steams, lakes, and reservoirs used for swimming, boating, fishing, and other water-related recreational activities has been seriously impaired or destroyed by bank cutting and channel scour - accelerated by a higher flood stages induced by sedimentation.

EROSION AND SEDIMENT HAZARDS ASSOCIATED WITH LAND DEVELOPMENT

The principal effect land development activities have on the natural or geologic erosion process consists of exposing disturbed soils to precipitation and to surface storm runoff. Shaping of land for construction or development purposes alters the soil cover and the soil in many ways, often detrimentally affecting on-site drainage and storm runoff patterns and eventually the off-site stream and streamflow characteristics. Protective vegetation is reduced or removed, excavations are made, topography is altered and the removed soil material is stockpiled - often without protective cover. In effect, the physical properties of the soil itself are changed. The development process is such that many citizens of a locality may be adversely affected even by development of areas of only limited size. Uncontrolled erosion and sediment from these areas often causes considerable economic damage to individuals and to society, in general. Surface water pollution, channel and reservoir siltation and damage to public facilities, as well as to private property, are some of many examples of problems caused by uncontrolled erosion and sedimentation.

Potential hazards associated with development include:

1. A large increase in areas exposed to storm runoff and soil erosion.

2. Increased volumes of storm runoff, accelerated soil erosion and sediment yield and higher peak flows caused by:

a. Removal of existing protective vegetative cover.
b. Exposure of underlying soil or geologic formations which are less pervious and/or more erodible than original soil surface.
c. Reduced capacity of exposed soils to absorb rainfall due to compaction caused by heavy equipment.
d. Enlarged drainage areas caused by grading operations, diversions, and street constructions.
e. Prolonged exposure of unprotected disturbed areas due to scheduling problems and/or delayed construction.
f. Shortened times of concentration of surface runoff caused by altering steepness, distance and surface roughness and through installation of "improved" storm drainage facilities.
g. Increased impervious surfaces associated with the construction of streets, buildings, sidewalks and paved driveways and parking lots.

3. Alteration of the groundwater regime that may adversely affect drainage systems, slope stability and survival of existing and/or newly established vegetation.

4. Creation of south and west directional exposure of property which may hinder plant growth due to adverse temperature and moisture conditions.

5. Exposure of subsurface materials that are rocky, acid, droughty or otherwise unfavorable to the establishment of vegetation.

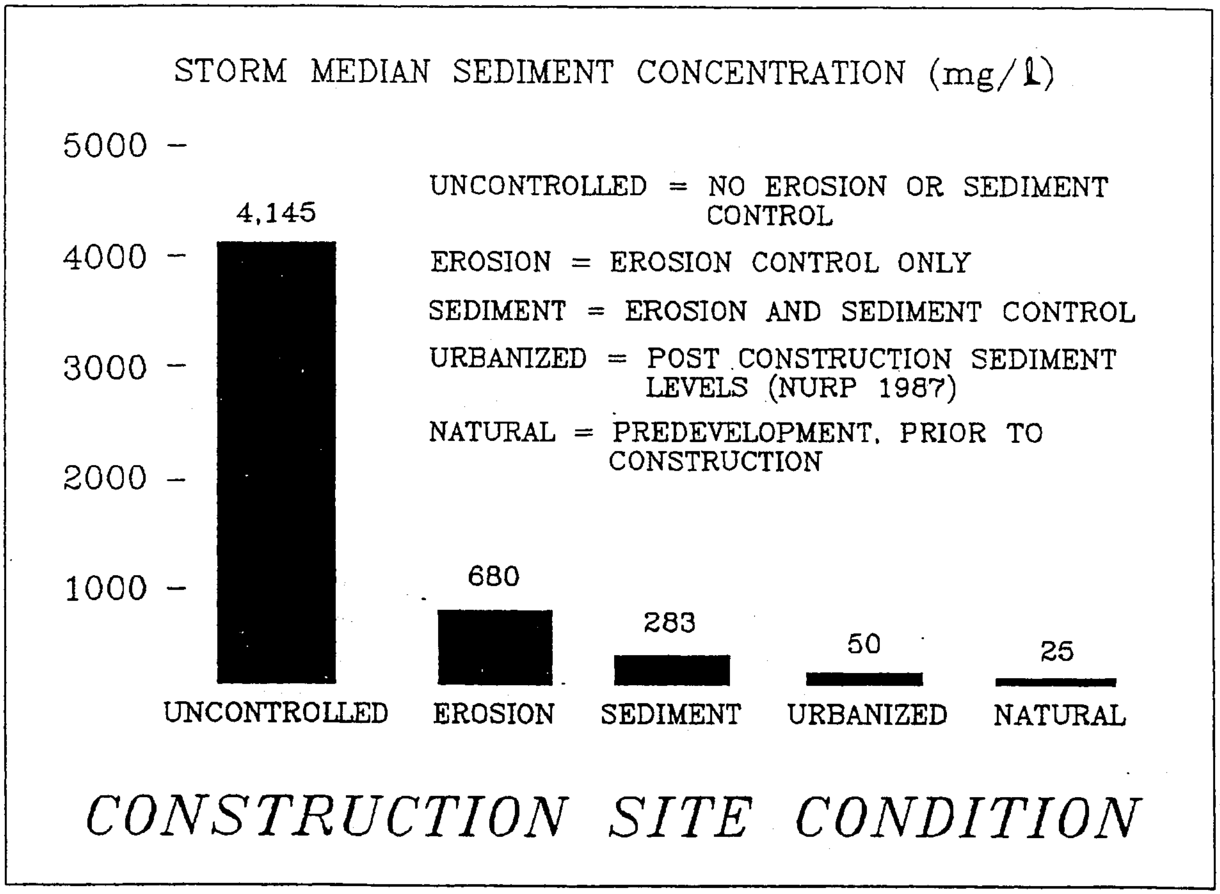
6. Adverse alteration of surface runoff patterns by construction and development.

Increases in sedimentation yield higher levels of nutrients and toxicants. The results of high sediment loading can have a profound effect on the environment. Sediment acts like a magnet to toxicants and trace metals. Additionally, the soil introduces nutrients into streams and groundwater. The net effect is to create a strata known as diagenesis. This activity decreases the oxygen available to support other aquatic life. Even more startling is the apparent ability of sediment to act as long term memory or storage media for toxicants. Studies show that pollutants such as DDT, DDE, PCBs and chlordane whose use has been banned or highly restricted, can still be found at detectable levels in sediment deposited years ago in the bottom of streams and rivers. It has been demonstrated that urbanization and associated sedimentation reduces the diversity of the fish populations in streams as well as the organisms that fish feed on.

The capacity of a stream to maintain its health can be related to the impervious areas within its watershed. Urbanization of a watershed increases the impervious surfaces and increases the pollutant load. One study suggests that once a watershed becomes 12% impervious, the quality of aquatic life has reached a critical threshold.

Responsible development requires that steps be taken to control erosion and sedimentation from construction sites. Plate 2-2 demonstrates the ability of good erosion and sediment controls, versus no controls, in minimizing the detrimental effects of sedimentation.

This chart also demonstrates the fact that once a naturally vegetated area has been developed, sediment levels can be twice the pre-development rate. It is well known that the erosion and sediment threat is greatest during construction; once development is complete (stabilization techniques implemented), there is a dramatic decrease in the pollutant level yield.



Source: <u>Performance of Current Sediment Control Measures at Maryland Construction Sites,</u> Metropolitan Washington Council of Governments

Plate 2-2

In the past, efforts have been made to quantify the damage caused by erosion and sedimentation in terms of dollars spent to dredge navigational channels, loss of reservoir capacity and so on. More recently, efforts have concentrated on the qualitative cost. It is very difficult to place a dollar figure on damage to the environment; however, we cannot escape the fact that human health and well-being is ultimately related to the environment in which we live.

DOLLARS AND SENSE

It is well known that urbanization has the following effects:

* Accelerated Rate of Soil Erosion
* Increase in the Peak Discharge and Total Volume of Stormwater
* Increased Potential for "Flash" Flooding
* Decreased Groundwater Recharge
* Increased Temperature in Natural Receiving Channels
* Increased Pollutant Loading to Receiving Waters

Each of these factors has an associated cost. The VESCL and the VESCR attempt to minimize these costs by regulating land-disturbing activities in the State of Virginia. All of the citizens of the Commonwealth stand to gain when local E&S programs are effective and developers follow responsible management procedures. The net results are dollars saved and a direct benefit to the environment.

COST TO THE DEVELOPER

The VESCL requires that land-disturbing activities have an approved E&S plan prior to commencement of work. The owner must provide the plan or pay someone else (i.e., engineer, architect, planner) to provide this plan. Once a plan is approved, generally a contractor places the controls. However, the owner is ultimately responsible and in fact must certify that the plan will be carried out. Once the project has moved through the bid process, the cost of implementation becomes the primary concern. Proper implementation of the E&S plan can save the developer and the contractor money in excavation costs. If denuded areas are stabilized initially, little or no additional work will be required later. This can speed up completion dates, and overall savings will be realized. This strategy requires that planning take on a more important role in the management of a project. Good management throughout the life of a project will lead to increased savings.

On the other hand, failure to implement an E&S plan or failure to maintain controls during construction of a project can mean additional costs to the developer and the contractor. These additional costs exist at three levels. The primary level is the cost of work being stopped for non-compliance with an approved plan; the secondary level is the cost of repairing damage to adjacent properties; the tertiary level would be the costs associated with missed deadlines, litigation with damaged parties and extra charges from the contractor for additional work. The perception of the public that the developer and the contractor were negligent in performing their responsibilities may also pose a negative cost -if not now, sometime in the future.

At least one engineer has tried to relate these costs to the developer and contractor, based on his own experience and his year of practice. In a seminar on E&S, Mr. Jack Rinker of Rinker-Detwiler and Associates, P.C. presents a scenario called the "Hidden Cost to Down Time from Construction Stops by Government." The following is an abbreviated version of this scenario:

> Assume that a 50-house subdivision is underway. During construction, a rainstorm occurs. This storm can be either moderate or severe. Accordingly, erosion and sedimentation damage from the storm, because E&S measures were never placed, can be either moderate or severe. After the storm, neighbors call the local building official's office to complain. The building official visits the site, observes sedimentation damage and the potential for more, and immediately stops work on the project. This hypothetical situation assumes that the chief administrative officer of the locality has delegated the ability to "stop work" to the building official and that this was deemed an "emergency situation." At this time, all land-disturbing activity on the project is stopped. Three crews are affected by the work stoppage: the grading crew, curb and gutter crew and the utilities contractor. The job superintendent has to divert all of his attention to the immediate erosion problem and calls his office. His office in-turn calls the owner and then the owner calls the engineer and his attorney. The job has come to a virtual standstill because everyone's attention is focused on "putting out the fire." The neighbors are now calling the developer and voicing their disgust. Action must be taken. On the advice of his attorney, the developer makes the decision to have the contractor remove the sediment that has moved onto the neighbors' property. At the request of the owner, the engineer visits the site to assess the damage. The next day, the developer meets with his attorney, the engineer and local government officials to see what must be done to get this job "back on track." The adjacent property owners are still complaining even though work to remove the sediment has begun. The engineer determines that the controls shown on the original E&S plan should have been installed during the first stage of grading to prevent damage to adjacent property. These controls could have prevented the problem in the first place, if they had been installed! Much of the attorney's costly time is spent trying to calm the mood of the neighbors and local officials.

At this point, let us look at the potential damage:

* <u>Moderate Damage</u>: 12 cubic yards of sediment must be removed from one neighbor's property and the lawn must be repaired.

* <u>Severe Damage</u>: 12 cubic yards of sediment must be removed from the neighbor's property; however, the sediment has moved past the property owner's fence and a large section of fence must be removed to gain access to the property with equipment. In the process of getting equipment in and out of the property, six trees and 20 shrubs are damaged. The neighbor is even more angry now!

Possible Costs

Item:	Moderate Damage	Severe Damage
Clean-up crew mobilization	$ 288.00	$ 288.00
Silt removal and hauling	153.00	153.00
Dumping charge at landfill	60.00	60.00
Grading work	133.00	133.00
Fertilizer and seed	111.00	------
Mulch and tack	150.00	------
Sod and fertilizer	------	640.00
Replace 20 shrubs	------	1,680.00
Replace 6 trees	------	1,476.00
Replace 50 feet of fence	------	640.00
Totals:	**$ 895.00**	**$5,070.00**

These items are a secondary cost to the developer. The primary cost still needs to be considered.

Item:	
Developer's infrastructure (cost attributed to the five-day delay of construction): $1,200 per day	$ 6,000.00
Attorney costs: 21 hours @ $150 per hour	3,150.00
Engineer and staff cost: 31 hours @ $75 per hour	2,325.00
Curb and gutter crew start-up cost	1,500.00
Utilities crew start-up cost	2,000.00
Grading crew start-up cost	2,000.00
Total:	**$16,975.00**

During the ten-day period that it took to repair the damage and get the project back on schedule, the developer incurred these expenses:

	Moderate Damage	Severe Damage
	$16,975.00	$16,975.00
	895.00	5,070.00
Totals:	**$17,870.00**	**$22,045.00**

Not reflected in these costs are the tertiary cost such as ten days of additional interest on the construction loan, lost sales of homes and possible litigation costs.

In this case, the cost of the controls shown on the original E&S plan that would have prevented the problem are as follows:

Item:	**Cost**
Silt fence, 350 feet @ $4.50/linear ft.	$ 1,575.00
Diversion dike, 50 feet @ $2.00/linear ft.	100.00
Sediment trap, 1 @ $240.00 each	240.00
Total:	$ 1,915.00

It should be noted that variation in the magnitude of the storm event could make these numbers vary and pose some required clean-up costs - even for a properly controlled site. However, <u>the use of properly installed control measures will still help to mitigate damage caused by less frequent, larger storms</u>.

<u>BASIC PRINCIPLES OF DESIGN AND CONTROL</u>

For an erosion and sediment control program to be effective, it is imperative that provisions for sediment control measures be made in the planning stage. These planned measures, when conscientiously and expeditiously applied during construction, will result in orderly development, which minimizes environmental degradation. From the previous discussion about erosion and sediment processes and the factors affecting erosion, basic technical principles can be formulated to assist the project planner or designer in providing for effective sediment control. These principles should be utilized to the maximum extent possible on all projects.

1. <u>Plan the development to fit the particular topography, soils, drainage patterns and natural vegetation of the site.</u>

   Detailed planning should be employed to assure that roadways, buildings, and other permanent features of the development conform to the natural characteristics of the site. Large graded areas should be located on the most level portion of the site. Areas subject to flooding should be avoided, and floodplains should be kept free from filling and other development. Areas with steep slopes, erodible soils and soils with severe limitations for the intended uses should not be utilized without first overcoming the limitations through sound engineering practices. For instance, long steep slopes can be broken by benching, terracing, or construction diversion structures and thus will not become an erosion problem or transfer a problem down the grade.

Erosion control, development 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 a site to conform to a proposed activity. This kind of planning can be more easily accomplished where there is a general land-use plan based upon a comprehensive inventory of soils, water and other related resources.

2. <u>Minimize the extent of the area exposed at one time and duration of exposure.</u>

When earth changes are required and the natural vegetation is removed, keep the area and the duration of exposure to a minimum. Plan the phases or stages of development so that only the area which are actively being developed are exposed. All other areas should have a good cover of temporary or permanent vegetation or mulch. Grading should be completed as soon as possible after it is begun. Immediately after grading is completed, permanent vegetative cover should be established in the area. As cut slopes are made and as fill slopes are brought up to grade, these areas should be revegetated as the work progresses. This is known as staged seeding. Minimizing grading of large or critical areas during the seasons of maximum erosion potential - spring thaw in February and March and the thunderstorm season from May through September reduces the risk of erosion (60).

3. <u>Apply erosion control practices to prevent excessive on-site damage.</u>

This third principle relates to using practices that control erosion on a site to prevent excessive sediment from being produced. Keep soil covered as much as possible with temporary or permanent vegetation or with various mulch materials. Special grading methods such as roughening a slope on the contour or tracking with a cleated dozer may be used. Other practices include diversion structures to divert surface runoff from exposed soils and grade stabilization structures to control surface water.

"Gross" erosion in the form of gullies must be prevented by these water control devices. Lesser types of erosion such as sheet and rill erosion should be prevented but, often, scheduling or the large number of practices required makes this impractical. However, when erosion is not adequately controlled at the source, sediment control for the project as a whole is more difficult and expensive.

4. <u>Apply perimeter control practices to protect the disturbed area from off-site runoff and to prevent sedimentation damage to areas below the development site.</u>

This principle relates to using practices that effectively isolate the development site from surrounding properties and especially to controlling sediment once it is produced and preventing its transport for the site.

Diversions, dikes, sediment traps, vegetative filters and sediment basins are examples of practices which control sediment. Vegetative and structural sediment control measures can be classified as either temporary or permanent depending on whether or not they will remain in use after development is complete. Generally, sediment can be retained by two methods: a) filtering runoff as it flows through an area, and b) impounding the sediment-laden runoff for a period of time so that the soil particles settle out. Many practices are combinations of these two methods. The best way to control sediment, however, is to prevent erosion as discussed in the third principle.

5. Keep runoff velocities low and retain runoff on the site.

The removal of existing vegetative cover and the resulting increase in impermeable surface area during development will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control. Keeping slope lengths short and gradients low and preserving natural vegetative cover can keep stormwater velocities low and limit erosion hazards. Runoff from the development should be safely conveyed to a stable outlet using storm drains, diversions, stable waterways, riprapped channels or similar measures. Consideration should be given to the installation of stormwater retention or detention structures when there is a potential for flooding and damage to downstream facilities resulting from increased runoff from the site. Conveyance systems should be designed to withstand the velocities of projected peak discharges. These facilities should be operational as soon as possible after the start of construction.

6. Stabilize disturbed areas immediately after final grade has been attained.

Permanent structures, temporary or permanent vegetation, and mulch, or a combination of these measures should be employed as quickly as possible after the land is disturbed. Temporary vegetation and mulches can be most effective where or when it is not practical to establish permanent vegetation. Such temporary measures should be employed immediately after rough grading is completed if a delay is anticipated in obtaining finished grade. The finished slope of a cut or fill should be stable, and ease of maintenance should be considered in the design. Stabilize roadways, parking areas, and paved areas with a gravel sub-base whenever possible.

7. Implement a thorough maintenance and follow-up program.

This last principle is vital to the success of the other six principles. A site cannot be effectively controlled without thorough, periodic checks of the erosion and sediment control practices.

These practices must be maintained just as construction equipment must be maintained and materials checked and inventoried. An example of applying this principle would be to start a routine "end of day check" to make sure that all control practices are working properly. Usually, these seven principles are integrated into a system of vegetative and structural measures along with management techniques and the "Minimum Standards" to develop a plan to prevent erosion and control sediment. In most cases, a combination of limited grading, limited time of exposure, and a judicious selection of erosion control practices and sediment trapping facilities will prove to be the most practical method of controlling erosion and the associated production and transport of sediment.

PART II

OVERVIEW OF PRACTICES

The following are summary overviews of the erosion and sediment control practices recommended for use in Virginia. Complete standards and specifications for these practices can be found in Chapter 3 of this handbook. The practices are numbered according to the following categories of use:

STRUCTURAL PRACTICES

- SAFETY (3.01)
- ROAD STABILIZATION (3.02 - 3.03)
- SEDIMENT BARRIERS (3.04 - 3.08)
- DIKES AND DIVERSIONS (3.09 - 3.12)
- SEDIMENT TRAPS AND BASINS (3.13 - 3.14)
- FLUMES (3.15 - 3.16)
- WATERWAY AND OUTLET PROTECTION (3.17 - 3.21)
- STREAM PROTECTION (3.22 - 3.27)
- SUBSURFACE DRAINAGE (3.28)

VEGETATIVE PRACTICES

- SITE PREPARATION FOR VEGETATION ESTABLISHMENT (3.29 - 3.30)
- GRASS ESTABLISHMENT (3.31 - 3.34)
- MULCHES (3.35 - 3.36)
- OTHER VEGETATIVE CONTROLS (3.37 - 3.38)
- DUST CONTROL (3.39)

3.01 SAFETY FENCE: A protective barrier installed to prohibit undesirable use of an erosion control measure.

3.02 TEMPORARY STONE CONSTRUCTION ENTRANCE: A stone pad, located at points of vehicular ingress and egress on a construction site, to reduce the soil transported onto public roads and other paved areas.

3.03 CONSTRUCTION ROAD STABILIZATION: Temporary stabilization with stone of access roads, subdivision streets, parking areas and other traffic areas immediately after grading to reduce erosion caused by vehicles during wet weather, and to prevent having to regrade permanent roadbeds between initial grading and final stabilization.

3.04 STRAW BALE BARRIER: A temporary sediment barrier composed of straw bales placed across or at the toe of a slope to intercept and detain sediment and decrease flow velocities from drainage areas of limited size; applicable where sheet and rill erosion may be a problem. Maximum effective life is 3 months.

3.05 SILT FENCE: A temporary sediment barrier constructed of posts, filter fabric and, in some cases, a wire support fence, placed across or at the toe of a slope or in a minor drainage way to intercept and detain sediment and decrease flow velocities from drainage areas of limited size; applicable where sheet and rill erosion or small concentrated flows may be a problem. Maximum effective life of 6 months.

3.06 BRUSH BARRIER: A temporary sediment barrier composed of limbs, weeds, vines, root mat, rock, and other cleared materials pushed together to form a berm; located across or at the toe of a slope to intercept and detain sediment and decrease flow velocities.

3.07 STORM DRAIN INLET PROTECTION: The installation of various kinds of sediment trapping measures around drop inlets or curb inlet structures prior to permanent stabilization of the disturbed area; limited to drainage areas not exceeding one acre, and not intended to control large, concentrated stormwater flows.

3.08 CULVERT INLET PROTECTION: A sediment filter located at the inlet to storm sewer culverts which prevents sediment from entering, accumulating in and being transferred by the culvert. It also provides erosion control at culverts during the phase of a project where elevations and drainage patterns are changing, causing original control measures to be ineffective.

3.09 TEMPORARY DIVERSION DIKE: A ridge of compacted soil constructed at the top or base of a sloping disturbed area which diverts off-site runoff away from unprotected slopes and to a stabilized outlet, or to divert sediment-laden runoff to a sediment trapping structure. Maximum effective life is 18 months.

3.10 TEMPORARY FILL DIVERSION: A channel with a supporting ridge on the lower side, constructed along the top of an active earth fill constructed in order to divert runoff away from the unprotected fill slope to a stabilized outlet or sediment trapping structure; applicable where the area at the top of the fill drains toward the exposed slope and continuous fill operations make the use of a TEMPORARY DIVERSION DIKE infeasible; maximum effective life is one week.

3.11 TEMPORARY RIGHT-OF-WAY DIVERSION: A ridge of compacted soil or loose gravel constructed across a disturbed right-of-way or similar sloping area to shorten the flow length within the disturbed strip and divert the runoff to a stabilized outlet. Earthen diversions are applicable where there will be little or no construction traffic within the right-of-way, and gravel structures are applicable where vehicular traffic must be accommodated.

3.12 DIVERSION: A permanent channel with a ridge on the lower side constructed across a slope to reduce slope length and intercept and divert stormwater runoff to a stabilized outlet at non-erosive velocities.

3.13 TEMPORARY SEDIMENT TRAP: A small ponding area, formed by constructing an earthen embankment with a stone outlet across a drainage swale, to detain sediment-laden runoff from small disturbed areas for enough time to allow most of the suspended solids to settle out. Maximum effective life is 18 months.

3.14 TEMPORARY SEDIMENT BASIN: A temporary barrier or dam with a controlled stormwater release structure which is formed by constructing an embankment of compacted soil across a drainageway. It is used to detain sediment-laden runoff from drainage areas 3 acres or greater for enough time to allow most of the suspended solids to settle out. It can be constructed only where there is sufficient space and appropriate topography. Maximum effective life is 18 months unless designed as a permanent pond by a qualified professional.

3.15 TEMPORARY SLOPE DRAIN: A flexible tubing or conduit, used before permanent drainage structures are installed, intended to conduct concentrated runoff safely from the top to the bottom of a disturbed slope without causing erosion on or below the slope.

3.16 PAVED FLUME: A permanent concrete-lined channel constructed to conduct concentrated runoff from the top to the bottom of a slope without causing erosion on or below the slope.

3.17 STORMWATER CONVEYANCE CHANNEL: A permanent channel designed to carry concentrated flows without erosion. Applicable to man-made channels, including roadside ditches, and natural channels that are modified to accommodate increased flows generated by land development; not generally applicable to major, continuous-flowing natural streams.

3.18 OUTLET PROTECTION: The installation of riprap channel sections and/or stilling basins below storm drain outlets to reduce erosion and under-cutting from scouring at outlets and to reduce flow velocities before stormwater enters receiving channels below these outlets.

3.19 RIPRAP: A permanent, erosion-resistant ground cover of large, loose, angular stone installed wherever soil conditions, water turbulence and velocity, expected vegetative cover, etc., are such that soil may erode under design flow conditions.

3.20 ROCK CHECK DAMS: Small, temporary stone dams constructed across a drainage ditch to reduce the velocity of concentrated flows, reducing erosion of the swale or ditch. Limited to use in small open channels which drain 10 acres or less; should not be used in live streams.

3.21 LEVEL SPREADER: An outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope to convert concentrated, sediment-free runoff to sheet flow and release it onto areas of undisturbed soil which is stabilized by existing vegetation.

3.22 VEGETATIVE STREAMBANK STABILIZATION: The establishment of appropriate vegetation on streambanks to protect the banks from erosion.

3.23 STRUCTURAL STREAMBANK STABILIZATION: Stabilizing the banks of live streams with permanent structural measures to protect them from erosion. Particularly applicable to watercourses which must pass increased flows due to upstream development; not applicable to tidal streams.

3.24 TEMPORARY VEHICULAR STREAM CROSSING: A temporary structural span across a live stream to provide vehicular access to construction activity on either side of the stream while keeping sediment out of the stream and preventing damage to the channel bed and banks.

3.25 UTILITY STREAM CROSSING: A strategy for crossing small waterways when in-stream utility construction is involved. The strategy helps to prevent sediment from entering the affected watercourse and minimizes the amount of disturbance within the stream itself.

3.26 DEWATERING STRUCTURE: A temporary settling and filtering device for water which is discharged from dewatering activities.

3.27 TURBIDITY CURTAIN: A floating geotextile material which minimizes sediment transport from a disturbed area adjacent to or within a body of water. It provides sedimentation protection for a watercourse from upslope land disturbance or from dredging or filling within the watercourse.

3.28 SUBSURFACE DRAIN: A perforated conduit installed beneath the ground to intercept and convey groundwater. Prevents sloping soils from becoming excessively wet and subject to sloughing, and improves the quality of the vegetative growth medium in excessively wet areas by lowering the water table. Can also be used to drain detention structures.

3.29 SURFACE ROUGHENING: Grading practices such as stair-stepping or grooving slopes or leaving slopes in a roughened condition by not fine-grading them. Reduces runoff velocity, provides sediment trapping and increases infiltration, all of which facilitate establishment of vegetation on exposed slopes. Applicable to all slopes steeper than 3:1 or that have received final grading but will not be stabilized immediately. Also recommended for other exposed slopes with flatter grades.

3.30 TOPSOILING: Preserving and using topsoil to provide a suitable growth medium for vegetation used to stabilize disturbed areas. Applicable where preservation or importation of topsoil is most cost-effective method of providing a suitable growth medium; not recommended for slopes steeper than 2:1 unless additional measures are taken to prevent sloughing and erosion.

3.31 TEMPORARY SEEDING: Establishment of temporary vegetative cover on disturbed areas that will not be brought to final grade for periods of 30 days to one year by seeding with appropriate rapidly-growing plants.

3.32 PERMANENT SEEDING: Establishment of perennial vegetative cover by planting seed on rough-graded areas that will not be brought to final grade for a year or more or where permanent, long-lived vegetative cover is needed on fine-graded areas.

3.33 SODDING: Stabilizing fine-graded areas by establishing permanent grass stands with sod. Provides immediate protection against erosion, and is especially effective in grassed swales and water-ways or in areas where an immediate aesthetic effect is desirable.

3.34 BERMUDAGRASS AND ZOYSIAGRASS ESTABLISHMENT: Establishment of vegetative cover with hybrid bermudagrass or zoysiagrass by planting sprigs, stolons or plugs to stabilize fine-graded areas where establishment by sod is not preferred.

3.35 MULCHING: Application of plant residues or other suitable materials to disturbed surfaces to prevent erosion and reduce overland flow velocities. Fosters plant growth by increasing available moisture and providing insulation against extreme heat or cold. Should be applied to all seeding operations, other plant materials which do not provide adequate soil protection by themselves, and bare areas which cannot be seeded due to the season but which still need protection to prevent soil loss.

3.36 SOIL STABILIZATION BLANKETS AND MATTING: The installation of a protective blanket (Treatment 1) or a soil stabilization mat (Treatment 2) on a prepared planting of a steep slope, channel or shoreline.

3.37 TREES, SHRUBS, VINES AND GROUND COVERS: Stabilizing disturbed areas by planting trees, shrubs, vines and ground covers where turf is not preferred. These plant materials also provide food and shelter for wildlife as well as many other environmental benefits. Especially effective where ornamental plants are desirable and turf maintenance is difficult.

3.38 TREE PRESERVATION AND PROTECTION: Protecting existing trees from mechanical and other injury during land-disturbing and construction activity to ensure the survival of desirable trees where they will be effective for erosion and sediment control and provide other environmental and aesthetic benefits.

3.39 DUST CONTROL: Reducing surface and air movement of dust during land disturbance, demolition or construction activities in areas subject to dust problems in order to prevent soil loss and reduce the presence of potentially harmful airborne substance.

PART III

COSTS

DATA LIMITATIONS

The cost of implementing erosion and sediment control practices is highly variable and dependent upon many factors including regional cost trends, availability and proximity of materials, time of year, prevailing labor rates, etc. It is therefore very difficult to develop cost estimates which are applicable statewide and year-round. The cost data contained in this chapter are based upon a February, 1991 survey of contractors and suppliers in mostly urban areas of the state. The following cost figures reflect statewide, average costs.

The intended use of this cost information is to provide an example format for local officials who have to calculate performance bond amounts or other guarantees. It may also aid project planners who seek to estimate E&S costs for feasibility studies.

The actual "dollar amounts" are not recommended for use in estimating and bidding construction contracts. It is advisable to check with local suppliers and contractors for this purpose.

COST vs. EFFECTIVENESS

The person who prepares an erosion and sediment control plan must pay careful attention to the selection of each practice. The practice with the least expensive initial cost may require a great deal of maintenance over the length of a project. Accessibility for maintenance can often be a factor that determines effectiveness. Silt fence for instance, requires regular maintenance. If placed in an area that drains too much disturbed area and is difficult to reach, maintenance potential for failure becomes a problem. In such a case, a diversion dike leading to a sediment trap would most likely be a better selection. The dike and trap are more suitable to handle larger runoff volume and would require less day-to-day maintenance if installed properly.

Once installed, the costs associated with a particular control can be kept to a minimum when maintenance is performed on a regular basis. Once a practice fails, the replacement cost can be double the initial cost of the practice. Regular maintenance also decreases the likelihood that damage to down slope property would be caused.

STRUCTURAL PRACTICE COSTS (Table 2-1)

The structural cost table consists of a numerical listing of the structural conservation practices with associated cost ranges for various applications. The cost estimates include materials (see end of Table 2-1), labor (at $6.00 per hour), equipment, and contractor's profit and overhead (figured at 30%).

VEGETATIVE PRACTICE COSTS (Table 2-2)

The cost items associated with vegetation establishment may include any combination of sod, seed, lime, fertilizer, equipment rental or purchase, soil testing, mulch, labor and maintenance. Due to the high potential for variability in actual total cost, Table 2-2 is primarily oriented for materials costs. Only estimates for sodding include installation costs. Users of the vegetative cost tables must add in cost for labor, fuel, machinery and other appropriate items. Examples using the cost data from Table 2-2 are given immediately following the table.

TABLE 2-1

STRUCTURAL PRACTICE COSTS

3.01	Safety Fence	
	Plastic - $1.50 - $2.50/linear ft. (including post)	
	Chain-link - $8 - $12/linear ft. (8 ft. height incl. post)	
3.02	Temporary Stone Construction Entrance	
	* Stone Pad	$3 - $6/yd.^{2}
	** Wash Rack	$500 - $1,000/unit
3.03	Construction Road Stabilization	
	Stone only	$3 - $6/yd.^{2}
	Stone with filter fabric	$6 - $9/yd.^{2}
3.04	Straw Bale Barrier	
	* $3 - $6/linear foot	
3.05	Silt Fence	
	* $2 - $5/linear foot	
3.06	Brush Barrier	
	* $2 - $5/linear foot	

* price does not reflect maintenance for long-term use.
** price does not reflect cost for hose-bib or personnel to man station.
*** price assumes hand placement with underliner according to specification.
**** installation is too site specific to offer accurate cost figures.

TABLE 2-1 (Continued)

3.07	Storm Drain Inlet Protection * $25 - $100/inlet
3.08	****Culvert Inlet Protection
3.09	Temporary Diversion Dike $3 - $5/linear foot
3.10	Temporary Fill Diversion $0.50 - $1/linear foot
3.11	Temporary Right-of-Way Diversion Stone: $2 - $2.50/linear foot Earth: $1.50 - $2.50/linear foot
3.12	Diversion $6.50 - $12/linear foot
3.13	Temporary Sediment Trap Drainage Area (acres) * 1 $500 - $700/unit * 2 $1,200 - $1,400/unit * 3 $1,800 - $2,100/unit
3.14	****Temporary Sediment Basin
3.15	Temporary Slope Drain $10 - $20/linear foot

* price does not reflect maintenance for long-term use.
** price does not reflect cost for hose-bib or personnel to man station.
*** price assumes hand placement with underliner according to specification.
**** installation of structure is too site specific to offer accurate cost figures.

TABLE 2-1 (Continued)

3.16	Paved Flume	$25 - $30/yd.^{2}
3.17	Stormwater Conveyance Channel	
	Grass-lined (seeded):	$ 3 - $ 7/yd.^{2}
	Grass-lined (sodded):	$ 8 - $12/yd.^{2}
	*** Riprap:	$35 - $50/yd.^{2}
3.18	Outlet Protection	
	*** Non-Grouted Riprap:	$35 - $50/yd.^{2}
	*** Grouted Riprap:	$45 - $65/yd.^{2}
	Concrete:	$25 - $30/yd.^{2}
3.19	Riprap	*** $35 - $50/yd.^{2}
3.20	Rock Check Dam	
	* Log Check Dam:	$400 - $600/unit
	* Rock Check Dam:	$13 - $20/yd.^{2}
3.21	Level Spreader:	$3 - $15/linear foot
3.23	Structural Streambank Protection	
	*** Non-Grouted Riprap:	$35 - $50/yd.^{2}
	*** Grouted Riprap:	$45 - 60/yd.^{2}
	Gabions:	$55 - $90/yd.^{3}
	Deflectors:	
	Timber and Pilings:	$25 - $50/linear foot
	Gabion or Rock:	$60 - $95/yd.^{3}
	Log Cribbing:	$60 - $95/yd.^{3}
	Grid Pavers:	$30 - $80/yd.^{2}

* price does not reflect maintenance for long-term use.
** price does not reflect cost for hose-bib or personnel to man station.
*** price assumes hand placement with underliner according to specification.
**** installation of structure is too site specific to offer accurate cost figures.

TABLE 2-1 (Continued)

3.24	Temporary Vehicular Stream Crossing	
	Pipe Diameter (inches)	Cost of Crossing (per linear foot)
	12 - 24	$20 - $43
	24 - 48	$43 - $86
	48 - 72	$86 - $130
	72 - 96	$130 - $172
3.25	**** Utility Stream Crossing	
3.26	**** Dewatering Structure	
3.27	**** Turbidity Curtain	
3.28	Subsurface Drains:	$1 - $3/linear foot

Maintenance Costs (General)

Sediment Removal:	$5 - $10/yd^3
Repair Cost (most often):	same as original cost
Replacement Cost:	1½ - 2 times original cost due to the necessity for removal of old measure

Material Costs (General)

VDOT #1 Coarse Aggregate:	$ 2 - $3/ton
Filter Fabric (Silt Fence):	$0.20 - $0.30/linear foot
Straw Bales:	$2 - $3.50/unit

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* price does not reflect maintenance for long-term use.
** price does not reflect cost for hose-bib or personnel to man station.
*** price assumes hand placement with underliner according to specification.
**** installation of structure is too site specific to offer accurate cost figures.

TABLE 2-1 (Continued)

Material Costs (General)

Wire, Chicken Wire (4' x 150' roll):	
1-inch mesh	$54 - $66
2-inch mesh	$30 - $42
Welded Wire (4' x 100' roll):	
2-inch x 4-inch mesh	$65 - $84
Concrete Masonry Block:	
8-inch	$0.75 - $.85/unit
10-inch	$0.95 - $1.15/unit
Riprap: 50 - 150 lb.	$4.50 - $5/ton (excludes transportation to site)
Filter Cloth Used with Riprap:	$0.50 - $.75/yd.^{2}
Concrete:	$40 - $80/yd.^{3}
Bituminous Paving:	$40 - $80/yd.^{3}
Gabions (12"-3' X 3' basket):	$55 - $66/unit
Pipe (Corrugated Metal Pipe)	

Diameter (inches)	Cost (per linear foot)
12"	$ 6 - $ 7
15"	$ 7 - $ 8
18"	$ 8 - $ 9
24"	$10 - $11
36"	$13 - $14
48"	$21 - $22
60"	$43 - $44
72"	$63 - $65
78"	$74 - $76
84"	$79 - $81
90"	$85 - $88
96"	$91 - $93

TABLE 2-2

MATERIALS COSTS FOR VEGETATIVE EROSION CONTROLS

MATERIAL		UNIT COST	RATE	COST PER 1000 SQ. FT	COST PER ACRE
SOD	Kentucky Bluegrass blends	\$.80 - \$1.25/yd.^{2}, cut \$2 - \$3.50/yd.^{2}, installed	1 yd.^{2} = 9 ft.^{2}	\$140 installed	\$9,680 - \$16,940
	Tall Fescue	\$.80 - \$1.25/yd.^{2}, cut \$2 - \$3.50 yd.^{2}, installed	1 yd.^{2} = 9 ft.^{2}	\$140 installed	\$9,680 - \$16,940
	Bermudagrass	\$1.05 - \$1.30/yd.^{2}, cut \$2.25 - \$3.75/yd.^{2}, installed	1 yd.^{2} = 9 ft.^{2}	\$180 installed	\$10,890 - \$18,150
MULCH	Small grain straw (see Chemical Mulches for tack coat)	Average \$2/bale or \$100/ton (using 40 lb. bale)	2 tons/acre	\$5 (material cost only)	\$215 (material cost only)
	Fiber Mulch (50 lb. bale)	Average \$175/ton (plus shipping)	2000 lbs./acre	\$4 (material cost only)	\$175 plus shipping
NETS AND MATS	Jute Mesh	\$55/100 yd.^{2} roll; staples: \$7/100 yd.^{2}	100 yds.^{2} = .02 ac.	\$69 with staples	\$3000 w/ staples
	Excelsior blanket	\$39/80 yd.^{2} roll; staples: \$7/100 yd.^{2}	100 yds.^{2} = .02 ac.	\$46 with staples	\$2003 w/ staples
	Mulchnet (used <u>over</u> straw only)	\$.02 ft.^{2}; staples: \$7/100 yd.^{2}	100 yds.^{2} =.02 ac.	\$27 with staples	\$1200 w/ staples
	Plastic Soil Reinforcement Mat (light / heavy):	\$3.50 yd.^{2} / \$5 yd.^{2}	4840 yd.^{2}/acre	\$390 / \$556	\$17,000 / \$24,000

TABLE 2-2 (Continued)

MATERIALS COSTS FOR VEGETATIVE EROSION CONTROLS

MATERIAL		UNIT COST	RATE	COST PER 1000 FT.^{2}	COST PER ACRE
TACKIFIERS	Asphalt - average for all grades used (used as straw tack coat)	$0.80/gal. bulk $2/gal. applied	400 - 480 gal./acre	$8.80 bulk $22 applied	$384, bulk $960, applied
	Typical synthetic binders	$1.50 - $3/gal.	45 - 75 lbs. /acre	$1.50 - $2.50	$65 - $115
	Terra Tack (as used with wood fiber)	$123/acre package	1 pkg./acre	$2.80	$123
	Fiber mulch	$200/ton	750 lbs./ac.	$1.75	$75
SOIL AMENDMENTS	Lime - pulverized agricultural limestone or dolomite	$40 -$100/ton	2-3 tons/ac., or according to soil test results	$1.85 - $6.70	$80 - $300
	10-20-10	$200 - $250/ton	Dependent on type of seeding and soil test results	--	--
	10-10-10 Note: Many formulations may be used to provide the necessary nutrients	$150 - $200/ton			
SEED	Cereal Rye	$0.25/lb., $13.50/bushel	2 bu./acre (110 lbs.)	$0.63	$27.50
	Oats	$0.15/lb., $5/bushel	3 bu./acre (100 lbs.)	$0.34	$15
	Annual Ryegrass	$0.35 - $0.50/lb.	50 lbs./acre	$0.57	$25
	German Millet	$0.40 - $0.50/lb.	60 lbs./acre	$0.69	$30

EXAMPLES:

Temporary Seeding

Seed a one-acre site using a cereal and annual rye mixture and standard soil amendments. Assume the soil is already at rough grade and does not need further preparation. Standard agricultural machinery (drill) is used.

Item	Cost
50 lbs. Cereal Rye @ $0.27/lb.	$13.50
50 lbs. Annual Rye @ $0.35/lb.	$17.50
600 lbs. 10-20-10 fertilizer @ $200/ton	$60.00
1 ton lime @ $50/ton	$50.00
Straw mulch - 100 bales @ $2/unit	$200.00
Mulch anchoring using "Krimper" method	$25.00
Materials Cost Per Acre	**$366.00**
Total Cost Per Acre for Temporary Seeding (including labor, fuel, and machinery)	**$650 - $850**

Permanent Seeding - Lawn-Type (Low Maintenance)

Item	Cost
100% Kentucky 31 Fescue @ 200 lbs./acre @ $0.75/lb..	$150.00
Annual Rye @ 20 lbs./acre @ $.40/lb.	$8.00
1000 lbs. 10-20-10 fertilizer @ $200/ton	$100.00
2 tons lime @ $50/ton	$100.00
Straw mulch - 125 bales @ $2/unit	$250.00

Tack Coat - 750 lbs. @ $200/ton	$75.00
Materials Cost Per Acre	**$683.00**
Total Cost Per Acre for Permanent Seeding of Low-Maintenance Area (including labor, fuel, and machinery)	**$1000 - $1500**

Permanent Seeding - Lawn-Type (High Maintenance)

Item		Cost
90% Turf-type Tall Fescue	225 lbs. @ $1.25/lb.	$281.25
5% Kentucky Bluegrass	12.5 lbs. @ $2.50/lb.	$31.25
5% Turf-type Perennial Rye	12.5 lbs. @ $1/lb..	$12.50
	250 lbs.	$325.00
1000 lbs. 10-20-10 fertilizer @ $200/ton		$100.00
2 tons lime @ $50/ton		$100.00
1 ton fiber mulch @ $200/ton		$200.00
Materials Cost Per Acre		**$725.00**
Total Cost Per Acre for Permanent Seeding of High-Maintenance Area (including labor, fuel, and machinery)		**$1100 - $1700**

General Slope (Non-Legume)

Item		Cost
Kentucky 31 Fescue	128 lbs. @ $0.75/lb.	$96.00
Redtop	2 lbs. @ $3.50/lb.	$7.00
Annual Rye	20 lbs. @ $.40/lb.	$8.00
	150 lbs.	$111.00

	1992
1000 lbs. 10-20-10 fertilizer @ $200/ton	$100.00
2 tons lime @ $50/ton	$100.00
Mulch (fiber)	$200.00
Materials Cost Per Acre	**$511.00**
Total Cost Per Acre for Permanent Seeding of General Slope with Non-Legume Mixture (including labor, fuel, and machinery)	**$800 - $1000**

General Slope (Legume)

Item		Cost
Kentucky 31 Fescue	108 lbs. @ $0.75/lb.	$81.00
Redtop	2 lbs. @ $3.50/lb.	$7.00
Annual Rye	20 lbs. @ $.40/lb.	$8.00
Crownvetch	20 lbs. @ $12.50 lb.	$250.00
	150 lbs.	$346.00
1000 lbs. 10-20-10 fertilizer @ $200/ton		$100.00
2 tons lime @ $50/ton		$100.00
Straw mulch - 125 bales @ $2/unit		$250.00
Tack Coat - 750 lbs. @ $200/ton		$75.00
Materials Cost Per Acre		**$871.00**
Total Cost Per Acre for Permanent Seeding of General Slope with Legume Mixture (including labor, fuel, and machinery)		**$1200 - $1600**

CHAPTER 3

State Minimum Standards and Specifications

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STATE MINIMUM STANDARDS AND SPECIFICATIONS

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MINIMUM STANDARDS FOR CONTROLLING EROSION AND SEDIMENT FROM LAND-DISTURBING ACTIVITIES

Application of the Minimum Standards

The Minimum Standards found in the VESCR are minimum state requirements for controlling erosion and sedimentation from land-disturbing activities. These Minimum Standards do not replace the requirement for individually developed erosion and sediment control plans; however, they do establish minimum requirements of soil conservation practice which apply to all land-disturbing projects.

Applicable Minimum Standards should be satisfied in each approved erosion and sediment control plan; however, if a plan is found to be inadequate in the field, the Minimum Standards apply in addition to the provisions of the approved plan, unless a written variance has been granted. Local inspectors and persons responsible for carrying out approved plans must therefore be aware of the Minimum Standards as well as the provisions of the approved plans themselves.

Nothing in the Minimum Standards shall limit the right of the Plan-Approving Authority to impose additional or more stringent standards for controlling erosion and sedimentation during the plan-approval process.

Note: See Chapter 8 for a complete copy of the Virginia Erosion and Sediment Control Regulations and the Minimum Standards.

Variances

The Plan-Approving Authority may waive or modify any of the Minimum Standards which are deemed inappropriate or too restrictive for site conditions, by granting a variance. Variances may be granted under the following conditions:

1. At the time of plan submission - an applicant may request a variance to become part of the approved erosion and sediment control plan. The applicant shall explain the reasons for requesting variances in writing. Specific variances which are allowed by the plan-approving authority shall be documented in the plan.

2. During construction - the person responsible for implementing the approved plan may request a variance in writing from the Plan-Approving Authority. The Plan-Approving Authority shall respond in writing either approving or disapproving such a request. If the Plan-Approving Authority does not approve a variance within 10 days of receipt of the request, the request shall

be considered to be disapproved. Following disapproval, the applicant may resubmit a variance request with additional documentation.

3. The Plan-Approving Authority shall consider variance requests judiciously, keeping in mind both the need of the applicant to maximize cost effectiveness and the need to protect off-site properties and resources from damage.

The variance procedure is an important element of the plan review and enforcement programs. It is intended to maintain a necessary flexible, practical working relationship between local officials and applicants.

STD & SPEC 3.01

SAFETY FENCE

SAF

Definition

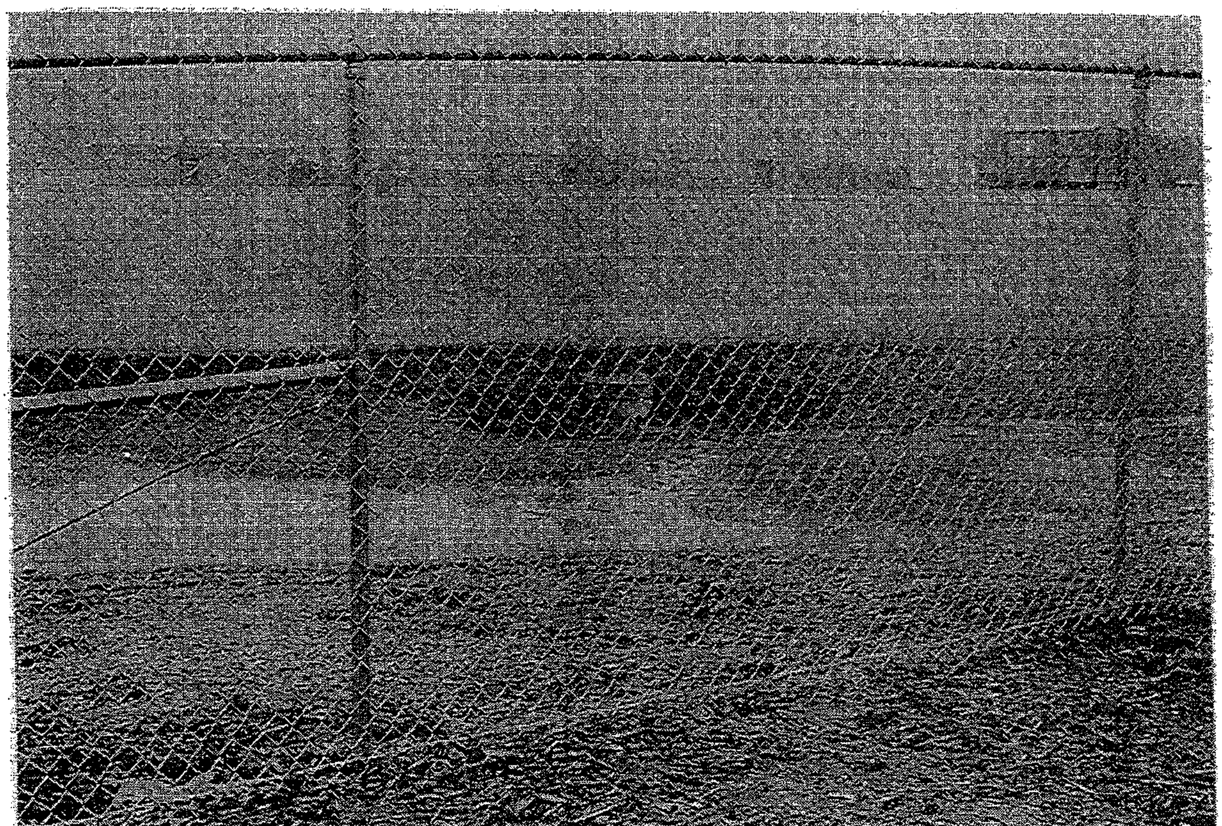
A protective barrier installed to prevent access to an erosion control measure.

Purpose

To prohibit the undesirable use of an erosion control measure by the public.

Conditions Where Practice Applies

Applicable to any control measure or series of measures which can be considered unsafe by virtue of potential for access by the public.



Planning Considerations

The safety of the public must always be considered at both the planning and implementation phases of a land-disturbing activity. If there is any question concerning the risk of a particular erosion control measure to the general public, the measure should be relocated to a safer area, or an appropriate safety fence should be installed to prevent undesired access. Many times, the danger posed by a control may not be easily seen by plan designers and reviewers - that is when the on-site contractor or inspector must correct such situations in the field. Properly designed and installed safety fences prevent the trespassing of people into potentially dangerous areas, such as children using a sediment basin or a stormwater retention structure as play areas. The installation of these fences will protect people from hazards and the owner from possible litigation.

Two different types of fence will be discussed in this specification. The designer, developer, and contractor should always be sure that the most appropriate type of fence is utilized for a particular need.

Design Criteria

1. Safety fences should be located so as to create a formidable barrier to undesired access, while allowing for the continuation of necessary construction operations.

2. Safety fences are most applicable to the construction of berms, traps, and dams. In use with those structures, safety fences should be located far enough beyond the outer toe of the embankment to allow for the passage of maintenance vehicles. Fences should not be installed across the slope of a dam or dike.

3. The height of the fence shall be a minimum of 5 feet for plastic fence and 6 feet for metal fence. A fence must never be so short as to become an attraction for children to climb on or over.

4. Signs noting potential hazards such as "DANGER-QUICKSAND" or "HAZARDOUS AREA - KEEP OUT" should be posted and easily seen by anyone approaching the protected area.

5. Plastic (polyethylene) fence may be used as safety fencing, primarily in situations where the need is for a temporary barrier (see Plate 3.01-1). The fence should meet the physical requirements noted in the following table:

TABLE 3.01-A

PHYSICAL PROPERTIES OF PLASTIC SAFETY FENCE

Physical Property	Test	Requirements
Recommended color	N/A	"International" orange
Tensile yield	ASTM D638	Average 2000 lbs. per 4 ft. width
Ultimate tensile strength	ASTM D638	Average 2900 lbs. per 4 ft. width
Elongation at break(%)	ASTM D638	Greater than 1000%
Chemical resistance	N/A	Inert to most chemicals and acids

Source: Conwed Plastics

6. Metal or "chain-link" fence should be used when a potentially dangerous control measure will remain in place permanently, such as a stormwater detention or retention basin (see Plate 3.01-1). However, they may also be used for measures which will only serve a temporary function, at the discretion of those responsible for project safety. The metal fence must meet the following physical requirements:

   a. Fabric shall be zinc-coated steel, 2-inch mesh, 9-gauge, minimum.

   b. Zinc coating shall have a minimum weight of 1.8 ounces per square foot.

   c. Posts shall be steel pipe, zinc-coated.

   d. Top nails shall be steel pipe, zinc-coated.

   e. Braces shall be made of zinc-coated steel.

   f. Gates shall be single or double swing, zinc-coated steel. They shall be a minimum of 12-feet wide.

Construction Specifications

1. Safety fences must be installed prior to the E&S measure becoming accessible.

2. The polyethylene web of the plastic safety fence shall be secured to a conventional metal "T" or "U" post driven into the ground to a minimum depth of 18 inches; posts should be spaced at 6-foot centers. See "perspective" view in Plate 3.01-1.

3. The metal safety fence shall be installed as per the following procedure:

   a. Line posts shall be placed at intervals of 10 feet measured from center to center of adjacent posts. In determining the post spacing, measurement will be made parallel with the ground surface. See "perspective" view in Plate 3.01-1.

   b. Posts will be set in concrete and backfilled or anchored by other acceptable means.

   c. Posts set in the tops of concrete walls shall be grouted into preformed holes to a minimum depth of 12 inches.

   d. All corner posts, end posts, gate posts, and pull posts shall be embedded, braced, and trussed as shown in the "Standard Fence - Chain Link" detail found in the latest version of the Virginia Department of Transportation (VDOT) Road and Bridge Standards.

   e. Fencing fabric shall not be stretched until at least 4 days after the posts are grouted into walls or 14 days after the posts are set into concrete.

   f. The fabric shall be stretched taut and securely fastened, by means of tie clips, to the posts at intervals not exceeding 15 inches and to the top rails or tension wires at intervals not exceeding 2 feet. Care shall be taken to equalize the tension on each side of each post.

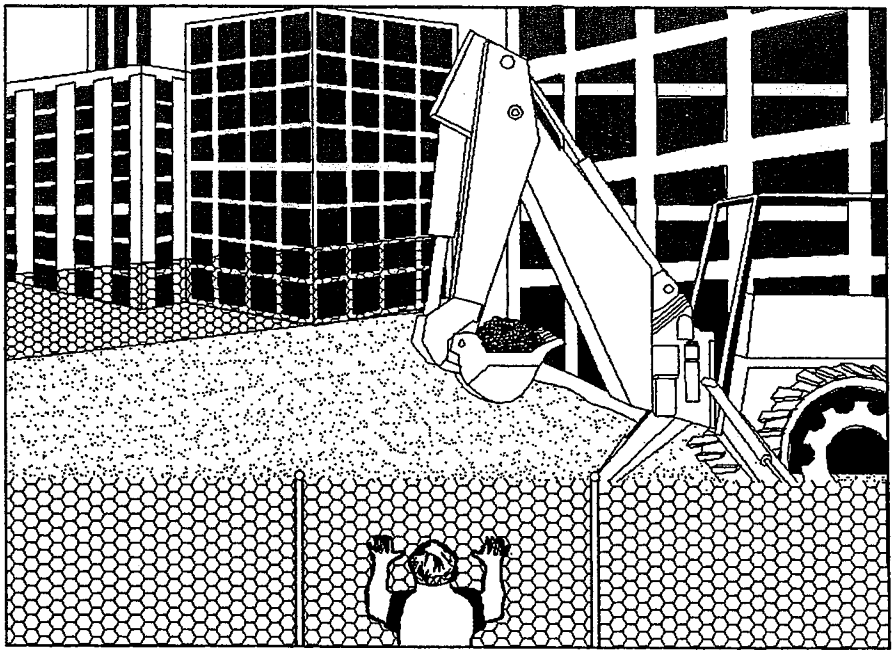
4. Applicable warning signs noting hazardous conditions must be installed immediately upon installation of safety fence.

Maintenance

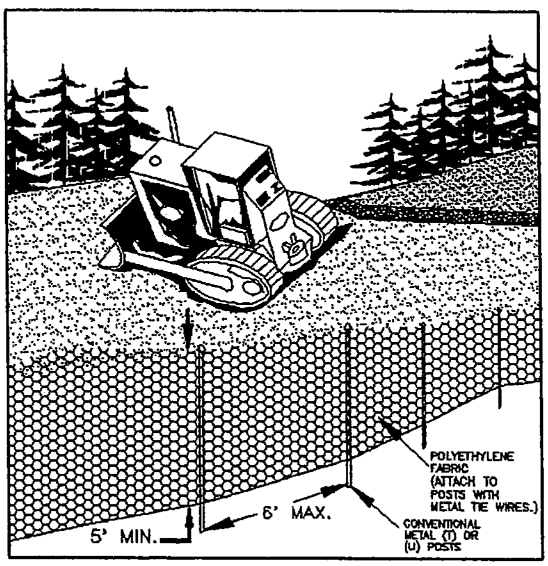
1. Safety fence shall be checked regularly for weather-related or other damage. Any necessary repairs must be made immediately.

2. Care should be taken to secure all access points (gates) at the end of each working day. All locking devices must be repaired or replaced as necessary.

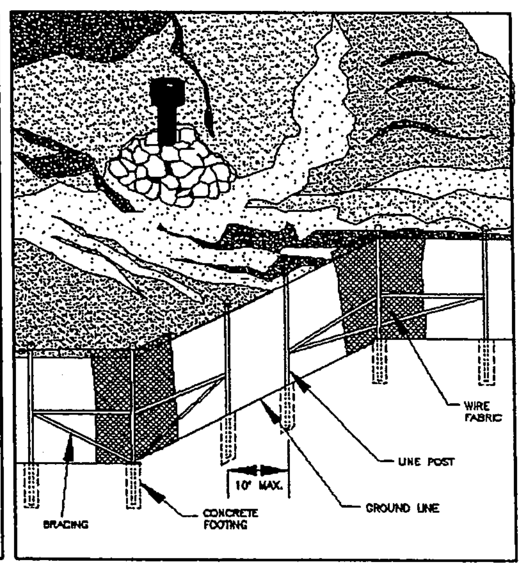
SAFETY FENCE



PERSPECTIVE VIEW



PERSPECTIVE VIEW
PLASTIC FENCE



PERSPECTIVE VIEW
METAL FENCE

Source: Adapted from Conwed Plastics and VDOT Road and Bridge Standards

Plate 3.01-1

STD & SPEC 3.02

TEMPORARY STONE CONSTRUCTION ENTRANCE

CE

Definition

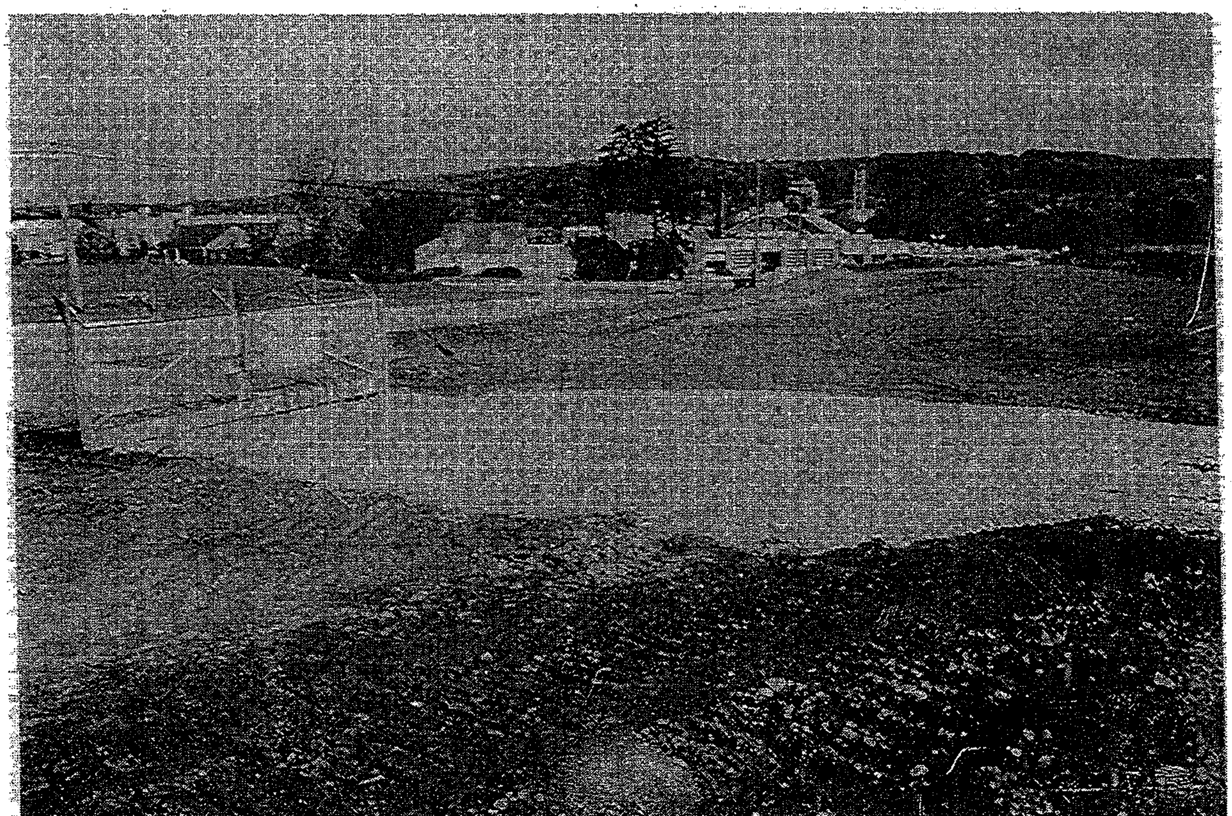
A stabilized stone pad with a filter fabric underliner located at points of vehicular ingress and egress on a construction site.

Purpose

To reduce the amount of mud transported onto paved public roads by motor vehicles or runoff.

Conditions Where Practice Applies

Wherever traffic will be leaving a construction site and move directly onto a public road or other paved area.



Planning Considerations

Minimum Standard #17 (MS #17) requires that provisions be made to minimize the transport of sediment by vehicular traffic onto a paved surface. Construction entrances provide an area where a significant amount of mud can be removed from construction vehicle tires before they enter a public road and, just as important, the soil adjacent to the paved surface can be kept intact. A filter fabric liner is used as a "separator" to minimize the dissipation of aggregate into the underlying soil due to construction traffic loads. If the action of the vehicles traveling over the gravel pad is not sufficient to remove the majority of the mud or there exists an especially sensitive traffic situation on the adjacent paved road, the tires must be washed before the vehicle enters the public road. If washing is necessary, provisions must be made to intercept the wash water and trap the sediment so it can be collected and stabilized. Construction entrances should be used in conjunction with the stabilization of construction roads (see Std. & Spec. 3.03, CONSTRUCTION ROAD STABILIZATION) to reduce the amount of mud picked up by construction vehicles and to do a better job of mud removal. Other innovative techniques for accomplishing the same purpose (such as a bituminous entrance) can be utilized, but only after specific plans and details are submitted to and approved by the appropriate Plan-Approving Authority.

Design Criteria

Aggregate Size

VDOT #1 Coarse Aggregate (2- to 3-inch stone) should be used.

Entrance Dimensions

The aggregate layer must be at least 6 inches thick; a minimum three inches of aggregate should be placed in a cut section to give the entrance added stability and to help secure filter cloth separator. It must extend the full width of the vehicular ingress and egress area and have a minimum 12-foot width. The length of the entrance must be at least 70 feet (see Plate 3.02-1).

Washing

If conditions on the site are such that the majority of the mud is not removed by the vehicles traveling over the stone, then the tires of the vehicles must be washed before entering the public road. Wash water must be carried away from the entrance to a approved settling area to remove sediment. All sediment shall be prevented from entering storm drains, ditches, or watercourses. A wash rack may also be used to make washing more convenient and effective (see Plate 3.02-1).

Location

The entrance should be located to provide for maximum utilization by all construction vehicles.

Construction Specifications

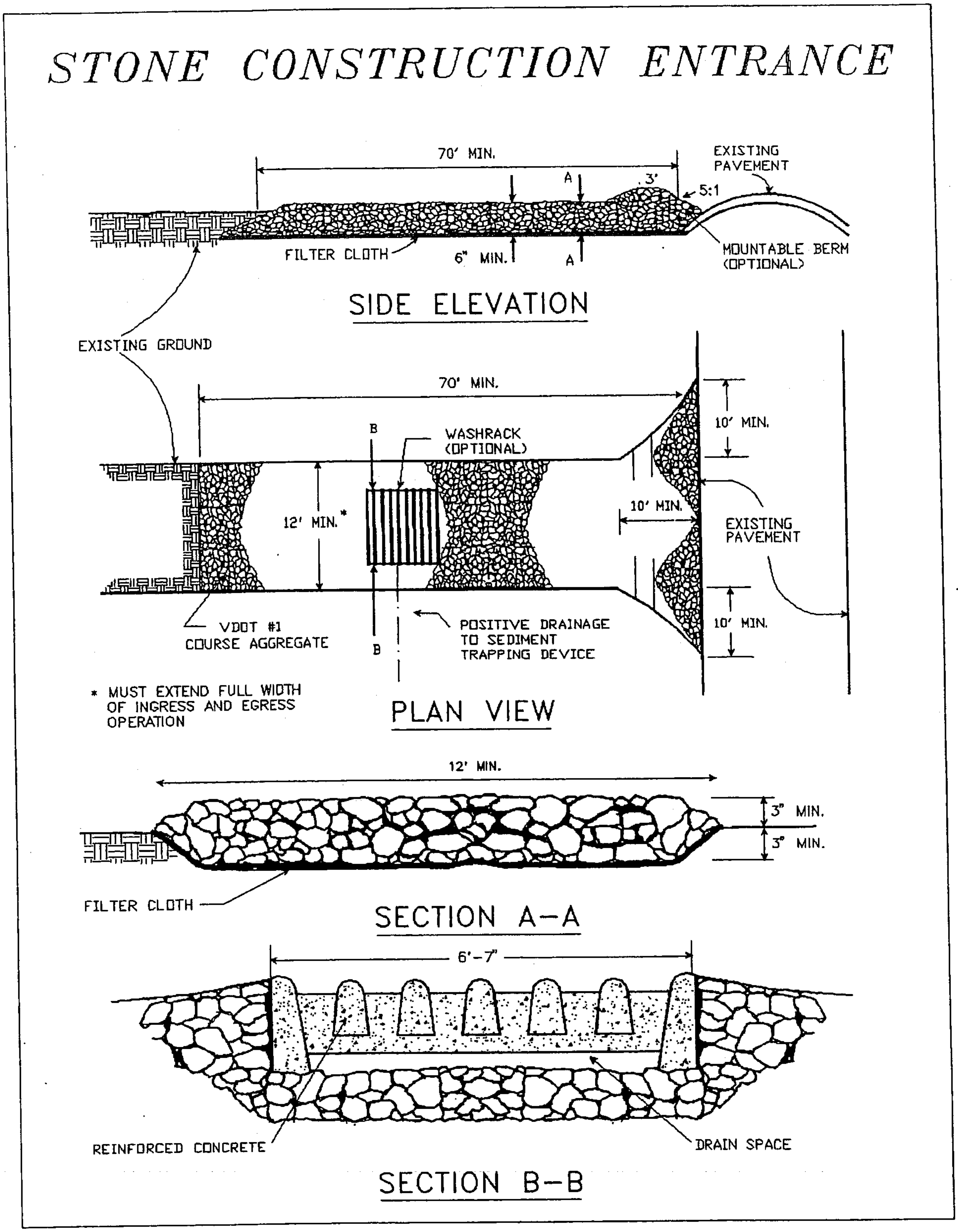
The area of the entrance must be excavated a minimum of 3 inches and must be cleared of all vegetation, roots, and other objectionable material. The filter fabric underliner will then be placed the full width and length of the entrance.

Following the installation of the filter cloth, the stone shall be placed to the specified dimensions. If wash racks are used, they should be installed according to manufacturer's specifications. Any drainage facilities required because of washing should be constructed according to specifications. Conveyance of surface water under entrance, through culverts, shall be provided as required. If such conveyance is impossible, the construction of a "mountable" berm with 5:1 slopes will be permitted.

The filter cloth utilized shall be a woven or nonwoven fabric consisting only of continuous chain polymeric filaments or yarns of polyester. The fabric shall be inert to commonly encountered chemicals and hydrocarbons, be mildew and rot resistant, and conform to the physical properties noted in Table 3.02-A.

Maintenance

The entrance shall be maintained in a condition which will prevent tracking or flow of mud onto public rights-of-way. This may require periodic top dressing with additional stone or the washing and reworking of existing stone as conditions demand and repair and/or cleanout of any structures used to trap sediment. All materials spilled, dropped, washed, or tracked from vehicles onto roadways or into storm drains must be removed immediately. The use of water trucks to remove materials dropped, washed, or tracked onto roadways will not be permitted under any circumstances.



Source: Adapted from 1983 Maryland Standards for Soil Erosion and Sediment Control, and Va. DSWC

Plate 3.02-1

TABLE 3.02-A

CONSTRUCTION SPECIFICATIONS FOR FILTER CLOTH UNDERLINER

Fabric Properties[1]	Light-Duty Entrance[2] (Graded Subgrade)	Heavy-Duty Entrance[3] (Rough Graded)	Test Method
Grab Tensile Strength (lbs.)	200	220	ASTM D1682
Elongation at Failure (%)	50	220	ASTM D1682
Mullen Burst Strength (lbs.)	190	430	ASTM D3786
Puncture Strength (lbs.)	40	125	ASTM D751 (modified)
Equivalent Opening Size (mm)	40-80	40-80	U.S. Standard Sieve CW-02215

[1] Fabrics not meeting these specifications may be used only when design procedure and supporting documentation are supplied to determine aggregate depth and fabric strength.

[2] Light Duty Entrance: Sites that have been graded to subgrade and where most travel would be single axle vehicles and an occasional multi-axle truck. Examples of fabrics which can be used are: Trevira Spunbond 1115, Mirafi 100X, Typar 3401, or equivalent.

[3] Heavy Duty Entrance: Sites with only rough grading and where most travel would be multi-axle vehicles. Examples of fabrics which can be used are: Trevira Spunbond 1135, Mirafi 600X, or equivalent.

Source: Virginia Highway and Transportation Research Council (VHTRC)

STD & SPEC 3.03

CONSTRUCTION ROAD STABILIZATION

CRS

Definition

The temporary stabilization of access roads, subdivision roads, parking areas, and other on-site vehicle transportation routes with stone immediately after grading.

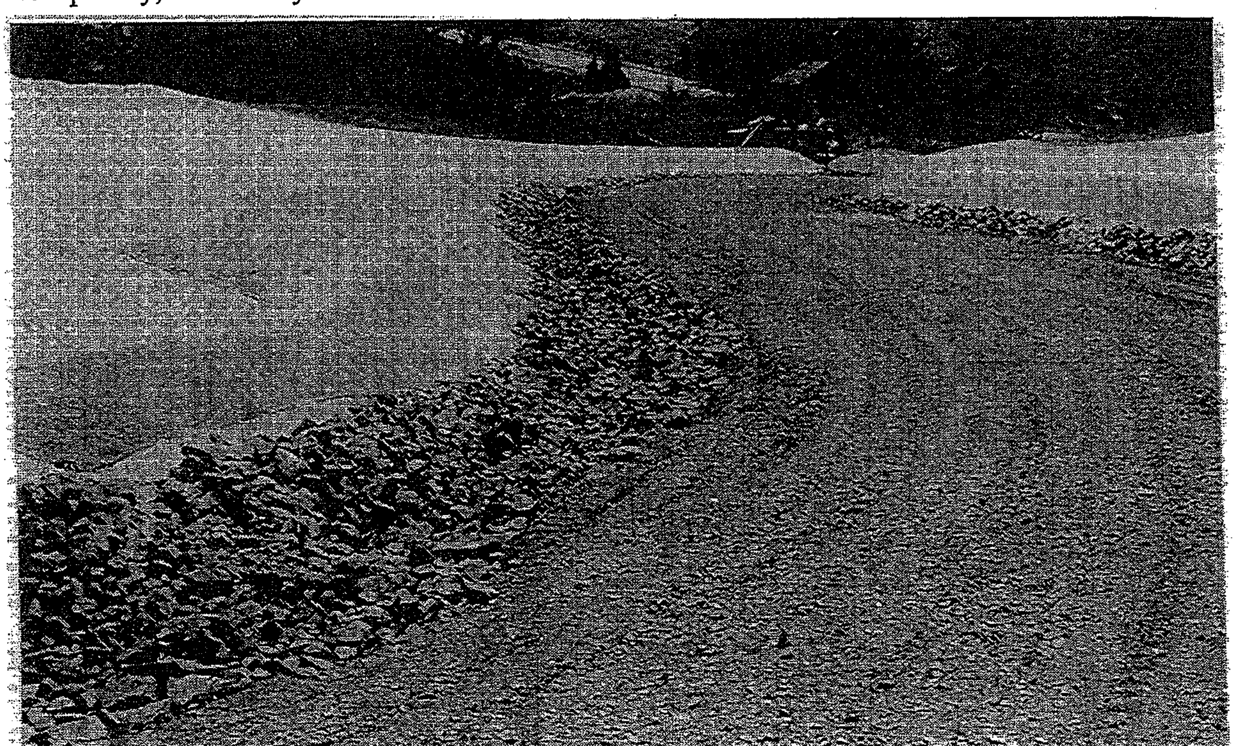
Purposes

1. To reduce the erosion of temporary roadbeds by construction traffic during wet weather.

2. To reduce the erosion and subsequent regrading of permanent roadbeds between the time of initial grading and final stabilization.

Conditions Where Practice Applies

Wherever stone-base roads or parking areas are constructed, whether permanent or temporary, for use by construction traffic.



Planning Considerations

Areas which are graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, they often become muddy quagmires which generate significant quantities of sediment that may pollute nearby streams or be transported off site on the wheels of construction vehicles. Dirt roads can become so unstable during wet weather that they are virtually unusable.

Immediate stabilization of such areas with stone may cost money at the outset, but it may actually save money in the long run by increasing the usefulness of the road during wet weather.

Permanent roads and parking areas should be paved as soon as possible after grading. However, it is understandable that weather conditions or the potential for damage may not make paving feasible in the early phases of the development project. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate later regrading costs. Some of the stone will also probably remain in place for use as part of the final base course in the construction of the road.

Specifications

Temporary Access Roads and Parking Areas

1. Temporary roads shall follow the contour of the natural terrain to the extent possible. Slopes should not exceed 10 percent.

2. Temporary parking areas should be located on naturally flat areas to minimize grading. Grades should be sufficient to provide drainage but should not exceed 4 percent.

3. Roadbeds shall be at least 14 feet wide for one-way traffic and 20 feet wide for two-way traffic.

4. All cuts and fills shall be 2:1 or flatter to the extent possible.

5. Drainage ditches shall be provided as needed and shall be designed and constructed in accordance with STORMWATER CONVEYANCE CHANNEL, Std. & Spec. 3.17.

6. The roadbed or parking surface shall be cleared of all vegetation, roots and other objectionable material.

7. A 6-inch course of VDOT #1 Coarse Aggregate shall be applied immediately after grading or the completion of utility installation within the right-of-way. Filter fabric may be applied to the roadbed for additional stability. Design specifications for filter fabric can be found within Std. & Spec. 3.02, TEMPORARY STONE CONSTRUCTION ENTRANCE. In "heavy duty" traffic situations (see Table 3.02-A), stone should be placed at an <u>8- to 10-inch depth</u> to avoid excessive dissipation or maintenance needs.

<u>Permanent Roads and Parking Areas</u>

Permanent roads and parking areas shall be designed and constructed in accordance with applicable VDOT or local criteria except that an initial base course of gravel of at least 6 inches shall be applied immediately following grading.

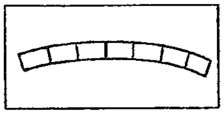
<u>Vegetation</u>

All roadside ditches, cuts, fills and disturbed areas adjacent to parking areas and roads shall be stabilized with appropriate temporary or permanent vegetation according to the applicable standards and specifications contained in this handbook.

Maintenance

Both temporary and permanent roads and parking areas may require periodic top dressing with new gravel. Seeded areas adjacent to the roads and parking areas should be checked periodically to ensure that a vigorous stand of vegetation is maintained. Roadside ditches and other drainage structures should be checked regularly to ensure that they do not become clogged with silt or other debris.

STD & SPEC 3.04



STRAW BALE BARRIER

STB

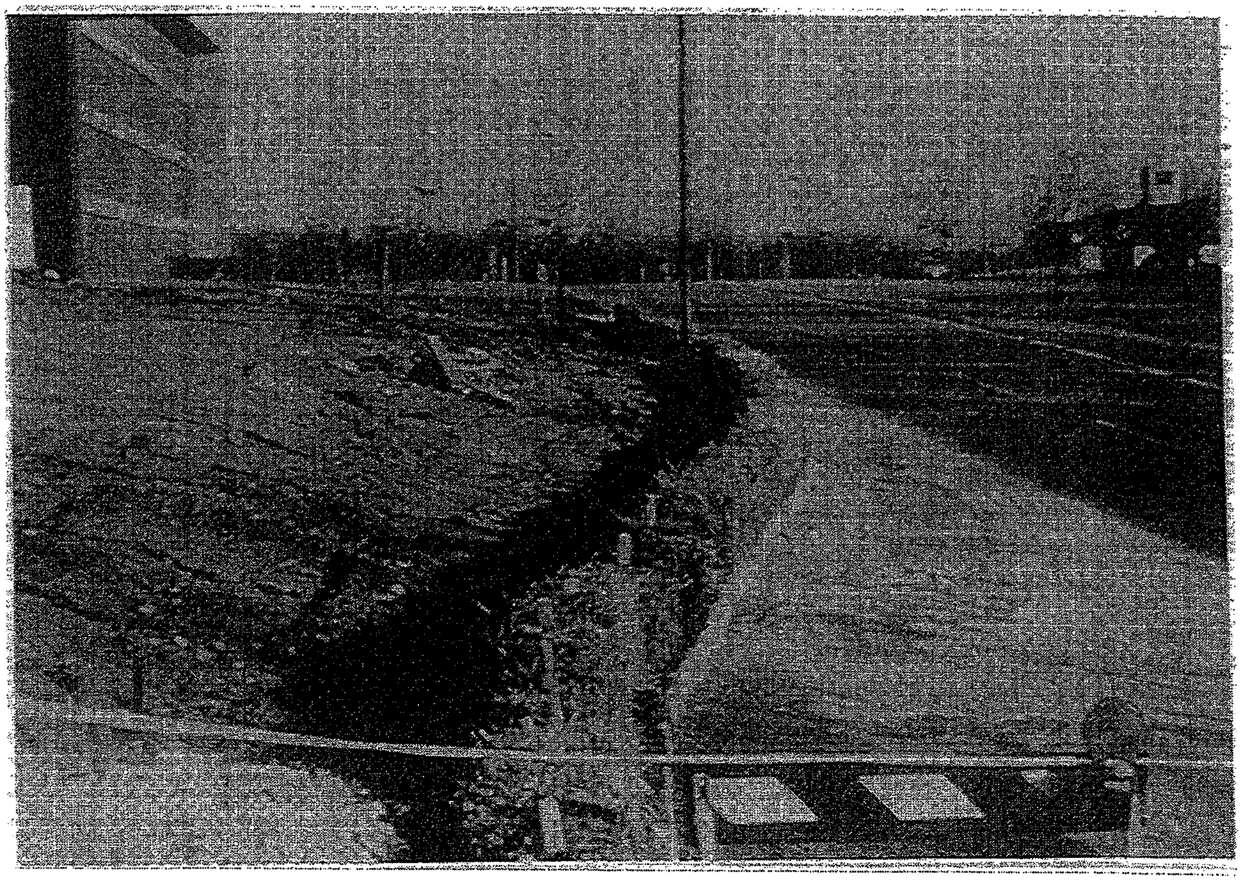
Definition

A temporary sediment barrier consisting of a row of entrenched and anchored straw bales.

Purposes

1. To intercept and detain small amounts of sediment from disturbed areas of limited extent in order to prevent sediment from leaving the construction site.

2. To decrease the velocity of sheet flows.



Conditions Where Practice Applies

1. Below disturbed areas subject to sheet and rill erosion.

2. Where the size of the drainage area is no greater than one-fourth of an acre per 100 feet of barrier length; the maximum slope length behind the barrier is 100 feet; and the maximum slope gradient behind the barrier is 50 percent (2:1).

3. Where effectiveness is required for less than 3 months.

4. Under no circumstances should straw bale barriers be constructed in live streams or in swales where there is the possibility of a washout.

5. The measure should not be used where water may concentrate in defined ditches and minor swales.

6. Straw bale barriers shall not be used on areas where rock or another hard surface prevents the full and uniform anchoring of the barrier.

Planning Considerations

Based on observations made in Virginia, Pennsylvania, Maryland and other parts of the nation, straw bale barriers have not been as effective as many users had hoped they would be - especially when used to slow down and filter concentrated flows. They should be used judiciously and with caution as erosion control measures. There are three major reasons for such ineffectiveness.

First, improper utilization of straw bale barriers has been a major problem. Straw bale barriers have been used in streams and drainageways where high water depth and velocities have destroyed or damaged the control. Secondly, improper placement and installation of the barriers, such as staking the bales directly to the ground with no soil seal or entrenchment, has allowed undercutting and end flow. This has resulted in additions of, rather than removal of, sediment from runoff waters. Finally, inadequate maintenance lowers the effectiveness of these barriers. Trapping efficiencies of carefully installed straw bale barriers on one project in Virginia dropped from 57% to 16% in one month due to lack of maintenance.

There are serious questions about the continued use of straw bale barriers as they are presently installed and maintained. Averaging from \$3 to \$6 per linear foot, the thousands of straw bale barriers used annually in Virginia represent such a considerable expense that optimum installation procedures should be emphasized.

Design Criteria

A formal design is not required. However, an effort should be made to locate the straw bale barrier, as well as other perimeter controls, at least 5 to 7 feet from the base of disturbed slopes with grades greater than 7%. This will help prevent the measure from being rendered useless following the initial movement of soil.

Construction Specifications

Sheet Flow Application

1. Bales shall be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.

2. All bales shall be either wire-bound or string-tied. Straw bales shall be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales in order to prevent deterioration of the bindings (see Plate 3.04-1).

3. The barrier shall be entrenched and backfilled. A trench shall be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. After the bales are staked and chinked (gaps filled by wedging), the excavated soil shall be backfilled against the barrier. Backfill soil shall conform to the ground level on the downhill side and shall be built up to 4 inches against the uphill side of the barrier (see Plate 3.04-1).

4. Each bale shall be securely anchored by at least two stakes (minimum dimensions 2 inches x 2 inches x 36 inches) or standard "T" or "U" steel posts (minimum weight of 1.33 pounds per linear foot) driven through the bale. The first stake or steel post in each bale shall be driven toward the previously laid bale to force the bales together. Stakes or steel pickets shall be driven a minimum 18 inches deep into the ground to securely anchor the bales.

5. The gaps between bales shall be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency.

6. Inspection shall be frequent and repair or replacement shall be made promptly as needed.

7. Straw bale barriers shall be removed when they have served their usefulness, but not before the upslope areas have been permanently stabilized.

Maintenance

1. Straw bale barriers shall be inspected immediately after each rainfall and at least daily during prolonged rainfall.

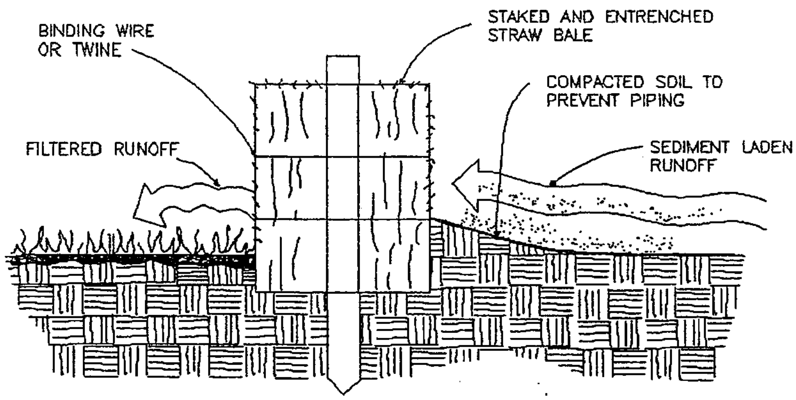
2. Close attention shall be paid to the repair of damaged bales, end runs and undercutting beneath bales.

3. Necessary repairs to barriers or replacement of bales shall be accomplished promptly.

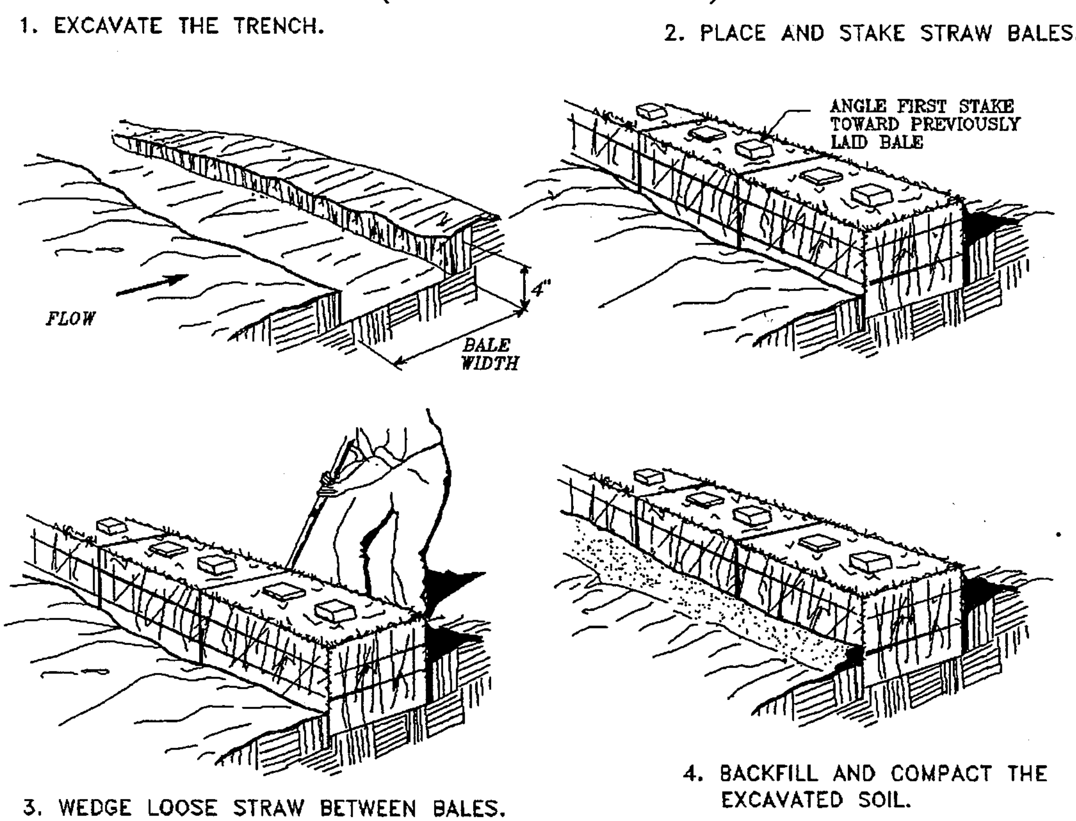
4. Sediment deposits should be removed after each rainfall. They must be removed when the level of deposition reaches approximately one-half the height of the barrier.

5. Any sediment deposits remaining in place after the straw bale barrier is no longer required shall be dressed to conform to the existing grade, prepared and seeded.

STRAW BALE BARRIER



PROPERLY INSTALLED STRAW BALE
(CROSS SECTION)



CONSTRUCTION OF STRAW BALE BARRIER

Source: Va. DSWC

Plate 3.04-1

STD & SPEC 3.05

X—X—X—X

SILT FENCE

SF

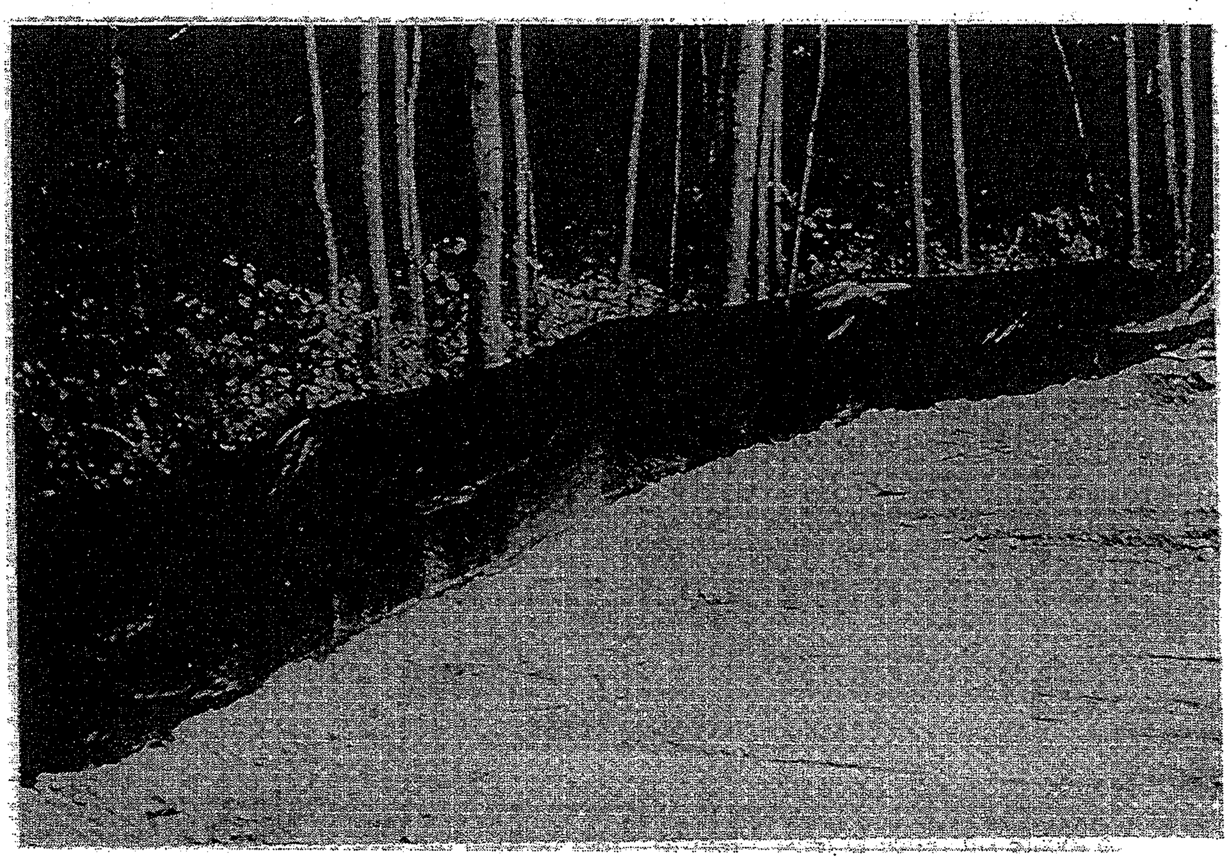
Definition

A temporary sediment barrier consisting of a synthetic filter fabric stretched across and attached to supporting posts and entrenched.

Purposes

1. To intercept and detain small amounts of sediment from disturbed areas during construction operations in order to prevent sediment from leaving the site.

2. To decrease the velocity of sheet flows and low-to-moderate level channel flows.



Conditions Where Practice Applies

1. Below disturbed areas where erosion would occur in the form of sheet and rill erosion.

2. Where the size of the drainage area is no more than one quarter acre per 100 feet of silt fence length; the maximum slope length behind the barrier is 100 feet; and the maximum gradient behind the barrier is 50 percent (2:1).

3. In minor swales or ditch lines where the maximum contributing drainage area is no greater than 1 acre and flow is no greater than 1 cfs.

4. Silt fence will not be used in areas where rock or some other hard surface prevents the full and uniform depth anchoring of the barrier.

Planning Considerations

Laboratory work at the Virginia Highway and Transportation Research Council (VHTRC) has shown that silt fences can trap a much higher percentage of suspended sediments than straw bales, though silt fence passes the sediment-laden water slower. Silt fences are preferable to straw barriers in many cases because of their durability and potential cost savings. While the failure rate of silt fences is lower than that of straw barriers, many instances have been observed where silt fences are improperly installed, inviting failure and sediment loss. The installation methods outlined here can improve performance and reduce failures.

As noted, flow rate through silt fence is significantly lower than the flow rate for straw bale barriers. This creates more ponding and hence more time for sediment to fall out. Table 3.05-A demonstrates these relationships.

Both woven and non-woven synthetic fabrics are commercially available. The woven fabrics generally display higher strength than the non-woven fabrics and, in most cases, do not require any additional reinforcement. When tested under acid and alkaline water conditions, most of the woven fabrics increase in strength, while the reactions of non-woven fabrics to these conditions are variable. The same is true of testing under extensive ultraviolet radiation. Permeability rates vary regardless of fabric type. While all of the fabrics demonstrate very high filtering efficiencies for sandy sediments, there is considerable variation among both woven and non-woven fabrics when filtering the finer silt and clay particles.

Design Criteria

1. No formal design is required. As with straw bale barriers, an effort should be made to locate silt fence at least 5 feet to 7 feet beyond the base of disturbed slopes with grades greater than 7%.

TABLE 3.05-A

TYPICAL FLOW RATES AND FILTERING EFFICIENCIES OF PERIMETER CONTROL

Material	Flow Rate (gal./sq.ft./min)	Filter Efficiency(%)
Straw	5.6	67
Synthetic Fabric	0.3	97

Source: VHTRC

2. The use of silt fences, because they have such a low permeability, is limited to situations in which only sheet or overland flows are expected and where concentrated flows originate from drainage areas of 1 acre or less.

3. Field experience has demonstrated that, in many instances, silt fence is installed too short (less than 16 inches above ground elevation). The short fence is subject to breaching during even small storm events and will require maintenance "clean outs" more often. Properly supported silt fence which stands 24 to 34 inches above the existing grade tends to promote more effective sediment control.

Construction Specifications

Materials

1. Synthetic filter fabric shall be a pervious sheet of propylene, nylon, polyester or ethylene yarn and shall be certified by the manufacturer or supplier as conforming to the requirements noted in Table 3.05-B.

2. Synthetic filter fabric shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0° F to 120° F.

3. If wooden stakes are utilized for silt fence construction, they must have a diameter of 2 inches when oak is used and 4 inches when pine is used. Wooden stakes must have a minimum length of 5 feet.

TABLE 3.05-B

**PHYSICAL PROPERTIES OF
FILTER FABRIC IN SILT FENCE**

Physical Property	Test	Requirements
Filtering Efficiency	ASTM 5141	75% (minimum)
Tensile Strength at 20% (max.) Elongation*	VTM-52	Extra Strength - 50 lbs./linear inch (minimum) Standard Strength - 30 lbs./linear inch (minimum)
Flow Rate	ASTM 5141	0.2 gal./sq.ft./ minute (minimum)
Ultraviolet Radiation Stability %	ASTM-G-26	90% (minimum)

* Requirements reduced by 50% after six months of installation.

Source: VHTRC

4. If steel posts (standard "U" or "T" section) are utilized for silt fence construction, they must have a minimum weight of 1.33 pounds per linear foot and shall have a minimum length of 5 feet.

5. Wire fence reinforcement for silt fences using standard-strength filter cloth shall be a minimum of 14 gauge and shall have a maximum mesh spacing of 6 inches.

Installation

1. The height of a silt fence shall be a minimum of 16 inches above the original ground surface and shall not exceed 34 inches above ground elevation.

2. The filter fabric shall be purchased in a continuous roll cut to the length of the barrier to avoid the use of joints. When joints are unavoidable, filter cloth shall be spliced together only at a support post, with a minimum 6-inch overlap, and securely sealed.

3. A trench shall be excavated approximately 4-inches wide and 4-inches deep on the upslope side of the proposed location of the measure.

4. When wire support is used, standard-strength filter cloth may be used. Posts for this type of installation shall be placed a maximum of 10-feet apart (see Plate 3.05-1). The wire mesh fence must be fastened securely to the upslope side of the posts using heavy duty wire staples at least one inch long, tie wires or hog rings. The wire shall extend into the trench a minimum of two inches and shall not extend more than 34 inches above the original ground surface. The standard-strength fabric shall be stapled or wired to the wire fence, and 8 inches of the fabric shall be extended into the trench. The fabric shall not be stapled to existing trees.

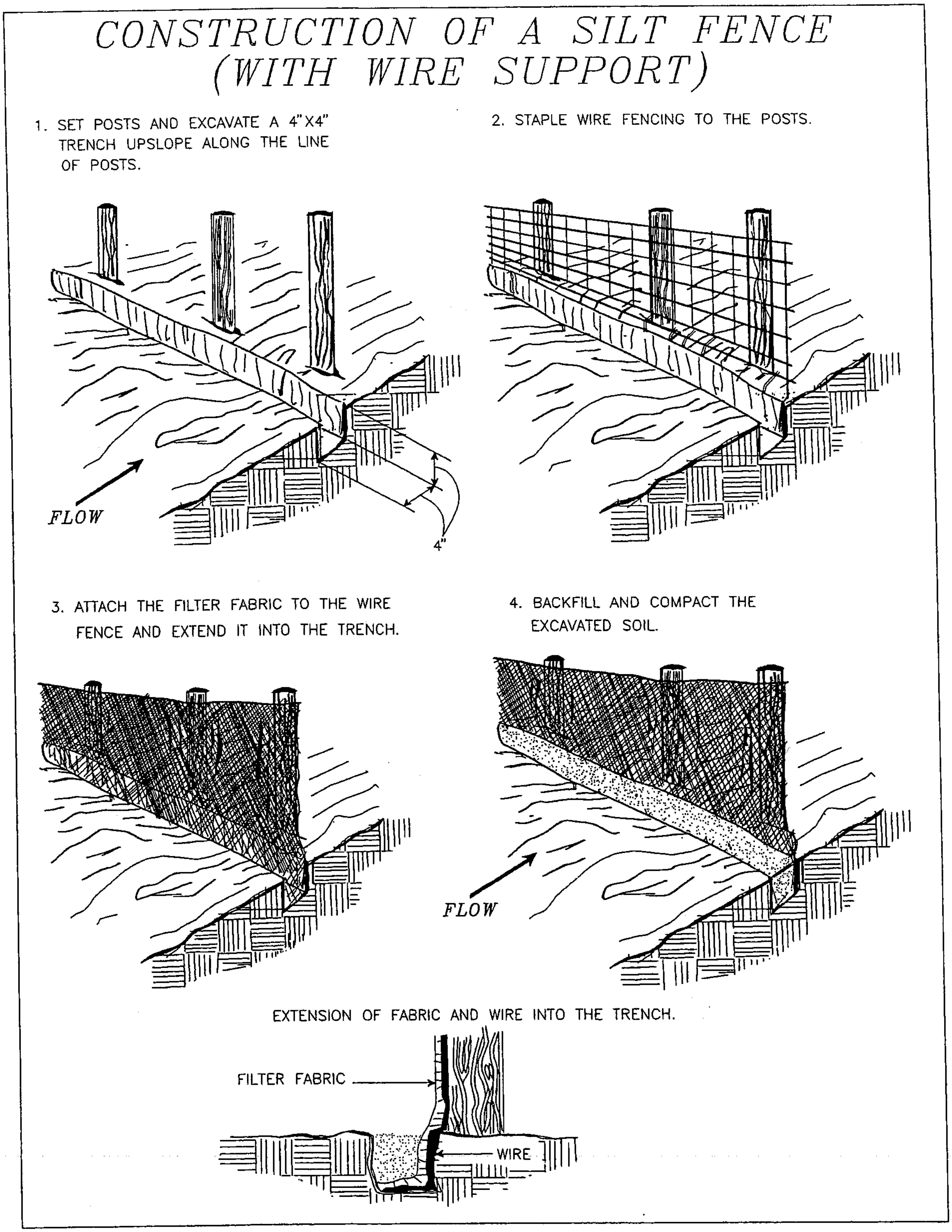
5. When wire support is not used, extra-strength filter cloth shall be used. Posts for this type of fabric shall be placed a maximum of 6-feet apart (see Plate 3.05-2). The filter fabric shall be fastened securely to the upslope side of the posts using one inch long (minimum) heavy-duty wire staples or tie wires and eight inches of the fabric shall be extended into the trench. The fabric shall not be stapled to existing trees. This method of installation has been found to be more commonplace than #4.

6. If a silt fence is to be constructed across a ditch line or swale, the measure must be of sufficient length to eliminate endflow, and the plan configuration shall resemble an arc or horseshoe with the ends oriented upslope (see Plate 3.05-2). Extra-strength filter fabric shall be used for this application with a maximum 3-foot spacing of posts.

   All other installation requirements noted in #5 apply.

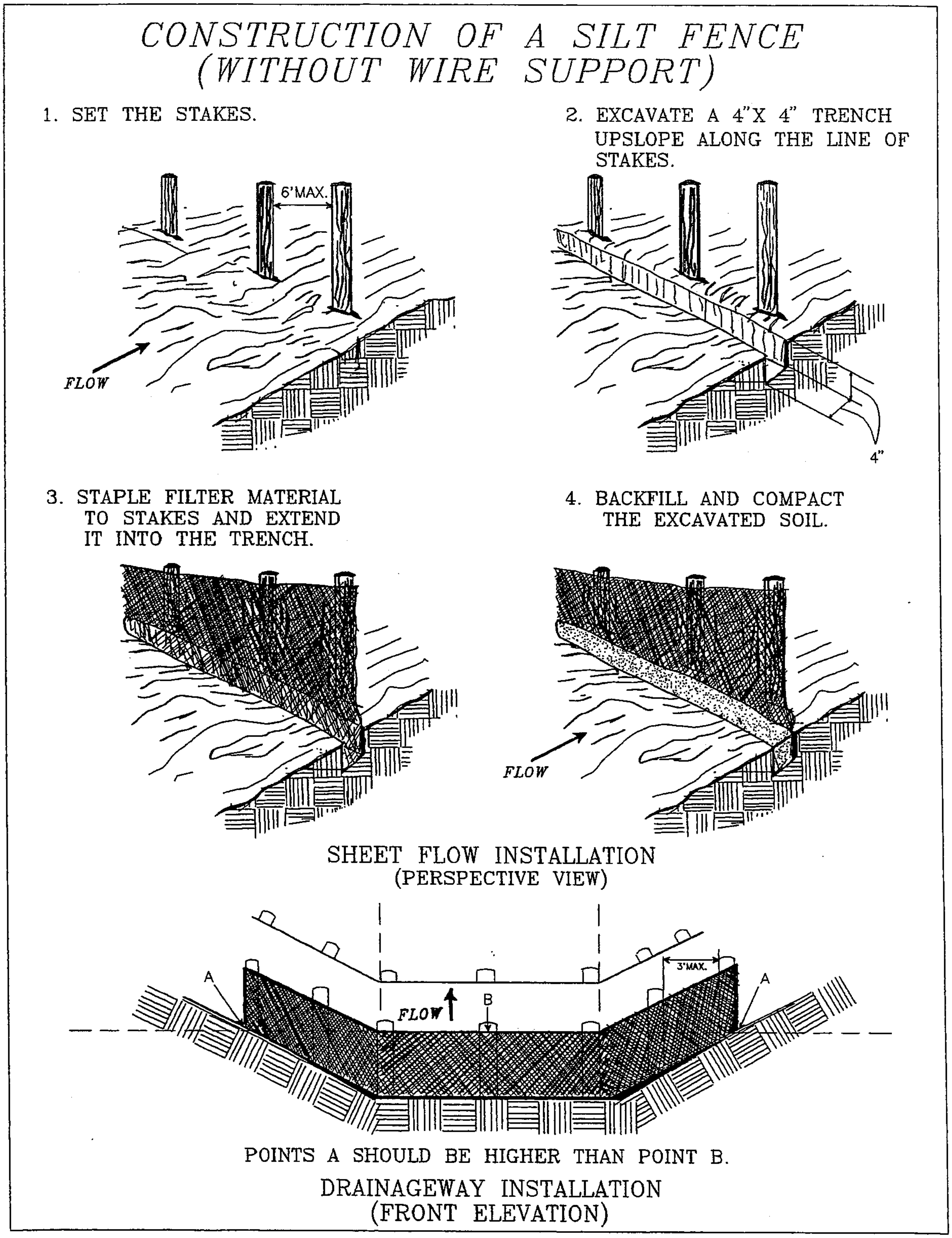
7. The 4-inch by 4-inch trench shall be backfilled and the soil compacted over the filter fabric.

8. Silt fences shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized.



Source: Adapted from Installation of Straw and Fabric Filter Barriers for Sediment Control, Sherwood and Wyant

Plate 3.05-1



Source: Adapted from Installation of Straw and Fabric Filter Barriers for Sediment Control, Sherwood and Wyant

Plate 3.05-2

Maintenance

1. Silt fences shall be inspected immediately after each rainfall and at least daily during prolonged rainfall. Any required repairs shall be made immediately.

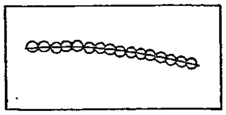
2. Close attention shall be paid to the repair of damaged silt fence resulting from end runs and undercutting.

3. Should the fabric on a silt fence decompose or become ineffective prior to the end of the expected usable life and the barrier still be necessary, the fabric shall be replaced promptly.

4. Sediment deposits should be removed after each storm event. They must be removed when deposits reach approximately one-half the height of the barrier.

5. Any sediment deposits remaining in place after the silt fence is no longer required shall be dressed to conform with the existing grade, prepared and seeded.

STD & SPEC 3.06



BRUSH BARRIER

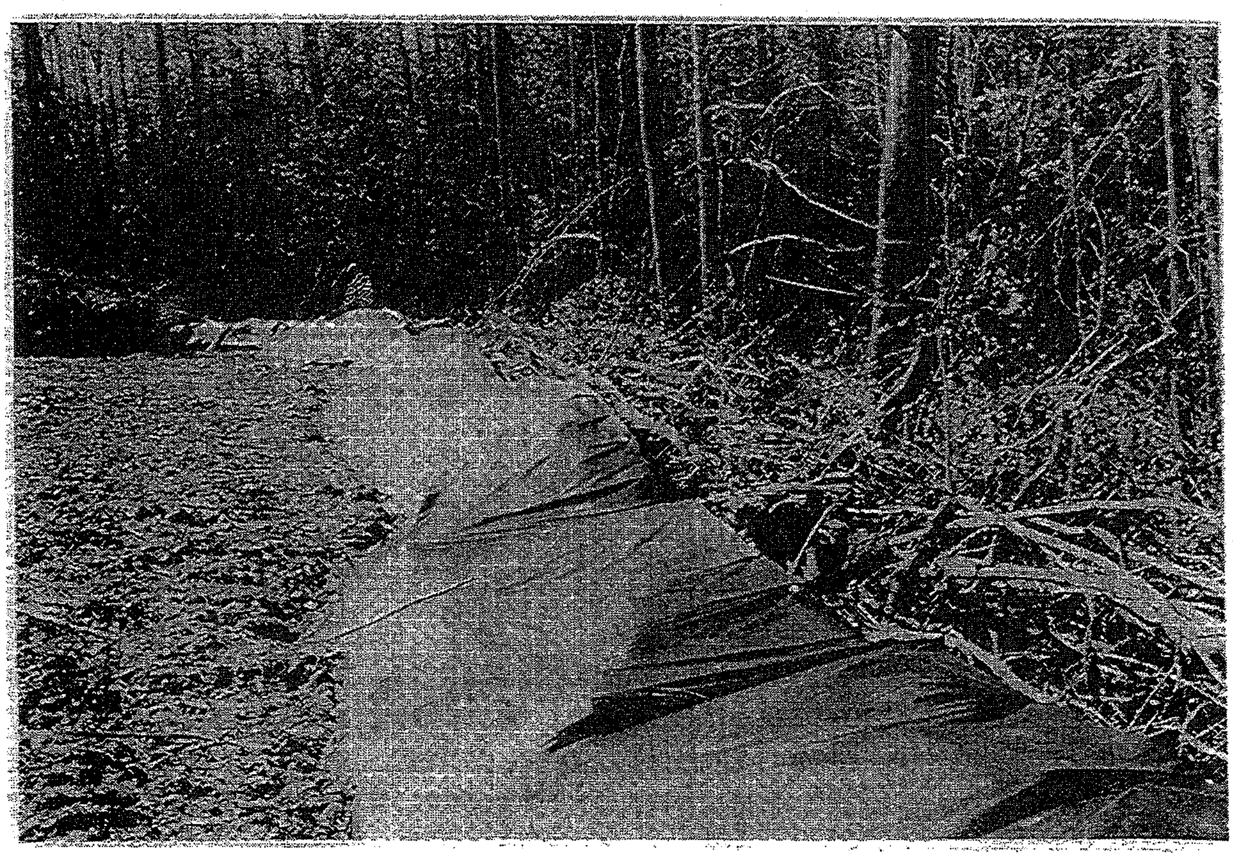
BB

Definition

A temporary sediment barrier constructed at the perimeter of a disturbed area from the residue materials available from clearing and grubbing the site.

Purpose

To intercept and retain sediment from disturbed areas of limited extent, preventing sediment from leaving the site.



Conditions Where Practice Applies

1. Below disturbed areas subject to sheet and rill erosion, where enough residue material is available for construction of such a barrier.

2. Where the size of the drainage area is no greater than one-fourth of an acre per 100 feet of barrier length; the maximum slope length behind the barrier is 100 feet; and the maximum slope gradient behind the barrier is 50 percent (2:1).

Planning Considerations

Organic litter and spoil material from site clearing operations is usually burned or hauled away to be dumped elsewhere. Much of this material can be used effectively on the construction site itself. During clearing and grubbing operations, equipment can push or dump the mixture of limbs, small vegetation and root mat along with minor amounts of rock into windrows along the toe of a slope where erosion and accelerated runoff are expected. Because brush barriers are fairly stable and composed of natural materials, maintenance requirements are small. Field experience has shown, however, that many brush barrier installations are not effective when there are large voids created by the use of material which is too large (such as tree stumps) to provide a compact, dense barrier. Therefore, it is necessary to use residual material under 6 inches in diameter which will create a more uniform barrier <u>or</u> utilize a filter fabric overlay to promote enhanced filtration of sediment-laden runoff.

Design Criteria

A formal design is not required.

Construction Specifications

Without Filter Cloth

1. The height of a brush barrier shall be a minimum of 3 feet.

2. The width of a brush barrier shall be a minimum of 5 feet at its base (the sizes of brush barriers may vary considerably based upon the amount of material available and the judgement of the design engineer).

3. The barrier shall be constructed by piling brush, stone, root mat and other material from the clearing process into a mounded row on the contour. <u>Material larger than 6 inches in diameter should not be used</u> to create the mound as the non-homogeneity of the mixture can lead to voids where sediment-laden flows can easily pass.

If a Filter is Used (see Plate 3.06-1)

1. Filter fabric must meet the minimum physical requirements noted in Table 3.05-B.

2. The filter fabric shall be cut into lengths sufficient to lay across the barrier from its up-slope base to just beyond its peak. Where joints are necessary, the fabric shall be spliced together with a minimum 6-inch overlap and securely sealed.

3. A trench shall be excavated 6-inches wide and 4-inches deep along the length of the barrier and immediately uphill from the barrier.

4. The lengths of filter fabric shall be draped across the width of the barrier with the uphill edge placed in the trench and the edges of adjacent pieces overlapping each other.

5. The filter fabric shall be secured in the trench with stakes set approximately 36 inches on center.

6. The trench shall be backfilled and the soil compacted over the filter fabric.

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

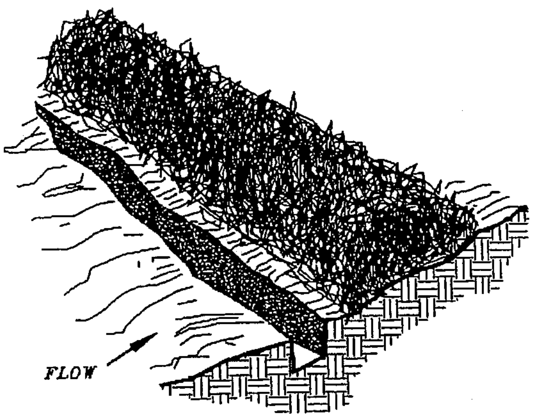
Maintenance

1. Brush barriers shall be inspected after each rainfall and necessary repairs shall be made promptly.

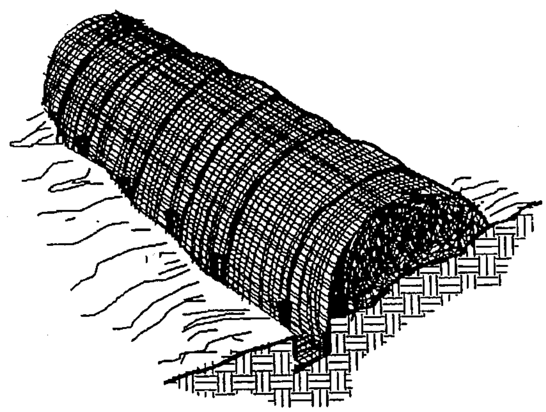
2. Sediment deposits must be removed when they reach approximately one-half the height of the barrier.

CONSTRUCTION OF A BRUSH BARRIER COVERED BY FILTER FABRIC

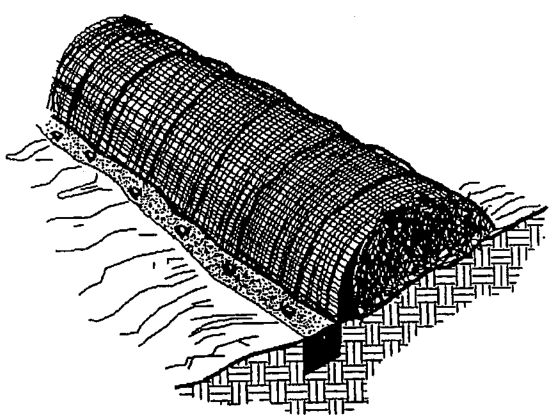
(TREE/RESIDUAL MATERIAL WITH DIAMETER > 6")



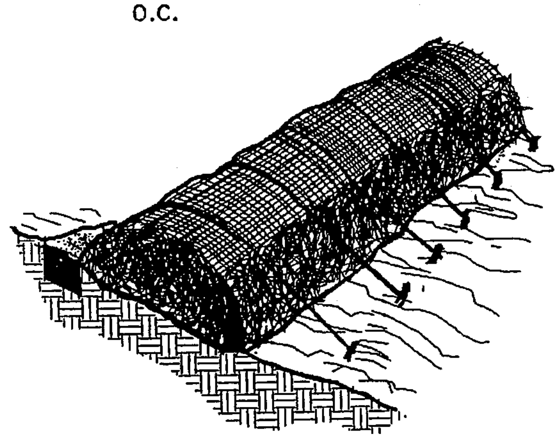
1. EXCAVATE A 4"X 4" TRENCH ALONG THE UPHILL EDGE OF THE BRUSH BARRIER.



2. DRAPE FILTER FABRIC OVER THE BRUSH BARRIER AND INTO THE TRENCH. FABRIC SHOULD BE SECURED IN THE TRENCH WITH STAKES SET APPROXIMATELY 36" O.C.



3. BACKFILL AND COMPACT THE EXCAVATED SOIL.

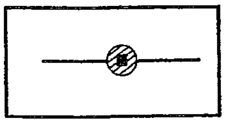


4. SET STAKES ALONG THE DOWN-HILL EDGE OF THE BRUSH BARRIER, AND ANCHOR BY TYING TWINE FROM THE FABRIC TO THE STAKES.

Source: Va. DSWC

Plate 3.06-1

STD & SPEC 3.07



STORM DRAIN INLET PROTECTION

IP

Definition

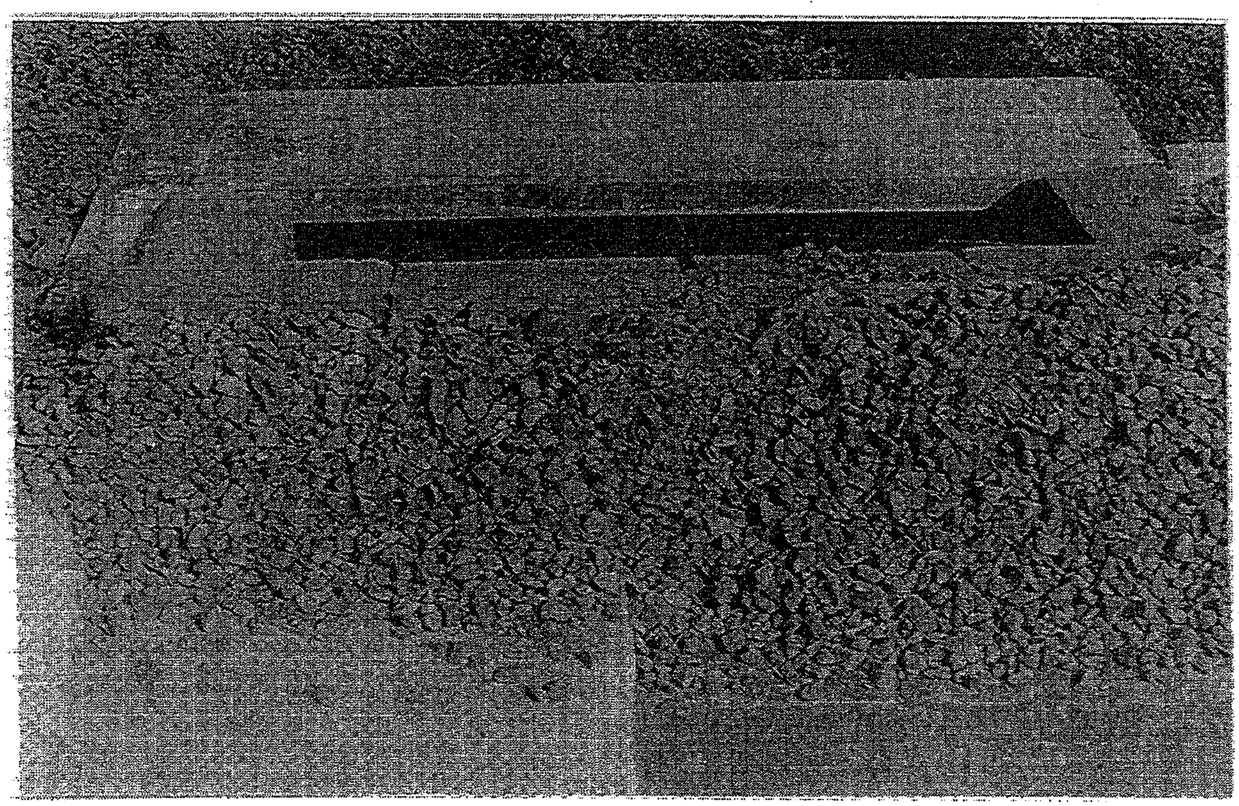
A sediment filter or an excavated impounding area around a storm drain drop inlet or curb inlet.

Purpose

To prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area.

Conditions Where Practice Applies

Where storm drain inlets are to be made operational before permanent stabilization of the corresponding disturbed drainage area. Different types of structures are applicable to different conditions (see Plates 3.07-1 through 3.07-8).



Planning Considerations

Storm sewers which are made operational prior to stabilization of the associated drainage areas can convey large amounts of sediment to natural drainageways. In case of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.

This practice contains several types of inlet filters and traps which have different applications dependent upon site conditions and type of inlet. Other innovative techniques for accomplishing the same purpose are encouraged, but only after specific plans and details are submitted to and approved by the appropriate Plan-Approving Authority.

Care should be taken when choosing a specific type of inlet protection. Field experience has shown that inlet protection which causes excessive ponding in an area of high construction activity may become so inconvenient that it is removed or bypassed, thus transmitting sediment-laden flows unchecked. In such situations, a structure with an adequate overflow mechanism should be utilized.

The following inlet protection devices are for drainage areas of one acre or less. Runoff from larger disturbed areas should be routed to a TEMPORARY SEDIMENT TRAP (Std. & Spec. 3.13) or a TEMPORARY SEDIMENT BASIN (Std. & Spec. 3.14).

The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source.

Stone is utilized as the chief ponding/filtering agent in most of the inlet protection types described in this specification. The various types of "coarse aggregates" which are depicted are able to filter out sediment mainly through slowing down flows directed to the inlet by creating an increased flow path for the stormwater (through void space in the respective stone). The stone filtering medium by no means slows stormwater flowrate as does filter cloth and therefore cannot provide the same degree of filter efficiency when smaller silt and clay particles are introduced into stormwater flows. However, as mentioned earlier, excessive ponding in busy areas adjacent to stormwater inlets is in many cases unacceptable - that is why stone must be utilized with many installations.

Fortunately, in most instances, inlet protection utilizing stone should not be the sole control measure. At the time that storm sewer inlet and associated appurtances become operational, areas adjacent to the structures are most likely at final grade or will not be altered for extended periods; this is the time when TEMPORARY SEEDING (Std. & Spec. 3.31) and other appropriate controls should be implemented to enhance sediment-loss mitigation. In addition, by varying stone sizes used in the construction of inlet protection, a greater degree of sediment removal can be obtained. As an option, filter cloth can be used with the stone in these devices to further enhance sediment removal. Notably, the potential inconvenience of excessive ponding must be examined with these choices, especially the latter.

Design Criteria

1. The drainage area shall be no greater than 1 acre.

2. The inlet protection device shall be constructed in a manner that will facilitate clean-out and disposal of trapped sediment and minimize interference with construction activities.

3. The inlet protection devices shall be constructed in such a manner that any resultant ponding of stormwater will not cause excessive inconvenience or damage to adjacent areas or structures.

4. Design criteria more specific to each particular inlet protection device will be found on Plates 3.07-1 through 3.07-8.

5. For the inlet protection devices which utilize stone as the chief ponding/filtering medium, a range of stone sizes is offered; VDOT #3, #357, or #5 Coarse Aggregate should be used. The designer/plan reviewer should attempt to get the greatest amount of filtering action possible (by using smaller-sized stone), while not creating significant ponding problems.

6. In all designs which utilize stone with a wire-mesh support as a filtering mechanism, the stone can be completely wrapped with the wire mesh to improve stability and provide easier cleaning.

7. Filter Fabric may be added to any of the devices which utilize "coarse aggregate" stone to significantly enhance sediment removal. The fabric, which must meet the physical requirements noted for "extra strength" found in Table 3.05-B, should be secured between the stone and the inlet (on wire-mesh if it is present). As a result of the significant increase in filter efficiency provided by the fabric, a larger range of stone sizes (VDOT #1, #2 or #3 Coarse Aggregate) may be utilized with such a configuration. The larger stone will help keep larger sediment masses from clogging the cloth. Notably, significant ponding may occur at the inlet if filter cloth is utilized in this manner.

Construction Specifications

1. Silt Fence Drop Inlet Protection

   a. Silt Fence shall conform to the construction specifications for "extra strength" found in Table 3.05-B and shall be cut from a continuous roll to avoid joints.

   b. For stakes, use 2 x 4-inch wood (preferred) or equivalent metal with a minimum length of 3 feet.

c. Space stakes evenly around the perimeter of the inlet a maximum of 3-feet apart, and securely drive them into the ground, approximately 18-inches deep (see Plate 3.07-1).

d. To provide needed stability to the installation, frame with 2 x 4-inch wood strips around the crest of the overflow area at a maximum of 1½ feet above the drop inlet crest.

e. Place the bottom 12 inches of the fabric in a trench (see Plate 3.07-1) and backfill the trench with 12 inches of compacted soil.

f. Fasten fabric securely by staples or wire to the stakes and frame. Joints must be overlapped to the next stake.

g. It may be necessary to build a temporary dike on the downslope side of the structure to prevent bypass flow.

2. Gravel and Wire Mesh Drop Inlet Sediment Filter

a. Wire mesh shall be laid over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Wire mesh with 1/2-inch openings shall be used. If more than one strip of mesh is necessary, the strips shall be overlapped.

b. Coarse aggregate shall be placed over the wire mesh as indicated on Plate 3.07-2. The depth of stone shall be at least 12 inches over the entire inlet opening. The stone shall extend beyond the inlet opening at least 18 inches on all sides.

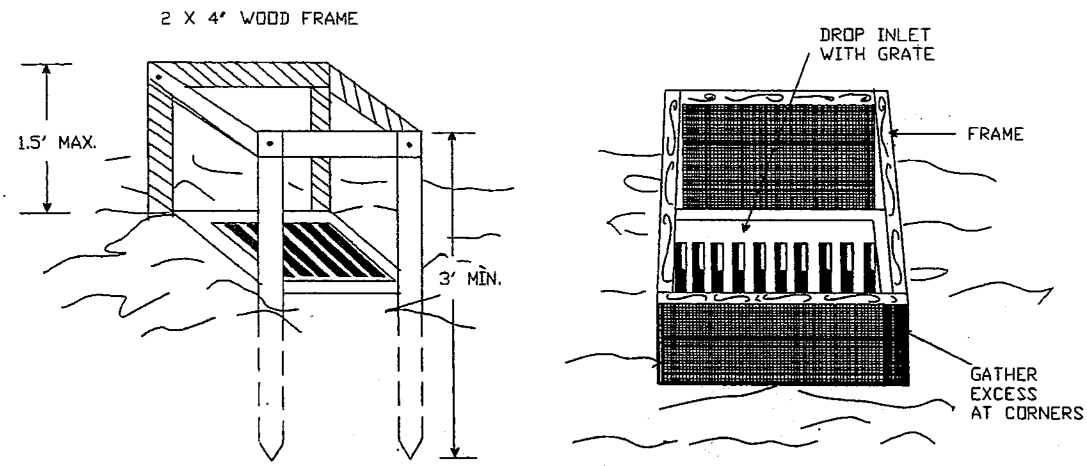
c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stones must be pulled away from the inlet, cleaned and/or replaced.

Note: This filtering device has no overflow mechanism; therefore, ponding is likely especially if sediment is not removed regularly. This type of device must never be used where overflow may endanger an exposed fill slope. Consideration should also be given to the possible effects of ponding on traffic movement, nearby structures, working areas, adjacent property, etc.

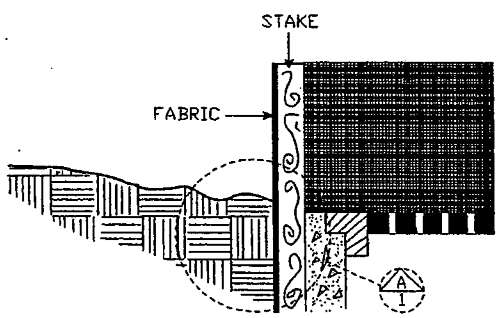
3. Block and Gravel Drop Inlet Sediment Filter

a. Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending on design needs, by stacking combinations of 4-inch, 8-inch and 12-inch wide blocks. The barrier of blocks shall be at least 12-inches high and no greater than 24-inches high.

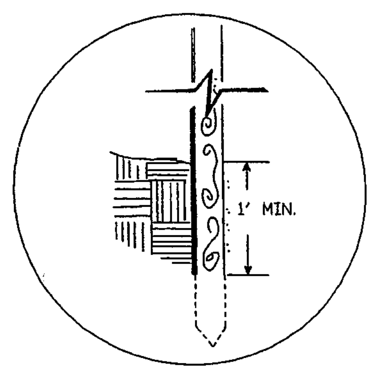
SILT FENCE DROP INLET PROTECTION



PERSPECTIVE VIEWS



ELEVATION OF STAKE AND FABRIC ORIENTATION



DETAIL A

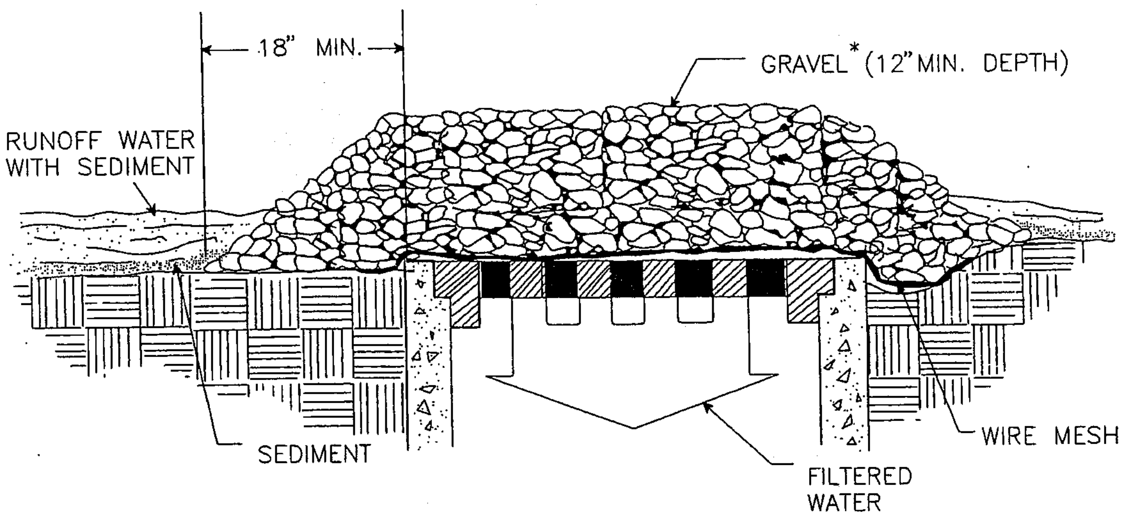
SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE THE INLET DRAINS A RELATIVELY FLAT AREA (SLOPE NO GREATER THAN 5%) WHERE THE INLET SHEET OR OVERLAND FLOWS (NOT EXCEEDING 1 C.F.S.) ARE TYPICAL. THE METHOD SHALL NOT APPLY TO INLETS RECEIVING CONCENTRATED FLOWS, SUCH AS IN STREET OR HIGHWAY MEDIANS.

Source: N.C. Erosion and Sediment Control Planning and Design Manual, 1988

Plate 3.07-1

GRAVEL AND WIRE MESH DROP INLET SEDIMENT FILTER



SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY CONCENTRATED FLOWS ARE EXPECTED, BUT NOT WHERE PONDING AROUND THE STRUCTURE MIGHT CAUSE EXCESSIVE INCONVENIENCE OR DAMAGE TO ADJACENT STRUCTURES AND UNPROTECTED AREAS.

* GRAVEL SHALL BE VDOT #3, #357 OR #5 COARSE AGGREGATE.

Source: Va. DSWC Plate 3.07-2

b. Wire mesh shall be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Wire mesh with 1/2-inch openings shall be used.

c. Stone shall be piled against the wire to the top of the block barrier, as shown in Plate 3.07-3.

d. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.

4. Excavated Drop Inlet Sediment Trap

a. The excavated trap shall be sized to provide a minimum storage capacity calculated at the rate of 134 cubic yards per acre of drainage area. A trap shall be no less than 1-foot nor more than 2-feet deep measured from the top of the inlet structure. Side slopes shall not be steeper than 2:1 (see Plate 3.07-4).

b. The slope of the basin may vary to fit the drainage area and terrain. Observations must be made to check trap efficiency and modifications shall be made as necessary to ensure satisfactory trapping of sediment. Where an inlet is located so as to receive concentrated flows, such as in a highway median, it is recommended that the basin have a rectangular shape in a 2:1 (length/width) ratio, with the length oriented in the direction of the flow.

c. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Removed sediment shall be deposited in a suitable area and in a manner such that it will not erode.

5. Sod Drop Inlet Sediment Filter

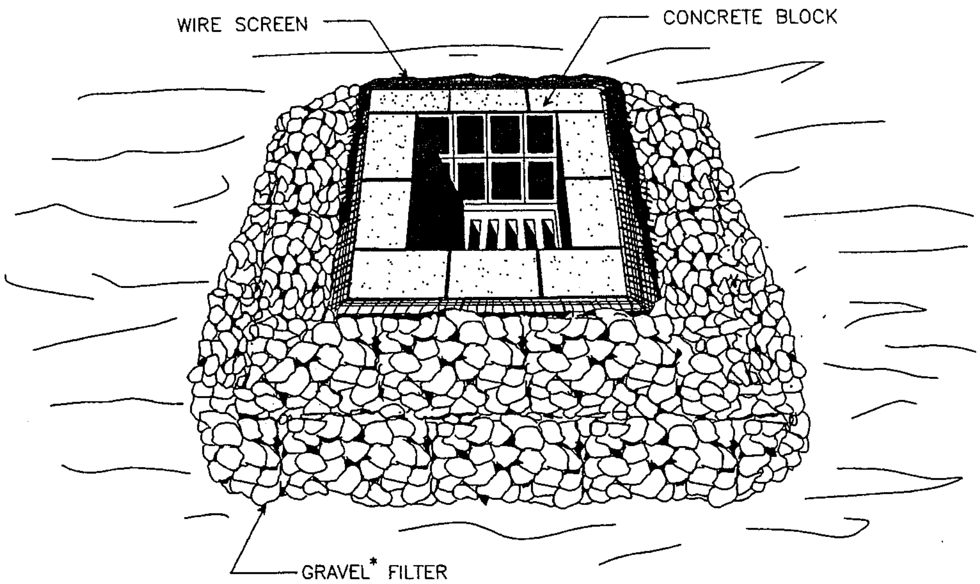
a. Soil shall be prepared and sod installed according to the specifications in Std. & Spec. 3.33, SODDING.

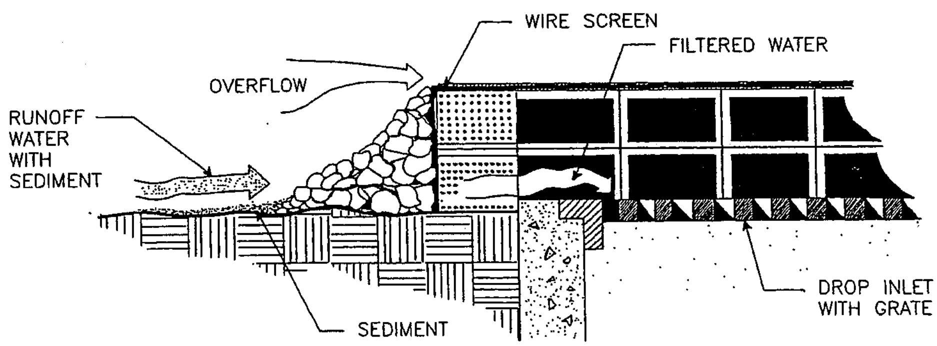
b. Sod shall be placed to form a turf mat covering the soil for a distance of 4 feet from each side of the inlet structure, as depicted in Plate 3.07-5.

6. Gravel Curb Inlet Sediment Filter

a. Wire mesh with 1/2-inch openings shall be placed over the curb inlet opening so that at least 12 inches of wire extends across the inlet cover and at least 12 inches of wire extends across the concrete gutter from the inlet opening, as depicted in Plate 3.07-6.

BLOCK AND GRAVEL DROP INLET SEDIMENT FILTER





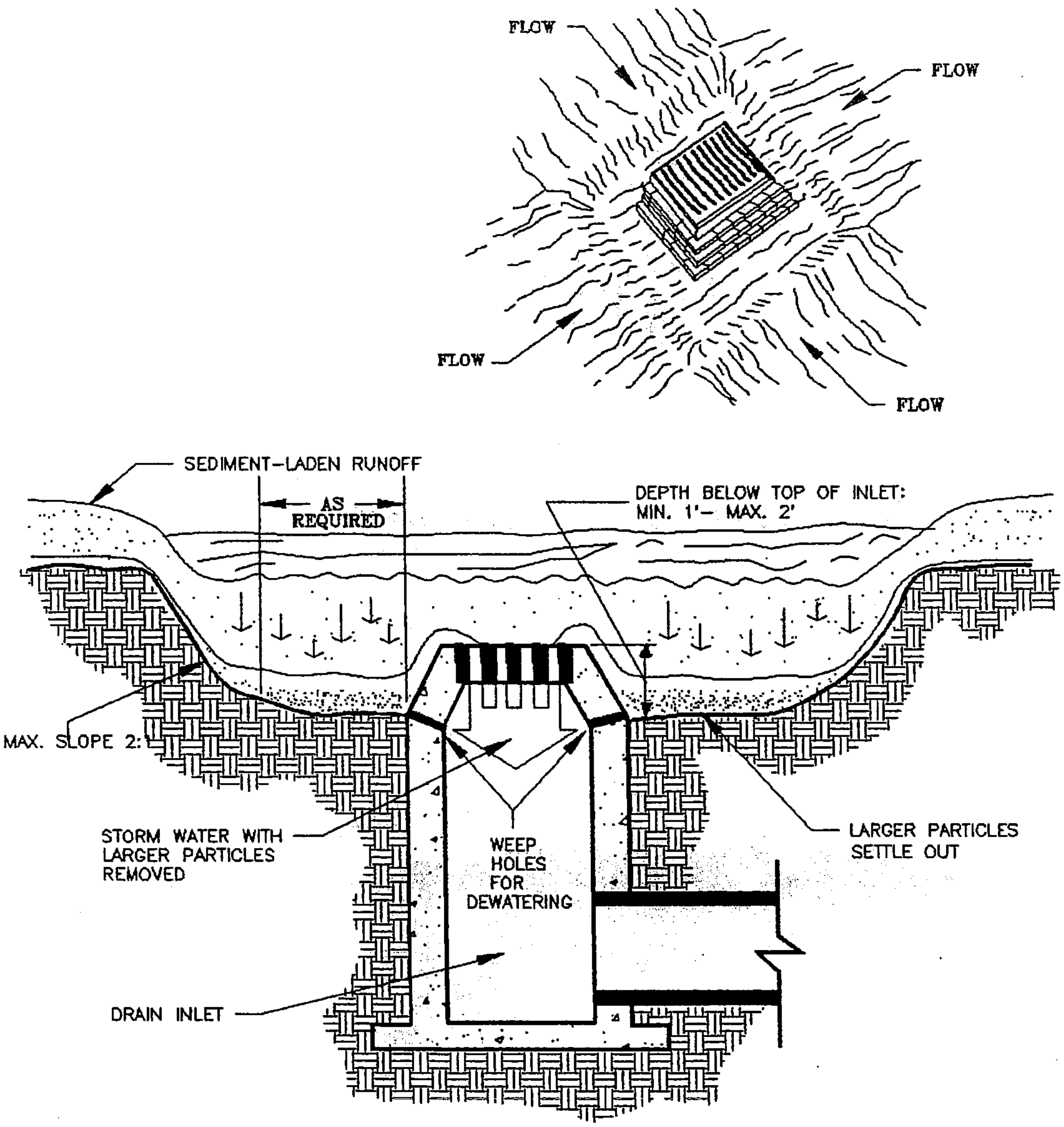
SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY FLOWS ARE EXPECTED AND WHERE AN OVERFLOW CAPACITY IS NECESSARY TO PREVENT EXCESSIVE PONDING AROUND THE STRUCTURE.

* GRAVEL SHALL BE VDOT #3, #357 OR #5 COARSE AGGREGATE.

Source: Va. DSWC Plate 3.07-3

EXCAVATED DROP INLET SEDIMENT TRAP



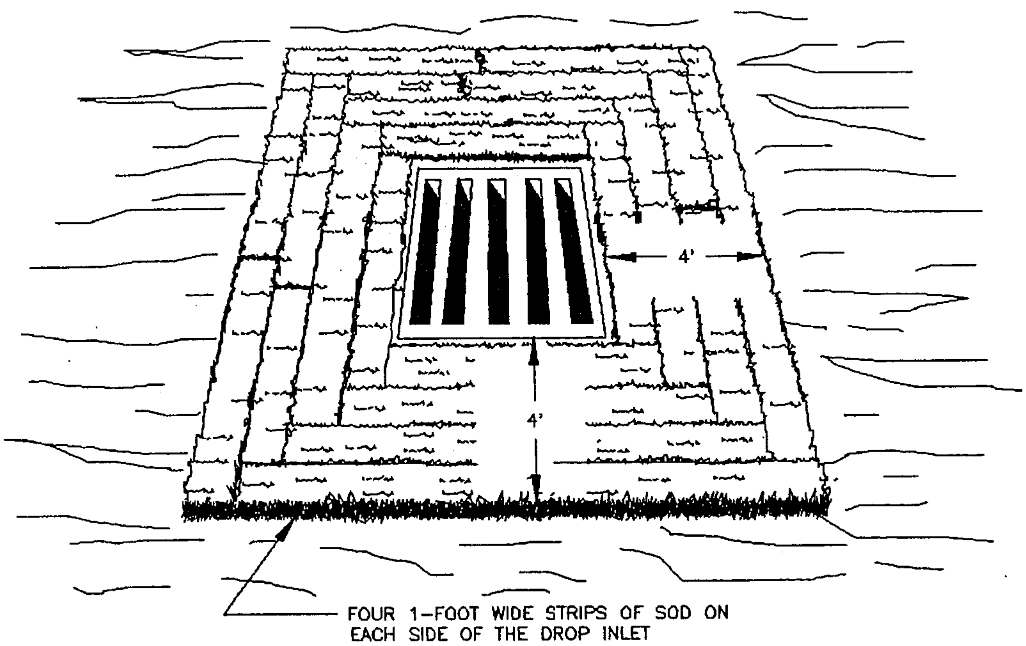
SPECIFIC APPLICATION

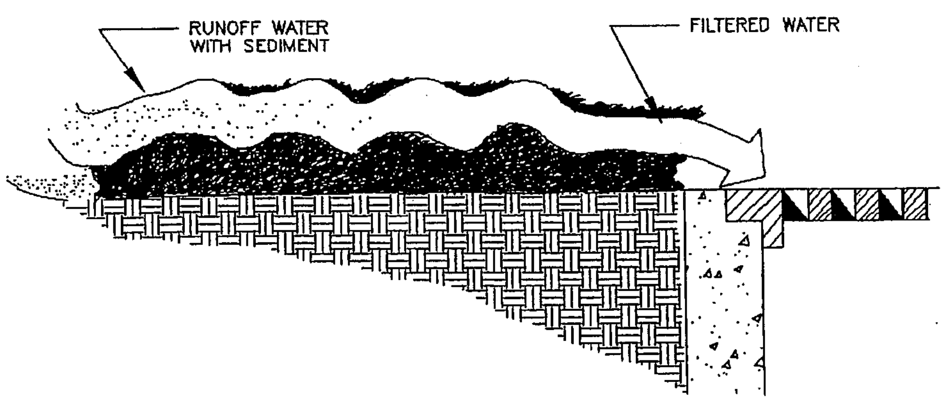
THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY FLOWS ARE EXPECTED AND WHERE AN OVERFLOW CAPABILITY AND EASE OF MAINTENANCE ARE DESIRABLE.

Source: Michigan Soil Erosion and Sediment Control Guidebook, 1975, and USDA-SCS

Plate 3.07-4

SOD DROP INLET SEDIMENT FILTER





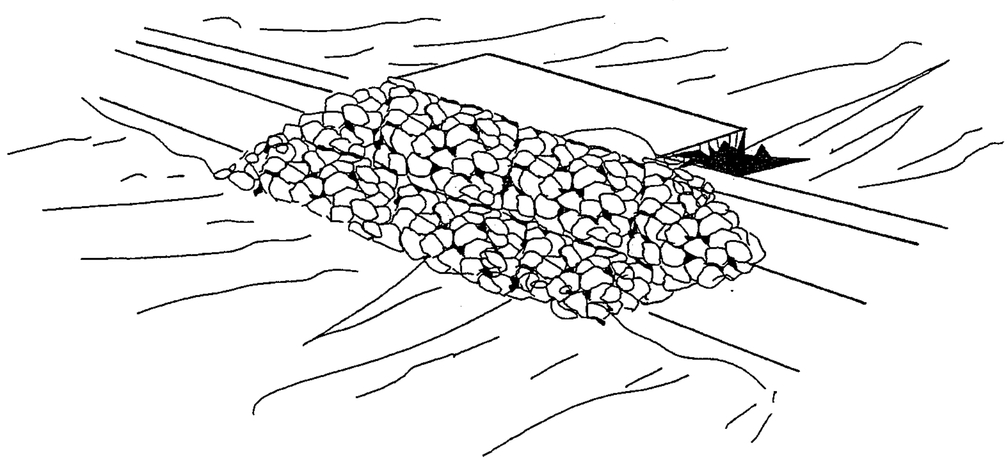
SPECIFIC APLLICATION

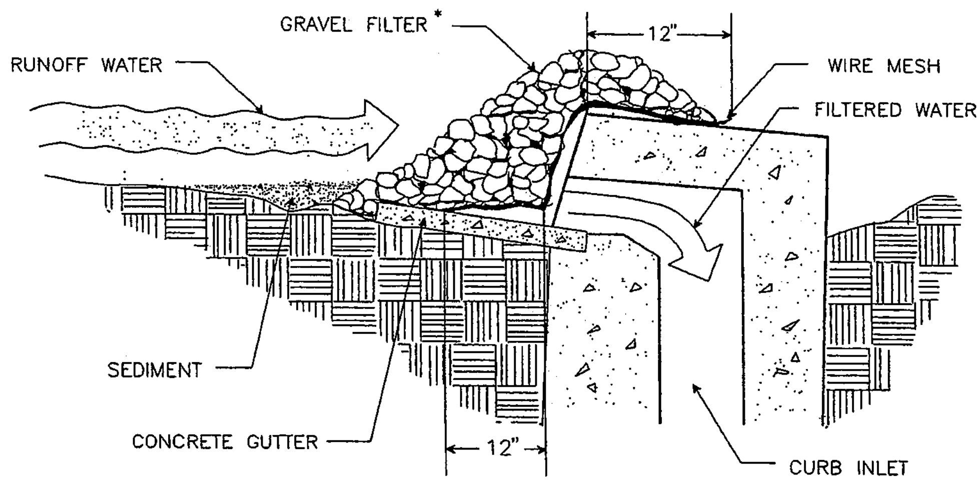
THIS METHOD OF INLET PROTECTION IS APPPLICABLE ONLY AT THE TIME OF PERMANENT SEEDING, TO PROTECT THE INLET FROM SEDIMENT AND MULCH MATERIAL UNTIL PERMANENT VEGETATION HAS BECOME ESTABLISHED.

Source: Va. DSWC

Plate 3.07-5

GRAVEL CURB INLET SEDIMENT FILTER





SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE AT CURB INLETS WHERE PONDING IN FRONT OF THE STRUCTURE IS NOT LIKELY TO CAUSE INCONVENIENCE OR DAMAGE TO ADJACENT STRUCTURES AND UNPROTECTED AREAS.

* GRAVEL SHALL BE VDOT #3, #357 OR 5 COARSE AGGREGATE.

Source: Va. DSWC

Plate 3.07-6

b. Stone shall be piled against the wire so as to anchor it against the gutter and inlet cover and to cover the inlet opening completely.

c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the block, cleaned and replaced.

7. Curb Inlet Protection with 2-inch x 4-inch Wooden Weir

a. Attach a continuous piece of wire mesh (30-inch minimum width x inlet throat length plus 4 feet) to the 2-inch x 4-inch wooden weir (with a total length of throat length plus 2 feet) as shown in Plate 3.07-7. Wood should be "construction grade" lumber.

b. Place a piece of approved "extra-strength" filter cloth of the same dimensions as the wire mesh over the wire mesh and securely attach to the 2-inch x 4-inch weir.

c. Securely nail the 2-inch x 4-inch weir to the 9-inch long vertical spacers which are to be located between the weir and inlet face at a maximum 6-foot spacing.

d. Place the assembly against the inlet throat and nail 2-foot (minimum) lengths of 2-inch x 4-inch board to the top of the weir at spacer locations. These 2-inch x 4-inch anchors shall extend across the inlet tops and be held in place by sandbags or alternate weight.

e. The assembly shall be placed so that the end spacers are a minimum 1 foot beyond both ends of the throat opening.

f. Form the wire mesh and filter cloth to the concrete gutter and against the face of curb on both sides of the inlet. Place coarse aggregate over the wire mesh and filter fabric in such a manner as to prevent water from entering the inlet under or around the filter cloth.

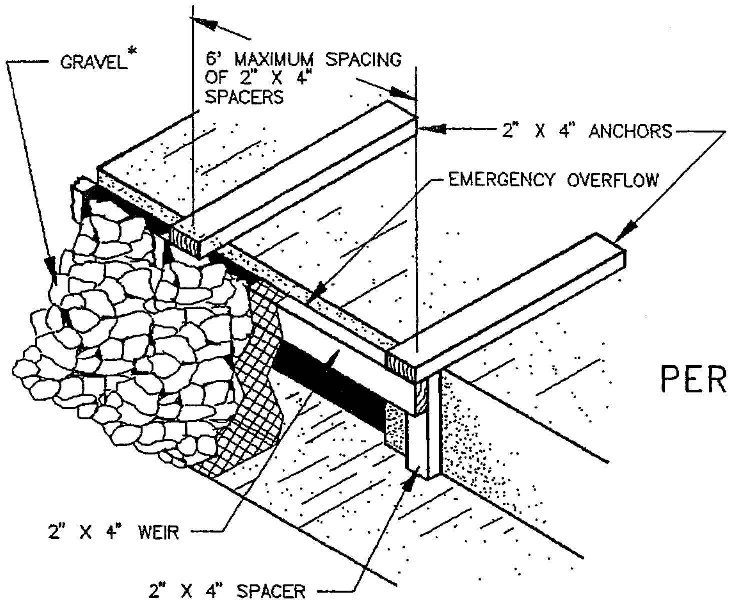
g. This type of protection must be inspected frequently and the filter cloth and stone replaced when clogged with sediment.

h. Assure that storm flow does not bypass inlet by installing temporary earth or asphalt dikes directing flow into inlet.

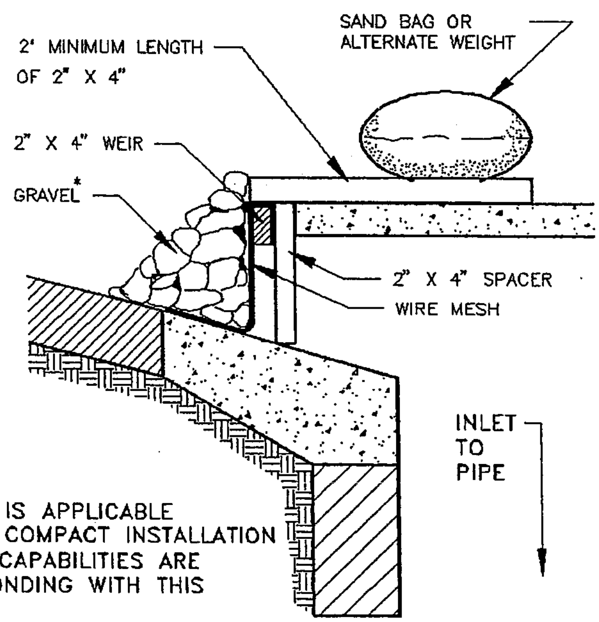
8. Block and Gravel Curb Inlet Sediment Filter

a. Two concrete blocks shall be placed on their sides abutting the curb at either side of the inlet opening.

CURB INLET PROTECTION WITH 2-INCH X 4-INCH WOODEN WEIR



PERSPECTIVE VIEW



SIDE ELEVATION

SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE TO CURB INLETS WHERE A STURDY, COMPACT INSTALLATION IS DESIRED. EMERGENCY OVERFLOW CAPABILITIES ARE MINIMAL, SO EXPECT SIGNIFICANT PONDING WITH THIS MEASURE.

*GRAVEL SHALL BE VDOT COARSE AGGREGATE #3, #357 OR #5

Source: 1983 Maryland Standards and Specifications for Soil Erosion and Sediment Control, and USDA-SCS

Plate 3.07-7

b. A 2-inch x 4-inch stud shall be cut and placed through the outer holes of each spacer block to help keep the front blocks in place.

c. Concrete blocks shall be placed on their sides across the front of the inlet and abutting the spacer blocks as depicted in Plate 3.07-8.

d. Wire mesh shall be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Wire mesh with 1/2-inch openings shall be used.

e. Coarse aggregate shall be piled against the wire to the top of the barrier as shown in Plate 3.07-8.

f. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and/or replaced.

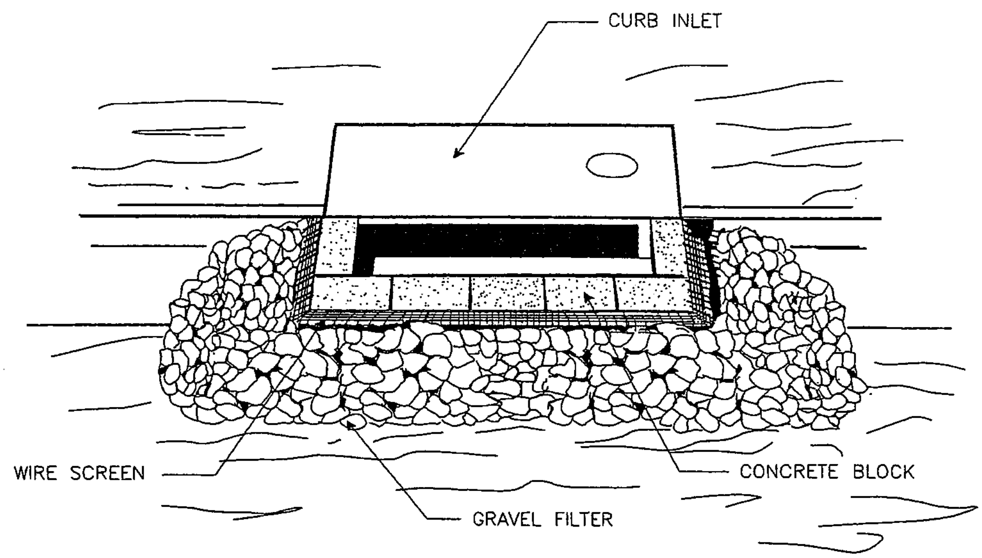
Maintenance

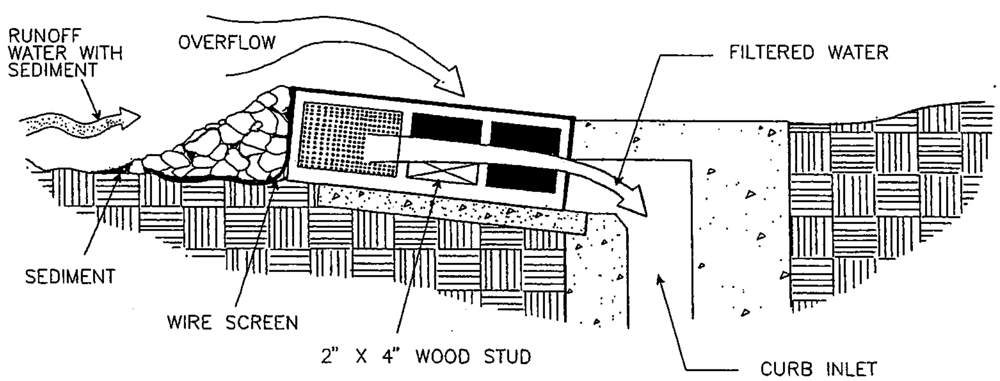
1. The structure shall be inspected after each rain and repairs made as needed.

2. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to one half the design depth of the trap. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode.

3. Structures shall be removed and the area stabilized when the remaining drainage area has been properly stabilized.

BLOCK & GRAVEL CURB INLET SEDIMENT FILTER





SPECIAL APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE AT CURB INLETS WHERE AN OVERFLOW CAPABILITY IS NECESSARY TO PREVENT EXCESSIVE PONDING IN FRONT OF THE STRUCTURE.

* GRAVEL SHALL BE VDOT #3, #357 OR #5 COARSE AGGREGATE

Source: Va. DSWC

Plate 3.07-8

STD & SPEC 3.08

CULVERT INLET PROTECTION

CIP

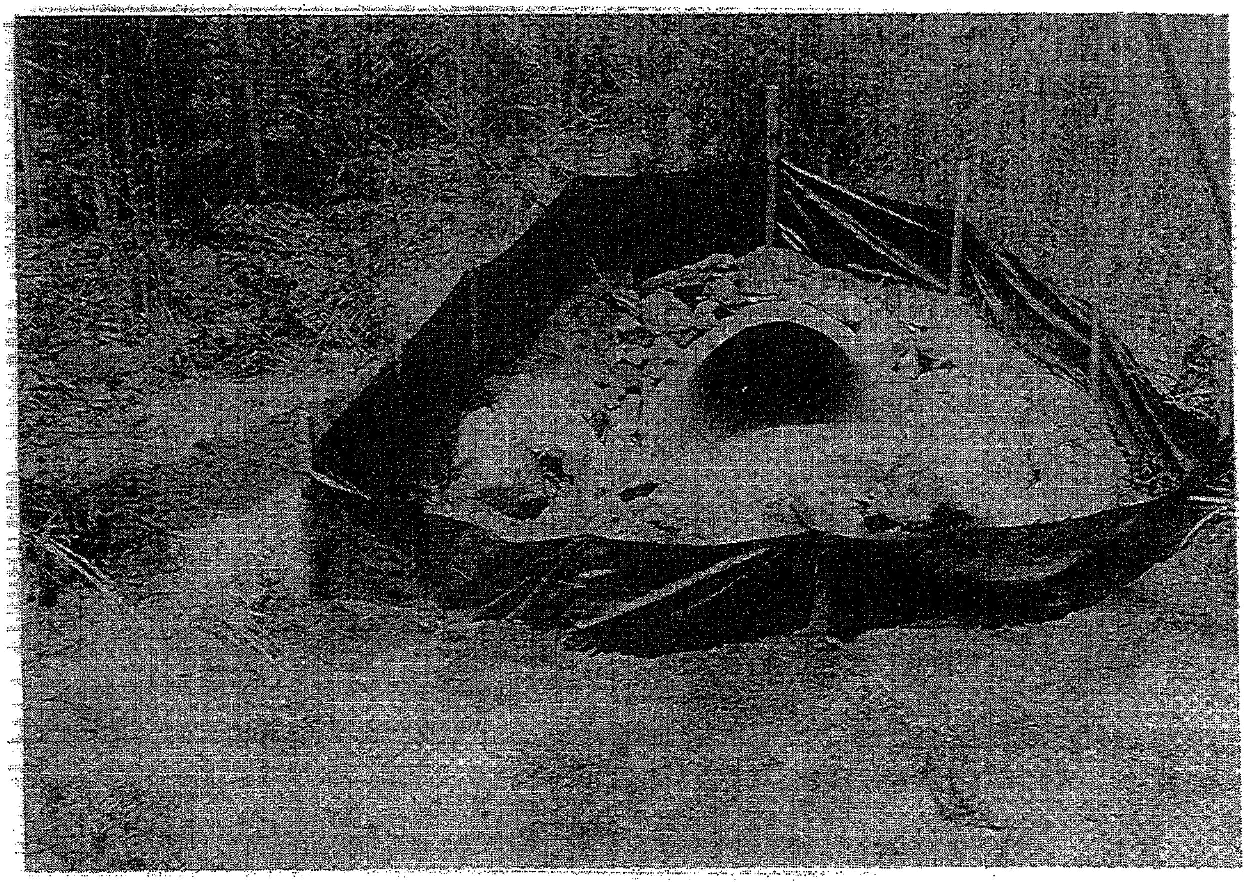
Definition

A sediment filter located at the inlet to storm sewer culverts.

Purposes

1. To prevent sediment from entering, accumulating in and being transferred by a culvert and associated drainage system prior to permanent stabilization of a disturbed project area.

2. To provide erosion control at culvert inlets during the phase of a project where elevation and drainage patterns change, causing original control measures to be ineffective or in need of removal.



Conditions Where Practice Applies

Where culvert and associated drainage system is to be made operational prior to permanent stabilization of the disturbed drainage area. Different types of structures are applicable to different conditions (see Plates 3.08-1 and 3.08-2).

Planning Considerations

When construction on a project reaches a stage where culverts and other storm sewer appurtenances are installed and many areas are brought to a desired grade, the erosion control measures used in the early stages normally need to be modified or may need to be removed altogether. At that time, there is a need to provide protection at the points where runoff will leave the area via culverts and drop or curb inlets.

Similar to drop and curb inlets, culverts which are made operational prior to stabilization of the associated drainage areas can convey large amounts of sediment to natural drainageways. In case of extreme sediment loading, the pipe or pipe system itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the culvert by using one of the methods noted in this section.

General Guidelines (All Types)

1. The inlet protection device shall be constructed in a manner that will facilitate clean-out and disposal of trapped sediment and minimize interference with construction activities.

2. The inlet protection devices shall be constructed in such a manner that any resultant ponding of stormwater will not cause excessive inconvenience or damage to adjacent areas or structures.

3. Design criteria more specific to each particular inlet protection device will be found in Plates 3.08-1 through 3.08-2.

Design Criteria

1. Silt Fence Culvert Inlet Protection

   a. No formal design is required.

   b. Silt fence culvert inlet protection has an expected maximum usable life of three months.

   c. The maximum area draining to this practice shall not exceed one acre.

2. Culvert Inlet Sediment Trap

   a. Runoff storage requirements shall be in accordance with information outlined under Std. & Spec. 3.13, TEMPORARY SEDIMENT TRAP.

   b. Culvert inlet sediment traps have a maximum expected useful life of 18 months.

   c. The maximum area draining to this practice shall not exceed 3 acres.

Construction Specifications

1. Silt Fence Culvert Inlet Protection

   a. The height of the silt fence (in front of the culvert opening) shall be a minimum of 16 inches and shall not exceed 34 inches.

   b. Extra strength filter fabric with a maximum spacing of stakes of 3 feet shall be used to construct the measure.

   c. The placement of silt fence should be approximately 6 feet from the culvert in the direction of incoming flow, creating a "horseshoe" shape as shown in Plate 3.08-1.

   d. If silt fence cannot be installed properly or the flow and/or velocity of flow to the culvert protection is excessive and may breach the structure, the stone combination noted in Plate 3.08-1 should be utilized.

2. Culvert Inlet Sediment Trap

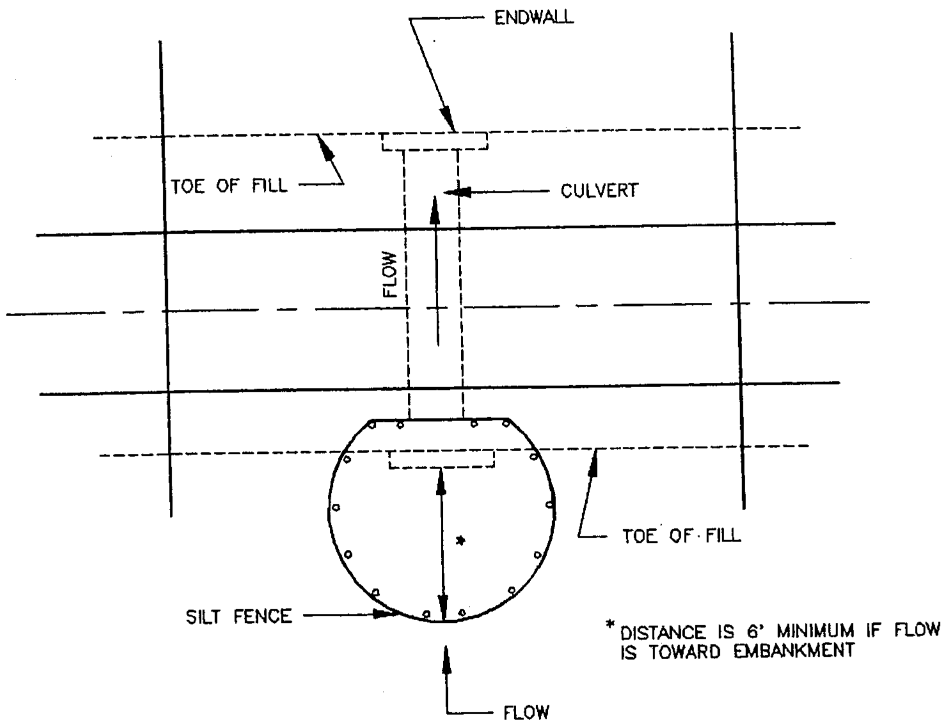
   a. Geometry of the design will be a "horseshoe" shape around the culvert inlet (see Plate 3.08-2).

   b. The toe of riprap (composing the sediment filter dam) shall be no closer than 24" from the culvert opening in order to provide an acceptable emergency outlet for flows from larger storm events.

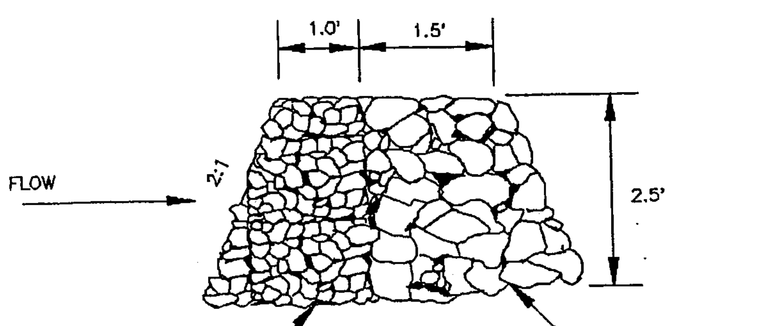
   c. All other "Construction Specifications" found within Std. & Spec. 3.13, TEMPORARY SEDIMENT TRAP, also apply to this practice.

   e. The proper installation of the culvert inlet sediment trap is a viable substitute for the installation of the TEMPORARY SEDIMENT TRAP.

SILT FENCE CULVERT INLET PROTECTION



OPTIONAL STONE COMBINATION**

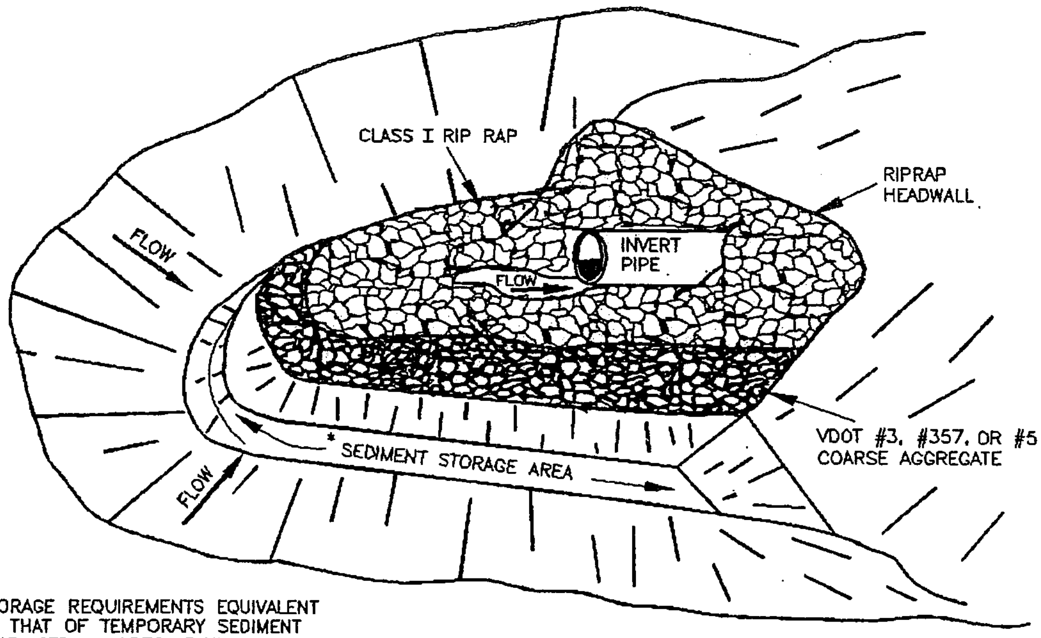


** VDOT #3, #357 OR #5 COARSE AGGREGATE TO REPLACE SILT FENCE IN " HORSESHOE " WHEN HIGH VELOCITY OF FLOW IS EXPECTED

Source: Adapted from VDOT Standard Sheets and Va. DSWC

Plate 3.08-1

CULVERT INLET SEDIMENT TRAP

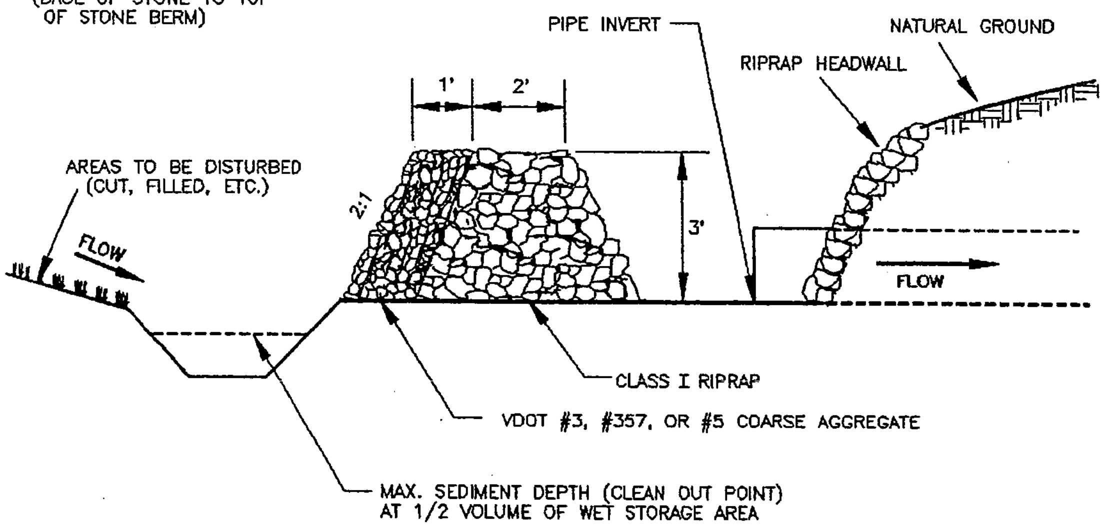


*STORAGE REQUIREMENTS EQUIVALENT TO THAT OF TEMPORARY SEDIMENT TRAP, STD. & SPEC. 3.13

67 C.Y./ACRE WET STORAGE (BELOW BASE OF STONE)

67 C.Y./ACRE DRY STORAGE (BASE OF STONE TO TOP OF STONE BERM)

PERSPECTIVE VIEW



ELEVATION

Source: North Carolina Sediment Control Commission

Plate 3.08-2

Maintenance

1. The structure shall be inspected after each rain and repairs made as needed.

2. Aggregate shall be replaced or cleaned when inspection reveals that clogged voids are causing ponding problems which interfere with on-site construction.

3. Sediment shall be removed and the impoundment restored to its original dimensions when sediment has accumulated to one-half the design depth. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode and cause sedimentation problems.

4. Temporary structures shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized.

STD & SPEC 3.09

TEMPORARY DIVERSION DIKE

DD

Definition

A temporary ridge of compacted soil constructed at the top or base of a sloping disturbed area.

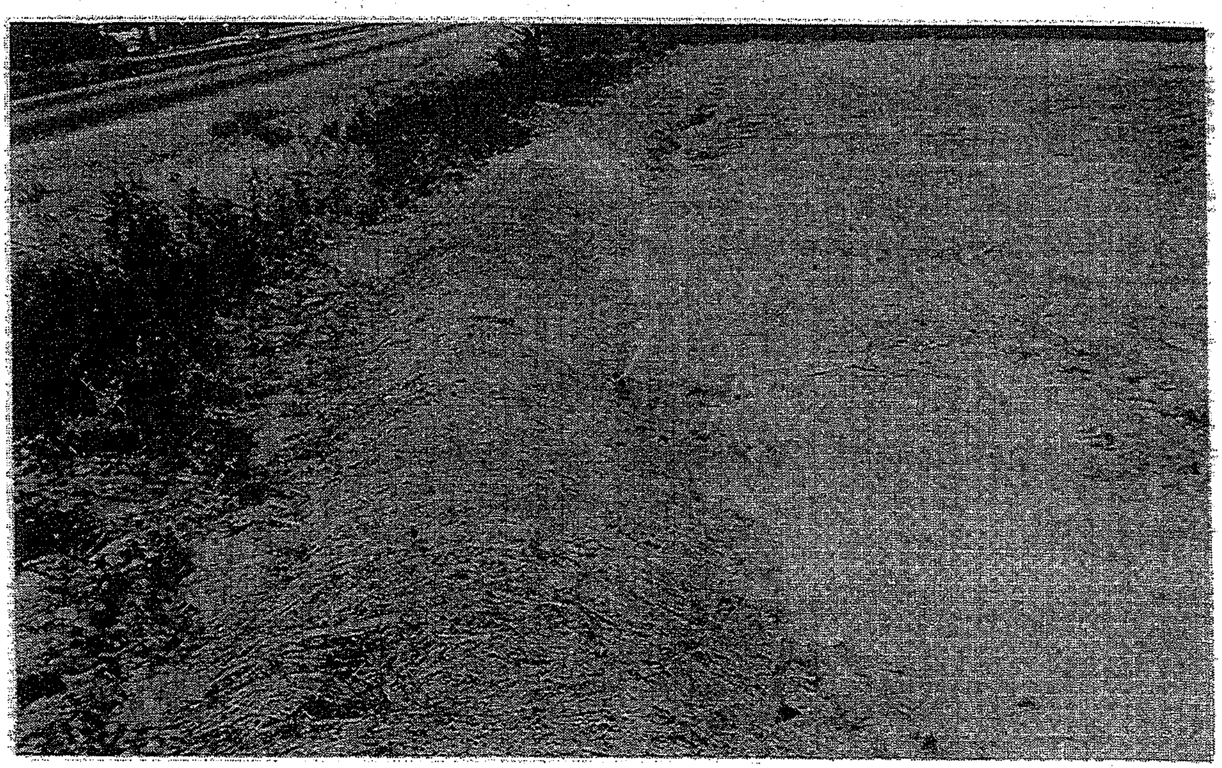
Purposes

1. To divert storm runoff from upslope drainage areas away from unprotected disturbed areas and slopes to a stabilized outlet.

2. To divert sediment-laden runoff from a disturbed area to a sediment-trapping facility such as a sediment trap or sediment basin.

Conditions Where Practice Applies

Wherever stormwater runoff must be temporarily diverted to protect disturbed areas and slopes or retain sediment on site during construction. These structures generally have a life expectancy of 18 months or less, which can be prolonged with proper maintenance.



Planning Considerations

A temporary diversion dike is intended to divert overland sheet flow to a stabilized outlet or a sediment-trapping facility during establishment of permanent stabilization on sloping disturbed areas. When used a the top of a slope, the structure protects exposed slopes by keeping upland runoff away. 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.

As per M.S. #5, it is very important that a temporary diversion dike be stabilized immediately following installation with temporary or permanent vegetation to prevent erosion of the dike itself. The gradient of the channel behind the dike is also an important consideration. The dike must have a positive grade to assure drainage, but if the gradient is too great, precautions must be taken to prevent erosion due to high-velocity channel flow behind the dike. The cross-section of the channel which runs behind the dike should be of a parabolic or trapezoidal shape to help inhibit a high velocity of flow which could arise in a vee ditch.

This practice is considered an economical one because it uses material available on the site and can usually be constructed with equipment needed for site grading. The useful life of the practice can be extended by stabilizing the dike with vegetation. Diversion dikes are preferable to silt fence because they are more durable, less expensive, and require much less maintenance when constructed properly. Along with a TEMPORARY SEDIMENT TRAP (Std. & Spec. 3.13), they become a logical choice for a control measure once the control limits of the silt fence or straw bale barrier have been exceeded.

Temporary diversion dikes are often used as a perimeter control in association with a sediment trap or a sediment basin, or a series of sediment-trapping facilities, on moderate to large construction sites. If installed properly and in the first phase of grading, maintenance costs are very low. Often, cleaning of sediment-trapping facilities is the only associated maintenance requirement.

As specified herein, this practice is intended to be temporary. However, with more stringent design criteria, it can be made permanent in accordance with DIVERSIONS (Std. & Spec. 3.12).

Design Criteria

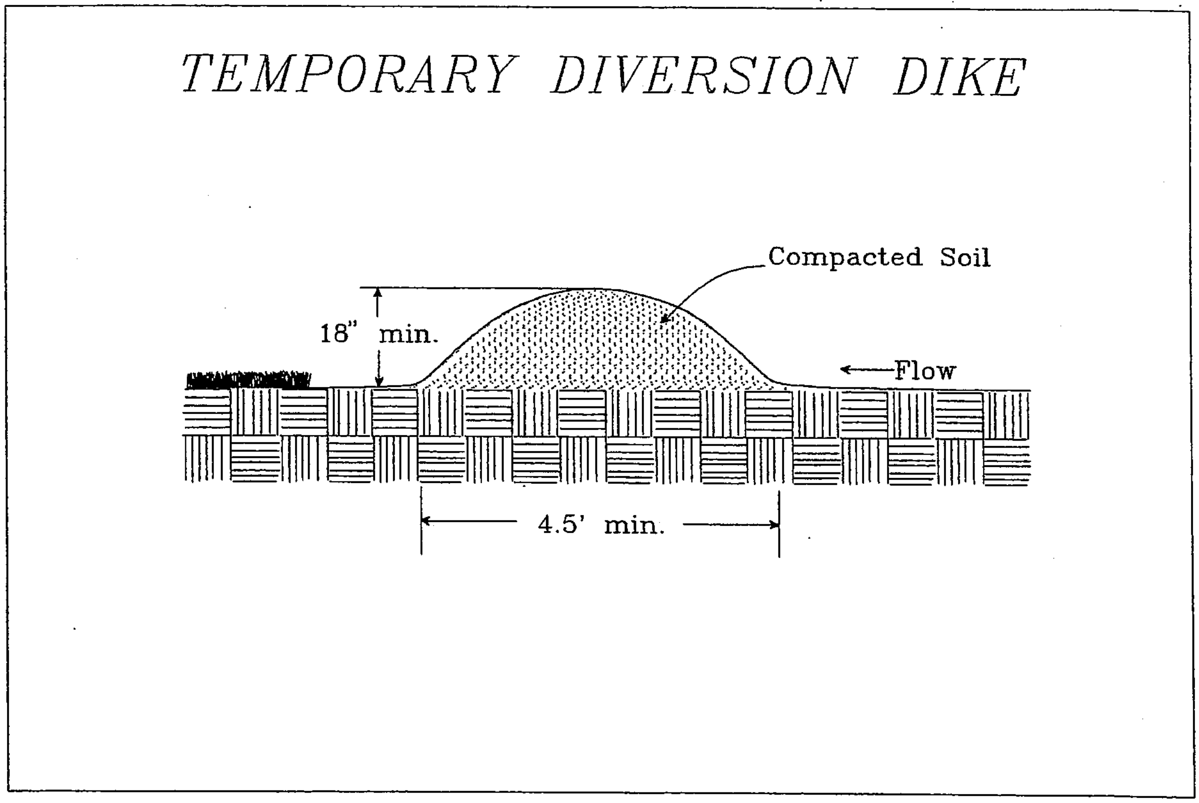
No formal design is required. The following criteria shall be met:

Drainage Area

The maximum allowable drainage area is 5 acres.

Height

The minimum allowable height measured from the upslope side of the dike is 18 inches (see Plate 3.09-1).



Source: Va. DSWC

Plate 3.09-1

Side Slopes

1½:1 or flatter, along with a minimum base width of 4.5 feet (see Plate 3.09-1).

Grade

The channel behind the dike shall have a positive grade to a stabilized outlet. If the channel slope is less than or equal to 2%, no stabilization is required. If the slope is greater than 2%, the channel shall be stabilized in accordance with Std. & Spec. 3.17, STORMWATER CONVEYANCE CHANNEL.

Outlet

1. The diverted runoff, if free of sediment, must be released through a stabilized outlet or channel.

2. Sediment-laden runoff must be diverted and released through a sediment-trapping facility such as a TEMPORARY SEDIMENT TRAP (Std. & Spec. 3.13) or TEMPORARY SEDIMENT BASIN (Std. & Spec. 3.14).

Construction Specifications

1. Temporary diversion dikes must be installed as a first step in the land-disturbing activity and must be functional prior to upslope land disturbance.

2. The dike should be adequately compacted to prevent failure.

3. Temporary or permanent seeding and mulch shall be applied to the dike immediately following its construction.

4. The dike should be located to minimize damages by construction operations and traffic.

Maintenance

The measure shall be inspected after every storm and repairs made to the dike, flow channel, outlet or sediment trapping facility, as necessary. Once every two weeks, whether a storm event has occurred or not, the measure shall be inspected and repairs made if needed. Damages caused by construction traffic or other activity must be repaired before the end of each working day.

STD & SPEC 3.10

TEMPORARY FILL DIVERSION

FD

Definition

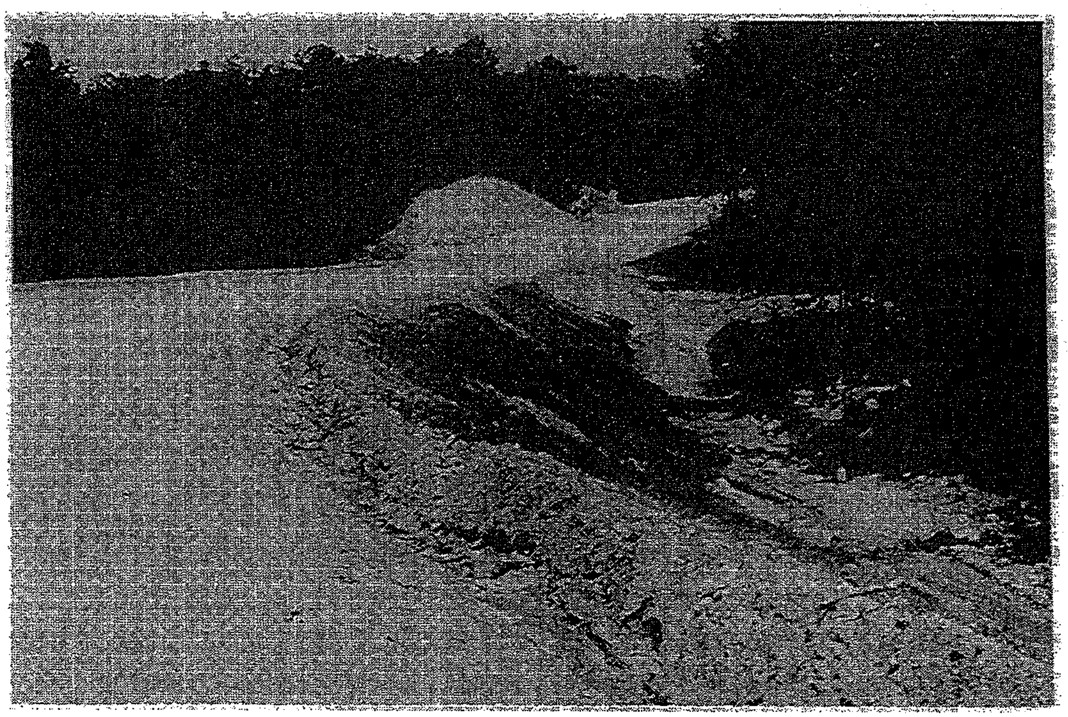
A channel with a supporting ridge of soil on the lower side, constructed along the top of an active earth fill.

Purpose

To divert storm runoff away from the unprotected slope of the fill to a stabilized outlet or sediment-trapping facility.

Conditions Where Practice Applies

Where the drainage area at the top of an active earth fill slopes toward the exposed slope and where continuous fill operations make the use of a DIVERSION (Std. & Spec. 3.12) unfeasible. This temporary structure should remain in place for less than one week.



Planning Considerations

One important principle of erosion and sediment control is to keep stormwater runoff away from exposed slopes. This is often accomplished by installing a dike, diversion, temporary slope drain or paved ditch at the top of a slope to carry the runoff away from the slope to a stabilized outlet. In general, these measures are installed after the final grade has been reached. On cuts, the measures may be installed at the beginning since the work proceeds from the top to the bottom of the slope, and the measures have little chance of being covered or damaged. On fills, the work proceeds from the bottom to the top and the elevation changes daily. It is therefore not feasible to construct a compacted dike or permanent diversion which may be covered by the next day's activity.

The temporary fill diversion is intended to provide some slope protection on a daily basis until final elevations are reached and a more permanent measure can be constructed. This practice can be constructed by the use of a motor grader or a small dozer. To shape the diversion, the piece of machinery used may run near the top edge of the fill with its blade tilted to form the channel as depicted in Plate 3.10-1. This work would be done at the end of the working day and provide a channel with a berm to protect the slope. Wherever possible, the temporary diversion should be sloped to direct water to a stabilized outlet. If the runoff is diverted over the fill itself, the practice may cause erosion by concentrating water at a single point.

Good timing is essential to fill construction. The filling operation should be completed as quickly as possible and the permanent slope protection measures and slope stabilization measures installed as soon after completion as possible. With prompt and proper construction, the landowner or contractor will save both time and money in building, repairing and stabilizing the fill area. The longer the time period for construction and stabilization extends, the more prone the fill operation is to be damaged by erosion. Repairing the damages adds additional time and expense to the project.

Design Criteria

No formal design is required. The following criteria shall be met:

Drainage Area

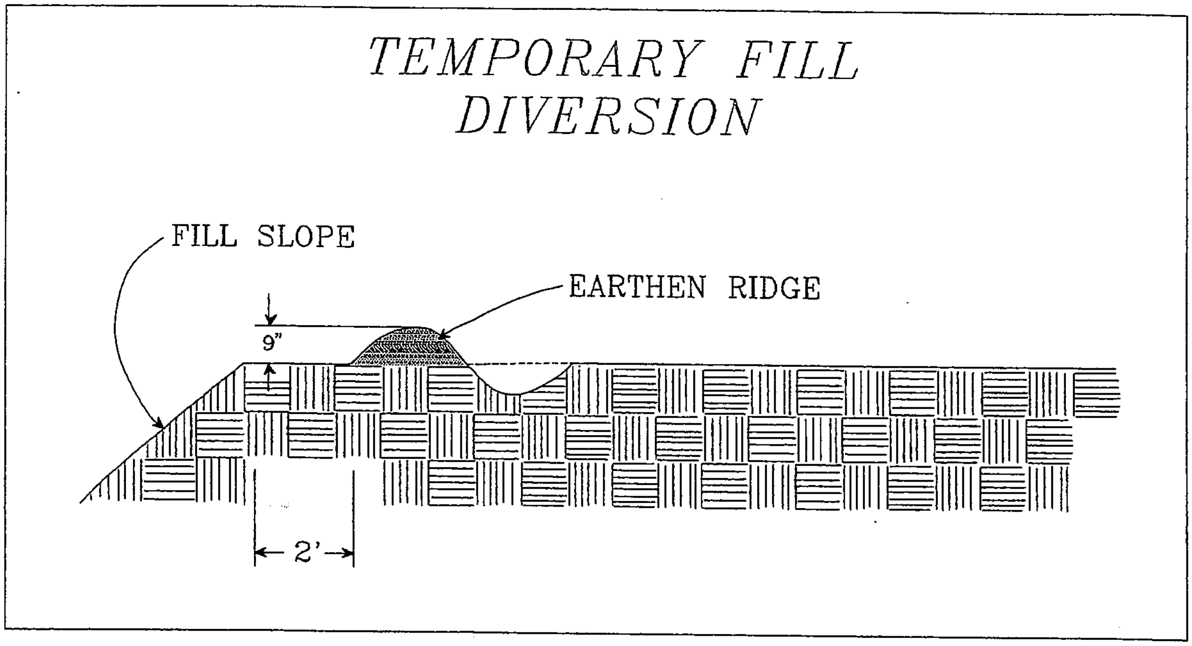
The maximum allowable drainage area is 5 acres.

Height

The minimum height of the supporting ridge shall be 9 inches (see Plate 3.10-1).

Grade

The channel shall have a positive grade to a stabilized outlet.



Source: Va. DSWC

Plate 3.10-1

Outlet

The diverted runoff should be released through a stabilized outlet, slope drain or sediment trapping measure.

Construction Specifications

1. The diversion shall be constructed at the top of the fill at the end of each work day as needed.

2. The diversion shall be located at least 2 feet inside the top edge of the fill (see Plate 3.10-1).

3. The supporting ridge shall be constructed with a uniform height along its entire length. Without uniform height, the fill diversion may be susceptible to breaching.

Maintenance

Since the practice is temporary and under most situations will be covered the next work day, the maintenance required should be low. If the practice is to remain in use for more than one day, an inspection will be made a the end of each work day and repairs made to the measure if needed. The contractor should avoid the placement of any material over the structure while it is in use. Construction traffic should not be permitted to cross the diversion.

STD & SPEC 3.11

TEMPORARY RIGHT-OF-WAY DIVERSION

RWD

Definition

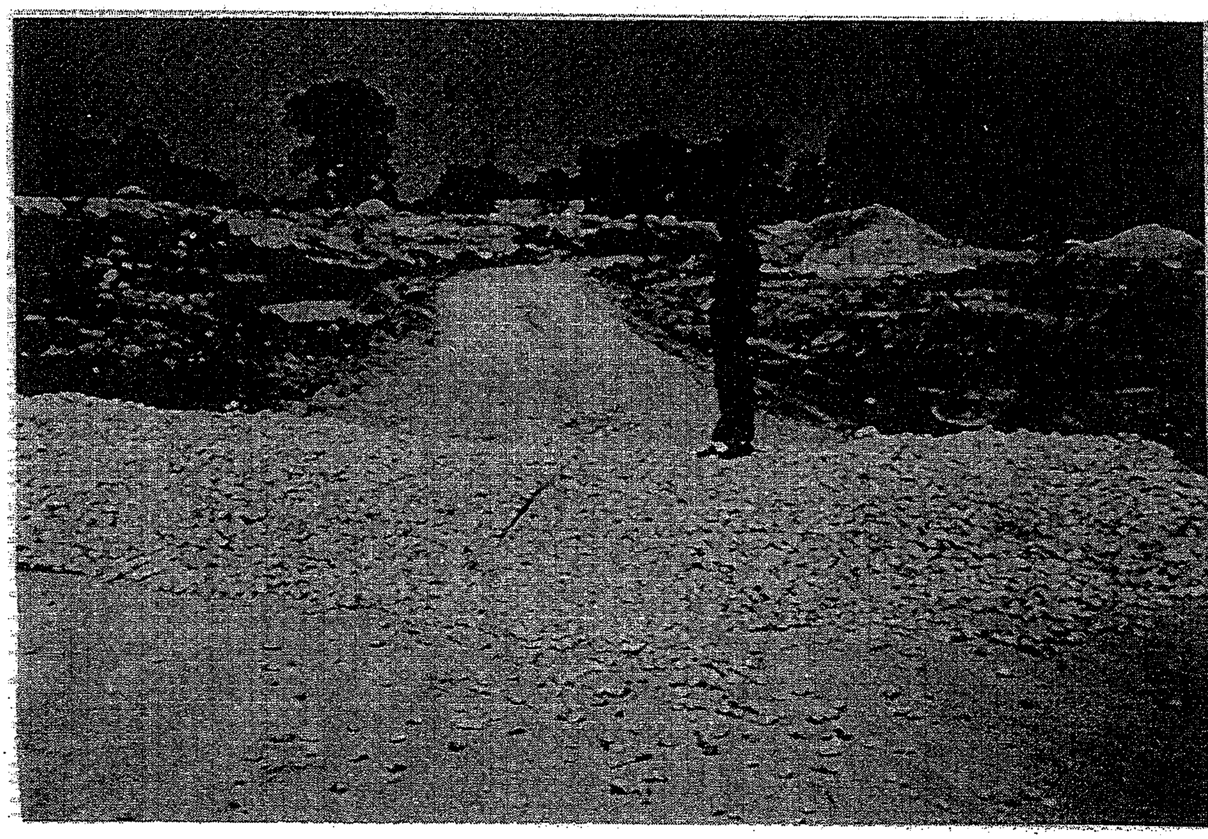
A ridge of compacted soil or loose rock or gravel constructed across disturbed rights-of-way and similar sloping areas.

Purpose

To shorten the flow length within a sloping right-of-way, thereby reducing the erosion potential by diverting storm runoff to a stabilized outlet.

Conditions Where Practice Applies

Generally, earthen diversions are applicable where there will be little or no construction traffic within the right-of-way. Gravel structures are more applicable to roads and other rights-of-way which accommodate vehicular traffic.



Planning Considerations

Construction of utility lines and roads often requires the clearing of long strips of right-of-way over sloping terrain. The volume and velocity of stormwater runoff tend to increase in these cleared strips and the potential for erosion is much greater since the vegetative cover is diminished or removed. To compensate for the loss of vegetation, it is usually a good practice to break up the flow length within the cleared strip so that runoff does not have a chance to concentrate and cause erosion. At proper intervals, temporary right-of-way diversions can significantly reduce the amount of erosion which will occur until the area is permanently stabilized. Since many right-of-ways are constructed through heavily vegetated areas, runoff can often be diverted into a vegetative buffer strip (if it provides a minimum flow length of 75 feet).

Design Criteria

No formal design is required. The following criteria shall be met:

Height

The minimum allowable height of the diversion is 18 inches (see Plate 3.11-1).

Side Slopes

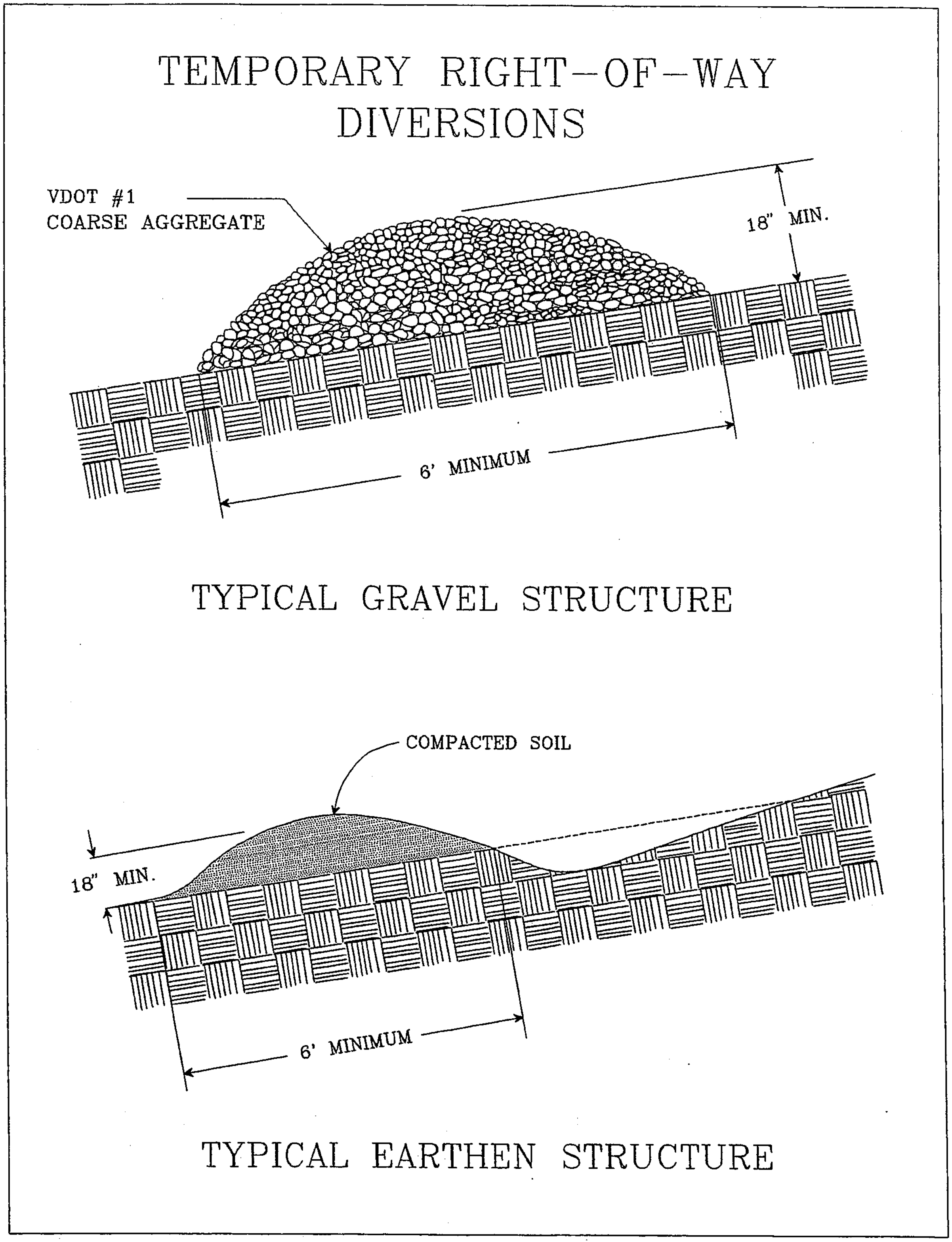
Side slopes should be 2:1 or flatter to allow the passage of construction traffic, along with a minimum base width of 6 feet (see Plate 3.11-1).

Width

The measure should be constructed completely across the disturbed portion of the right-of-way.

Spacing

Table 3.11-A will be used to determine the spacing of right-of-way diversions.



Source: Va. DSWC

Plate 3.11-1

TABLE 3.11-A

SPACING OF RIGHT-OF-WAY DIVERSIONS

% Slope	Spacing (ft.)
Less than 7%	100
Between 7% and 25%	75
Between 25% and 40%	50
Greater than 40%	25

Source: Va. DSWC

Grade

Positive drainage (with less than 2% slope) should be provided to a stabilized outlet, sediment-trapping facility, or a vegetative buffer strip of adequate size.

Outlet

Interceptor dikes must have an outlet which is not subject to erosion.

The on-site location may need to be adjusted to meet field conditions in order to utilize the most suitable outlet. Concentrated flows should spread over the widest possible area after release. Flows with high sediment concentrations should pass through an appropriate sediment-trapping measure.

Construction Specifications

1. The diversion shall be installed as soon as the right-of-way has been cleared and/or graded.

2. All earthen diversions shall be machine- or hand-compacted in 8-inch lifts.

3. The outlet of the diversion shall be located on an undisturbed and stabilized area when at all possible. The field location should be adjusted as needed to utilize a stabilized outlet.

4. Earthen diversions which will not be subject to construction traffic should be stabilized in accordance with TEMPORARY SEEDING (Std. & Spec. 3.31).

Maintenance

The practice shall be inspected after every rainfall and repairs made if necessary. At least once every two weeks, whether a storm has occurred or not, the measure shall be inspected and repairs made if needed. Right-of-way diversions, which are subject to damage by vehicular traffic, should be reshaped at the end of each working day.

STD & SPEC 3.12

DIVERSION

DV

Definition

A channel constructed across a slope with a supporting earthen ridge on the lower side.

Purpose

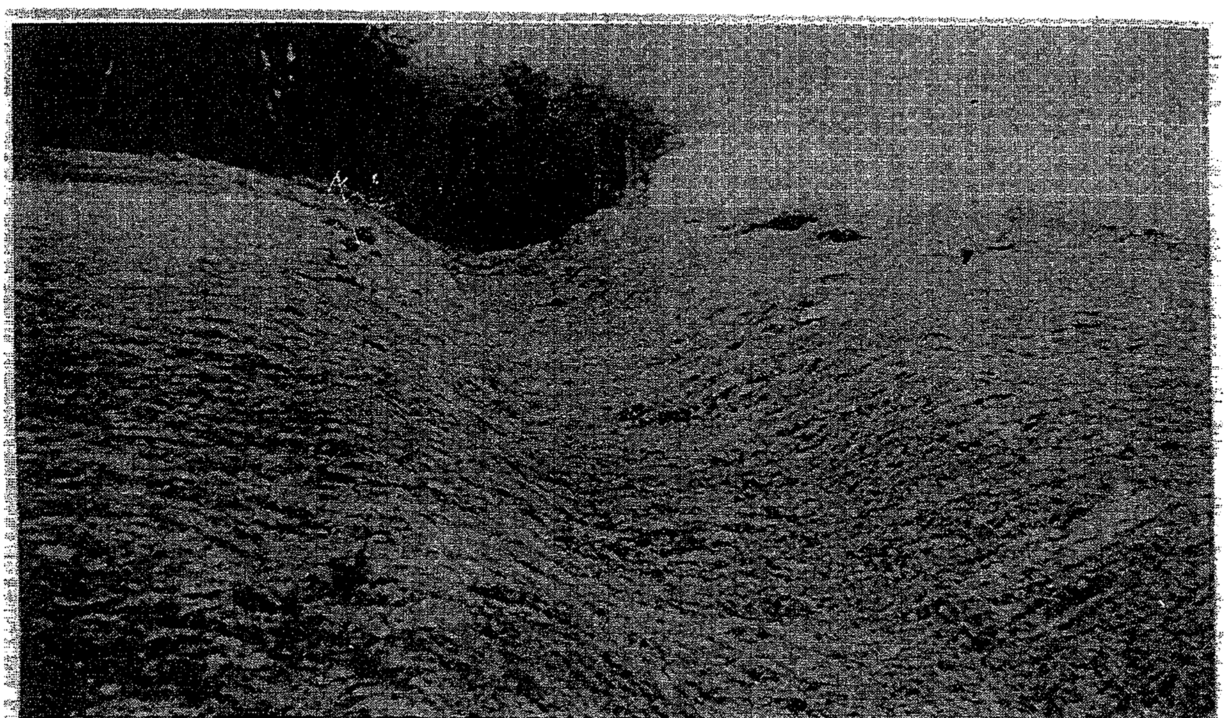
To reduce slope length and to intercept and divert stormwater runoff to stabilized outlets at non-erosive velocities.

Conditions Where Practice Applies

1. Where runoff from areas of higher elevation may damage property, cause erosion, or interfere with the establishment of vegetation on lower areas.

2. Where surface and/or shallow subsurface flow is damaging sloping upland.

3. Where the slope length needs to be reduced to minimize soil loss.



Planning Considerations

Diversions can be useful tools for managing surface water flows and preventing soil erosion. On moderately sloping areas, they may be placed at intervals to trap and divert sheet flow before it has a chance to concentrate and cause rill and gully erosion. They may be placed at the top of cut or fill slopes to keep runoff from upland drainage areas off the slope. They can also be used to protect structures, parking lots, adjacent properties, and other special areas from flooding.

Diversions are preferable to other types of man-made stormwater conveyance systems because they more closely simulate natural flow patterns and characteristics. Flow velocities are generally kept to a minimum. When properly coordinated into the landscape design of a site, diversions can be visually pleasing as well as functional.

As with any earthen structure, it is very important to establish adequate vegetation as soon as possible after installation. It is equally important to stabilize the drainage area above the diversion so that sediment will not enter and accumulate in the diversion channel.

Design Criteria

Location

Diversion location shall be determined by considering outlet conditions, topography, land use, soil type, length of slope, seepage planes (where seepage is a problem) and the development layout.

Capacity

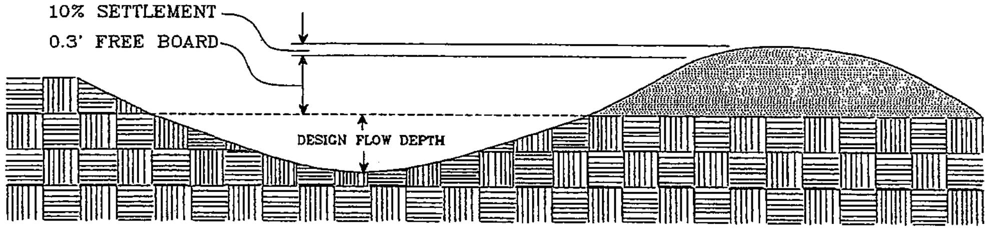
1. The diversion channel must have a minimum capacity to carry the runoff expected from a 10-year frequency storm with a freeboard of at least 0.3 foot (see Plate 3.12-1).

2. Diversions designed to protect homes, schools, industrial buildings, roads, parking lots, and comparable high-risk areas, and those designed to function in connection with other structures, shall have sufficient capacity to carry peak runoff expected from a storm frequency consistent with the hazard involved.

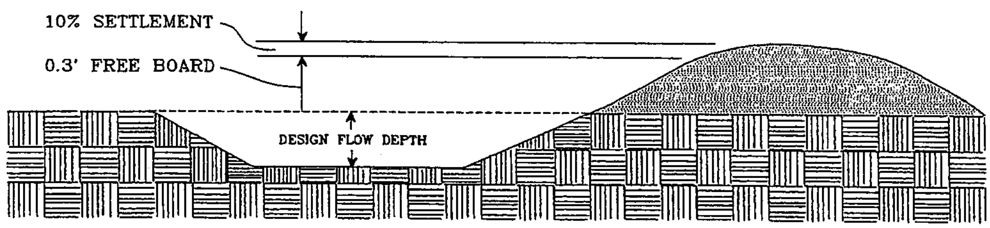
Channel Design

The diversion channel may be parabolic, trapezoidal or vee-shaped and shall be designed and constructed according to Std. & Spec. 3.17, STORMWATER CONVEYANCE CHANNELS.

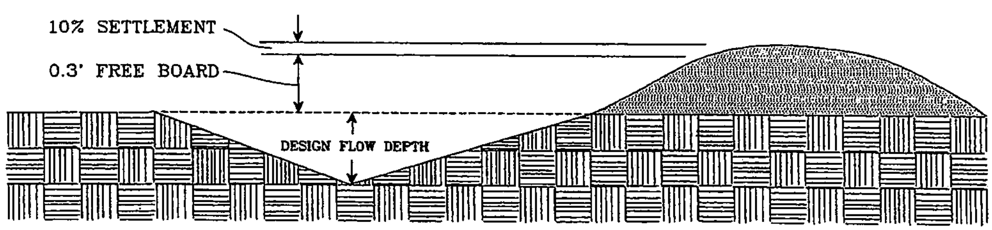
DIVERSIONS



TYPICAL PARABOLIC DIVERSION



TYPICAL TRAPEZOIDAL DIVERSION



TYPICAL VEE-SHAPED DIVERSION

Source: Va. DSWC

Plate 3.12-1

Ridge Design

The supporting ridge cross-section shall meet the following criteria (see Plate 3.12-1):

1. The side slopes shall be no steeper than 2:1.

2. The width at the design water elevation shall be a minimum of 4 feet.

3. The minimum freeboard shall be 0.3 foot.

4. The design shall include a 10 percent settlement factor.

Outlet

Diversions shall have adequate outlets which will convey concentrated runoff without erosion. Acceptable outlets include STORMWATER CONVEYANCE CHANNEL (Std. & Spec. 3.17); LEVEL SPREADER (Std. & Spec. 3.21); OUTLET PROTECTION (Std. & Spec. 3.18); and PAVED FLUME (Std. & Spec. 3.16).

Stabilization

1. The ridge and channel shall be seeded and mulched immediately following their construction in accordance with Std. & Spec. 3.32, PERMANENT SEEDING.

2. Disturbed areas draining into the diversion should normally be seeded and mulched prior to the time the diversion is constructed. Sediment trapping measures must remain in place to prevent soil movement into the diversion if upslope area is not stabilized.

Construction Specifications

1. All trees, brush, stumps, obstructions, and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the diversion.

2. The diversion shall be excavated or shaped to line, grade, and cross-section as required to meet the criteria specified herein, free of irregularities which will impede flow.

3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the completed diversion. Fill shall be composed of soil which is free from excessive organic debris, rocks or other objectionable materials.

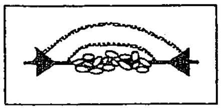
4. All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the functioning of the diversion.

5. Permanent stabilization of disturbed areas shall be done in accordance with the applicable standard and specification contained in this handbook. Permanent stabilization techniques include PERMANENT SEEDING (Std. & Spec. 3.32).

Maintenance

Before final stabilization, the diversion should be inspected after every rainfall and at least once every two weeks. Sediment shall be removed from the channel and repairs made as necessary. Seeded areas which fail to establish a vegetative cover shall be reseeded as necessary.

STD & SPEC 3.13



TEMPORARY SEDIMENT TRAP

ST

Definition

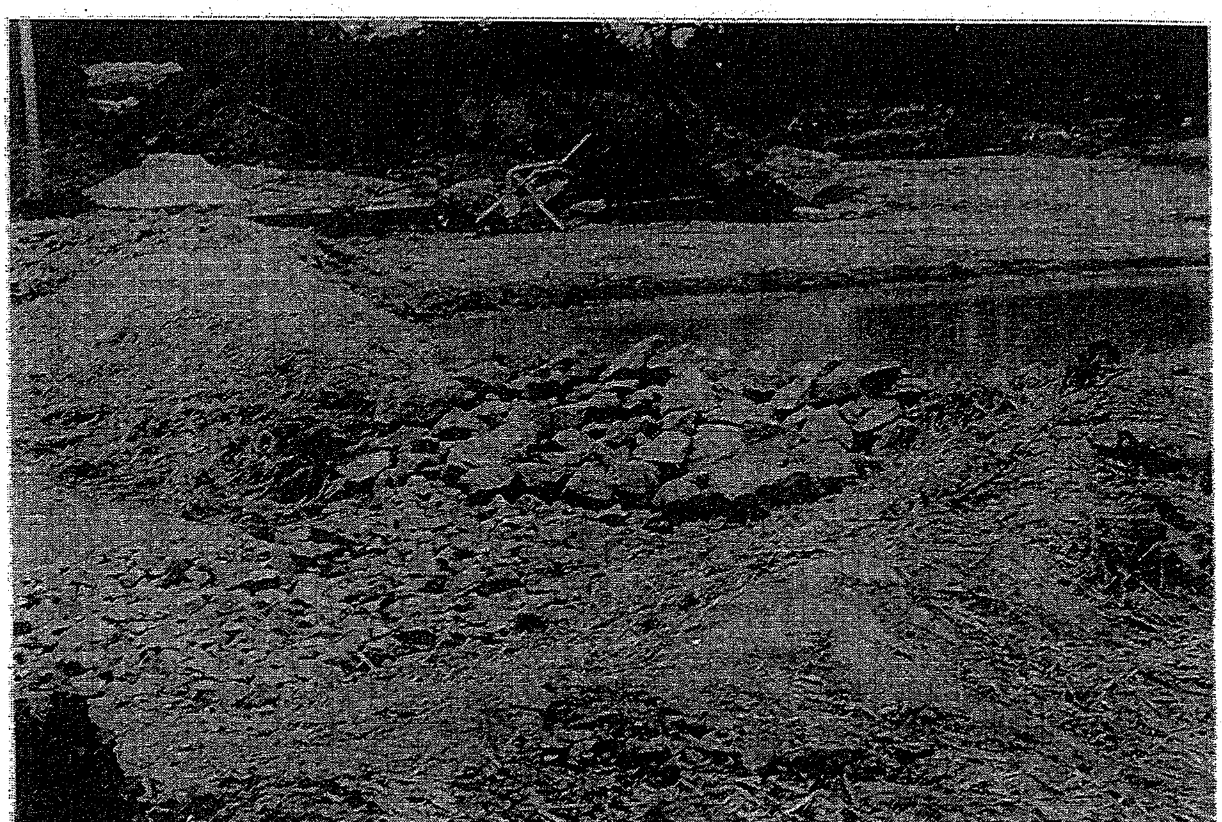
A temporary ponding area formed by constructing an earthen embankment with a stone outlet.

Purpose

To detain sediment-laden runoff from small disturbed areas long enough to allow the majority of the sediment to settle out.

Conditions Where Practice Applies

1. Below disturbed areas where the total contributing drainage area is less than 3 acres.



2. Where the sediment trap will be used no longer than 18 months (the maximum useful life is 18 months).

3. The sediment trap may be constructed either independently or in conjunction with a TEMPORARY DIVERSION DIKE (Std. & Spec. 3.09).

Planning Considerations

Sediment traps should be used only for small drainage areas. If the contributing drainage area is 3 acres or greater, refer to SEDIMENT BASIN (Std. & Spec. 3.14).

Sediment traps, along with other perimeter controls intended to trap sediment, shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

Recent studies have been conducted on the performance of sediment traps (and basins) which were constructed using the design criteria found in previous editions of this handbook. The studies indicate that the control measures only achieved a 46% removal of sediment which flowed into them during storm events which caused measurable outflow. To achieve a more acceptable removal rate (60%), it was necessary to revise the design of these measures in this handbook. The total initial storage volume for both the sediment trap and the TEMPORARY SEDIMENT BASIN (Std. & Spec. 3.14) has been doubled. There are both a "wet" storage volume and a drawdown or "dry" storage volume which help to enhance sediment fall-out and prevent excessive sediment losses during large storm events which occur during the advanced stages of land disturbance (28).

In most cases excavation will be required to attain the necessary storage volume. Also, sediment must be periodically removed from the trap to maintain the required volume. Plans should detail how excavated sediment is to be disposed of, such as by use in fill areas on site or removal to an approved off-site location.

As noted previously in this handbook, there are numerous other acceptable ways to design many of the erosion control practices within. This is certainly true in the case of the sediment trap. However, variations in its design should be considered judiciously by plan reviewers to ensure that the minimum storage requirements and structural integrity noted in this specification are maintained.

Design Criteria

Trap Capacity

The sediment trap must have an initial storage volume of 134 cubic yards per acre of drainage area, half of which shall be in the form of a permanent pool or wet storage to provide a stable settling medium. The remaining half shall be in the form of a drawdown or dry storage which will provide extended settling time during less frequent, larger storm events. The volume of the wet storage shall be measured from the low point of the excavated area to the base of the stone outlet structure. The volume of the dry storage shall be measured from the base of the stone outlet to the crest of the stone outlet (overflow mechanism). Sediment should be removed from the basin when the volume of the wet storage is reduced by one-half.

For a sediment trap, the wet storage volume may be approximated as follows:

$$V_1 = 0.85 \times A_1 \times D_1$$

where,

V_1 = the wet storage volume in cubic feet

A_1 = the surface area of the flooded area at the base of the stone outlet in square feet

D_1 = the maximum depth in feet, measured from the low point in the trap to the base of the stone outlet

The dry storage volume may be approximated as follows:

$$V_2 = \frac{A_1 + A_2}{2} \times D_2$$

where,

V_2 = the dry storage volume in cubic feet

A_1 = the surface area of the flooded area at the base of the stone outlet in square feet

A_2 = the surface area of the flooded area at the crest of the stone outlet (overflow mechanism), in square feet

D_2 = the depth in feet, measured from the base of the stone outlet to the crest of the stone outlet

The designer should seek to provide a storage area which has a minimum 2:1 length to width ratio (measured from point of maximum runoff introduction to outlet).

Note: Conversion between cubic feet and cubic yards is as follows:

number of cubic feet x 0.037 = number of cubic yards

Excavation

Side slopes of excavated areas should be no steeper than 1:1. The maximum depth of excavation within the wet storage area should be 4 feet to facilitate clean-out and for site safety considerations.

Outlet

The outlet for the sediment trap shall consist of a stone section of the embankment located at the low point in the basin. A combination of coarse aggregate and riprap shall be used to provide for filtering/detention as well as outlet stability. The smaller stone shall be VDOT #3, #357, or #5 Coarse Aggregate (smaller stone sizes will enhance filter efficiency) and riprap shall be "Class I." Filter cloth which meets the physical requirements noted in Std. & Spec. 3.19, RIPRAP shall be placed at the stone-soil interface to act as a "separator." The minimum length of the outlet shall be 6 feet times the number of acres comprising the total area draining to the trap. The crest of the stone outlet must be at least 1.0 foot below the top of the embankment to ensure that the flow will travel over the stone and not the embankment. The outlet shall be configured as noted in Plate 3.13-2.

Embankment Cross-Section

The maximum height of the sediment trap embankment shall be 5 feet as measured from the base of the stone outlet. Minimum top widths (W) and outlet heights (Ho) for various embankment heights (H) are shown in Plate 3.13-1. Side slopes of the embankment shall be 2:1 or flatter.

Removal

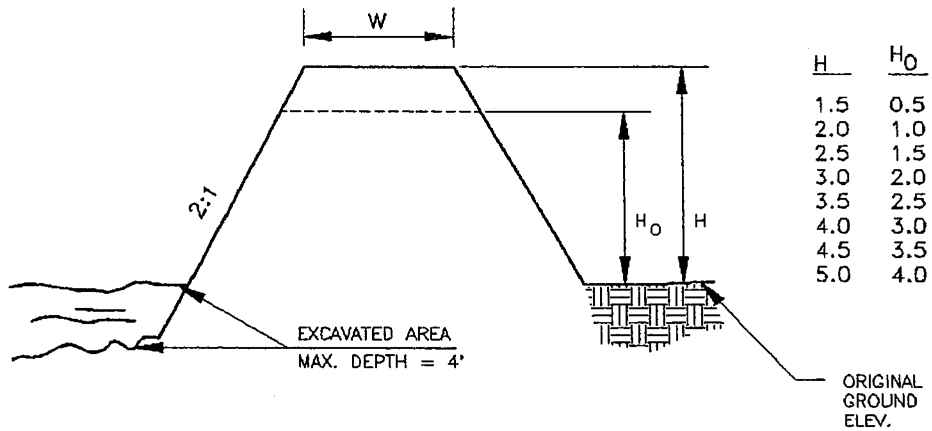
Sediment traps must be removed after the contributing drainage area is stabilized. Plans should show how the site of the sediment trap is to be graded and stabilized after removal.

Construction Specifications

1. The area under the embankment shall be cleared, grubbed, and stripped of any vegetation and root mat.

2. Fill material for the embankment shall be free of roots or other woody vegetation, organic material, large stones, and other objectionable material. The embankment should be compacted in 6-inch layers by traversing with construction equipment.

MINIMUM TOP WIDTH (W) REQUIRED FOR SEDIMENT TRAP EMBANKMENTS ACCORDING TO HEIGHT OF EMBANKMENT (FEET)



H	H_O	W
1.5	0.5	2.0
2.0	1.0	2.0
2.5	1.5	2.5
3.0	2.0	2.5
3.5	2.5	3.0
4.0	3.0	3.0
4.5	3.5	4.0
5.0	4.0	4.5

Source: Va. DSWC Plate 3.13-1

3. The earthen embankment shall be seeded with temporary or permanent vegetation (see Std. & Spec.'s 3.31 and 3.32) immediately after installation.

4. Construction operations shall be carried out in such a manner that erosion and water pollution are minimized.

5. The structure shall be removed and the area stabilized when the upslope drainage area has been stabilized.

6. All cut and fill slopes shall be 2:1 or flatter (except for excavated, wet storage area which may be at a maximum 1:1 grade).

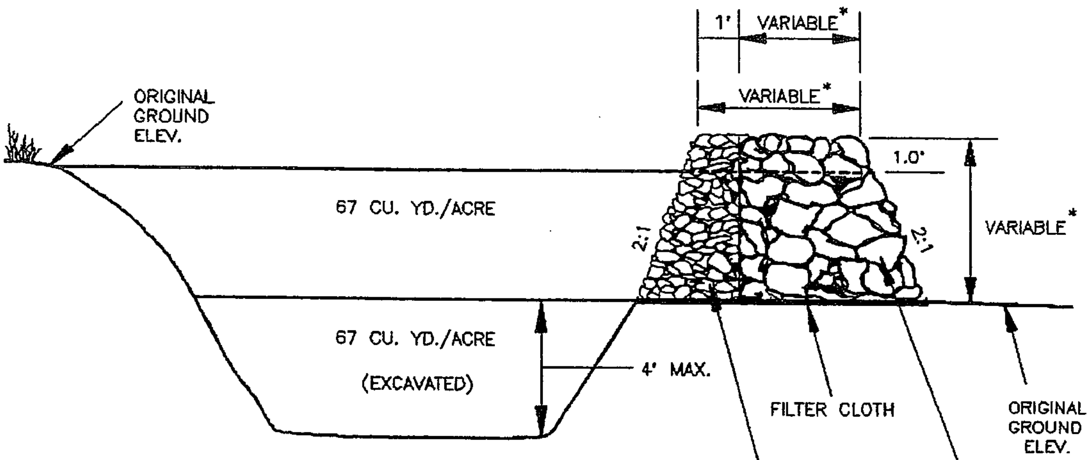
Maintenance

1. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to one half the design volume of the wet storage. Sediment removal from the basin shall be deposited in a suitable area and in such a manner that it will not erode and cause sedimentation problems.

2. Filter stone shall be regularly checked to ensure that filtration performance is maintained. Stone choked with sediment shall be removed and cleaned or replaced.

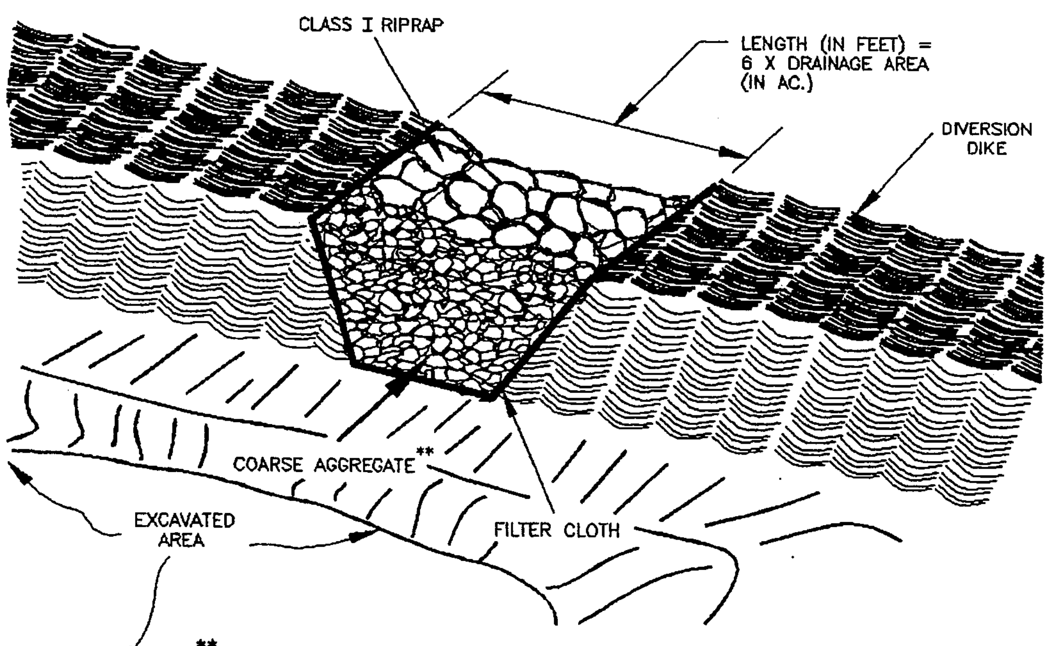
3. The structure should be checked regularly to ensure that it is structurally sound and has not been damaged by erosion or construction equipment. The height of the stone outlet should be checked to ensure that its center is at least 1 foot below the top of the embankment.

TEMPORARY SEDIMENT TRAP



*SEE PLATE 3.13-1

CROSS SECTION OF OUTLET



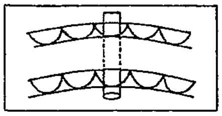
**COARSE AGGREGATE SHALL BE VDOT #3, #357 OR #5

OUTLET (PERSPECTIVE VIEW)

Source: Va. DSWC

Plate 3.13-2

STD & SPEC 3.14



TEMPORARY SEDIMENT BASIN

SB

Definition

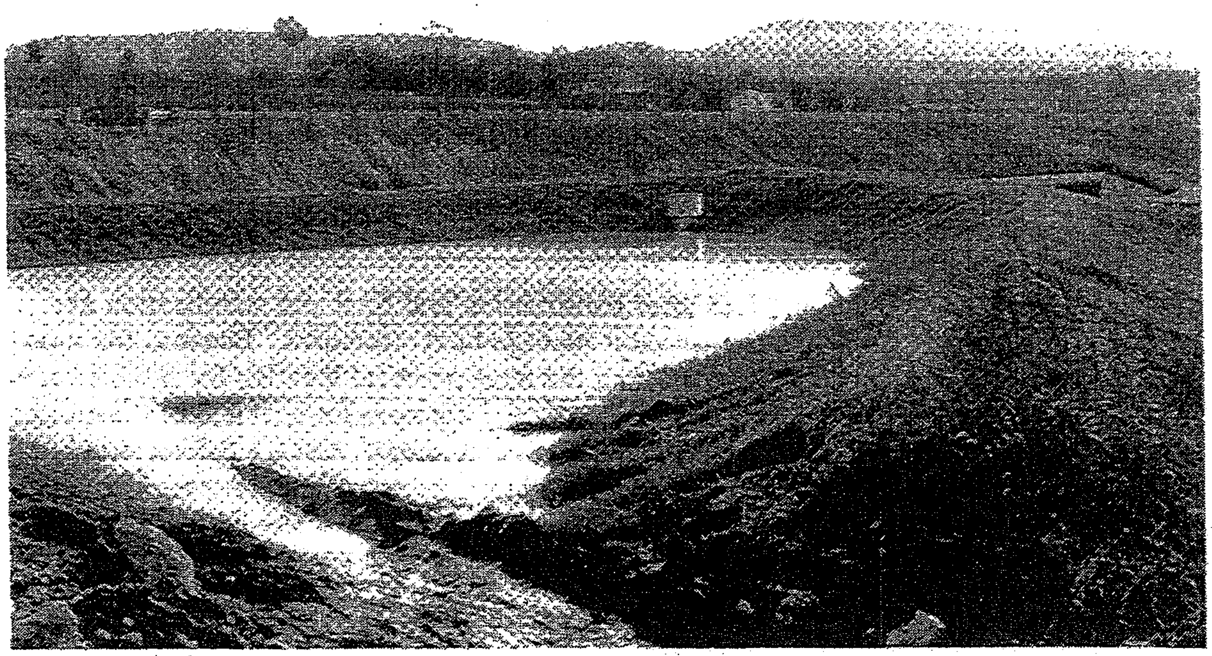
A temporary barrier or dam with a controlled stormwater release structure formed by constructing an embankment of compacted soil across a drainageway.

Purpose

To detain sediment-laden runoff from disturbed areas in "wet" and "dry" storage long enough for the majority of the sediment to settle out.

Conditions Where Practice Applies

Below disturbed areas where the total contributing drainage area is equal to or greater than three (3) acres. There must be sufficient space and appropriate topography for the construction of a temporary impoundment. These structures are limited to a useful life of 18 months unless they are designed as permanent impoundments. It is recommended that these measures, by virtue of their potential to impound large volumes of water, be designed by a qualified professional.



Planning Considerations

Effectiveness

Sediment basins constructed as per this specification are, at best, 60% effective in trapping sediment which flows into them during large storm events (those which cause flow from the outfall pipe) or during periods of minimal vegetative cover at a construction site (28). Therefore, they should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc., to reduce the amount of sediment flowing into the basin.

The sediment removal efficiency problems noted for previous designs of the TEMPORARY SEDIMENT TRAP (Std. & Spec. 3.13) are also applicable to the sediment basin. In order to contain the majority of sediment which flows to the structure, the basin should have a permanent pool, or wet storage area and a dry storage area which dewaters over time. The volume of the permanent pool (needed to protect against re-suspension of sediment and promote better settling conditions) must be 67 cubic yards per acre of drainage area and the volume of dry storage above the permanent pool (needed to prevent "short-circuiting" of basin during larger storm events) must be an additional 67 cubic yards per acre of drainage area. The total storage volume of the basin at the principal spillway riser crest will therefore be 134 cubic yards per acre of drainage area (28).

Sediment basins, along with other perimeter controls which are intended to trap sediment, shall be constructed as a first step in any land disturbing activity and shall be made functional before upslope land disturbance takes place (MS #4).

Location

To improve the effectiveness of the basin, it should be located so as to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally low areas and natural drainageways below disturbed areas. Drainage into the basin can be improved by the use of diversion dikes and ditches. The basin must not be located in a live stream but should be located to trap sediment-laden runoff before it enters a stream. The basin should not be located where its failure would result in the loss of life or interruption of the use or service of public utilities or roads.

Multiple Use

Sediment basins may remain in place after construction and final site stabilization are completed to serve as permanent stormwater management structures. Because the most practical location for a sediment basin is often the most practical location for a stormwater management basin, it is often desirable to utilize these structures for permanent stormwater management purposes. It should be noted, however, that in most cases, a typical structure's outfall system will vary during the construction and post-construction periods. Care must be taken to avoid constructing an outfall system which will achieve the desired post-construction quantity or quality control but will not provide the necessary medium for the containment and settling of sediment-laden construction runoff. Notably, the design for permanent ponds is beyond the scope of these standards and specifications.

Design Criteria

Maximum Drainage Area

The maximum allowable drainage area into a temporary sediment basin shall be 100 acres. It is recommended that when the drainage area to any one temporary basin exceeds 50 acres, an alternative design procedure which more accurately defines the specific hydrology and hydraulics of the site and the control measure be used. The design procedures in this standard and specification do not generate hydrographs, utilize storage volumes or provide a routing of the design storms; for a large drainage area, this may result in an excessively large diameter riser or an oversized basin. Notably, design considerations which are more accurate and project-specific than those in this specification are acceptable and encouraged with any size basin.

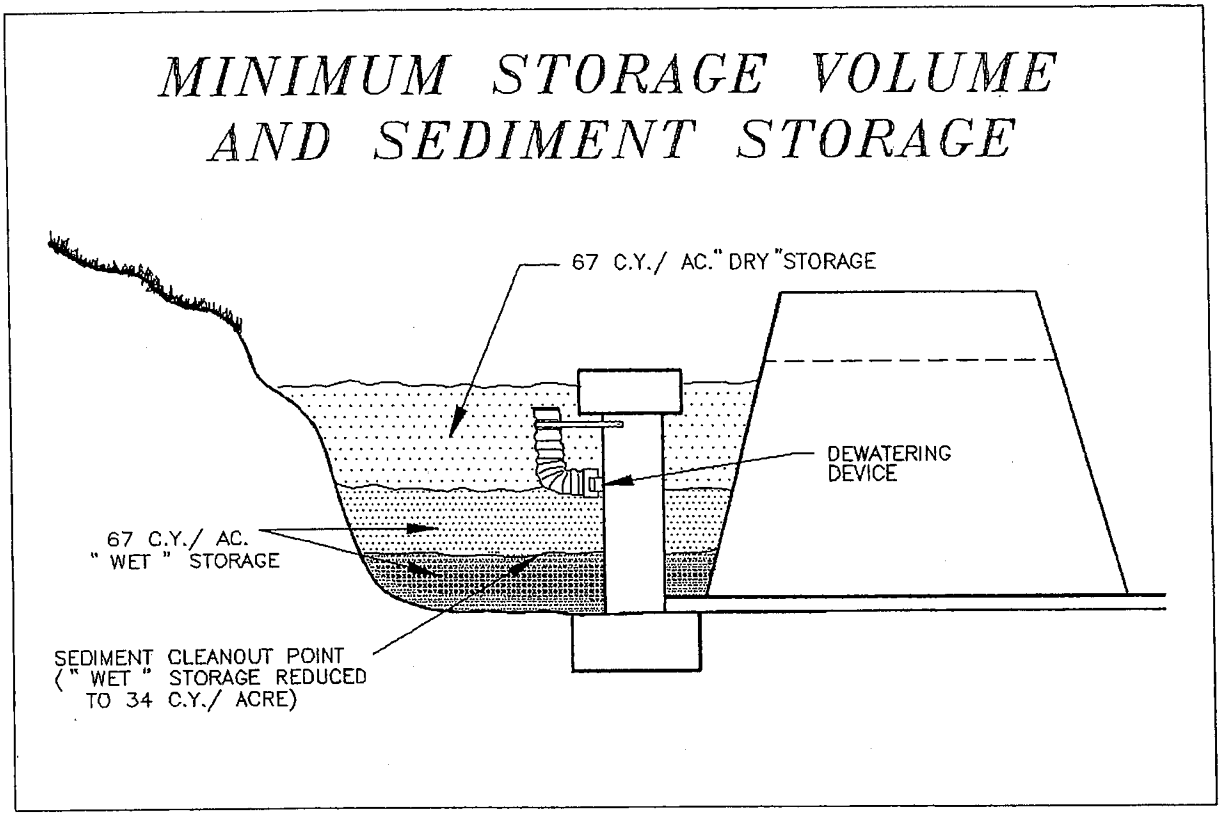
Basin Capacity

The design storage capacity of the basin must be at least 134 cubic yards per acre of total contributing drainage area (see Plate 3.14-1). One half of the design volume (or 67 cubic yards) shall be in the form of a permanent pool, and the remaining half as drawdown volume. The volume of the permanent pool shall be measured from the low point of the basin to the elevation corresponding to one half the total storage volume. The volume of the drawdown area shall be measured from the elevation of the permanent pool to the crest of the principal spillway (riser pipe). Sediment should be removed from the basin when the volume of the permanent pool has been reduced by one half. In no case shall the sediment cleanout level be higher than one foot below the bottom of the dewatering device. The elevation of the sediment cleanout level should be calculated and clearly marked on the plans and riser (since this part of the riser normally will be under water, a mark should appear above the permanent pool a measured distance above the cleanout elevation).

While attempting to attain the desired storage capacities, efforts should be made to keep embankment heights to a minimum. This precaution takes on added significance when the basin will only serve as a temporary measure or will need substantial retrofitting prior to functioning as a permanent measure. When site topography permits, the designer should give strong consideration to the use of excavation to obtain the required capacity and to possibly reduce the height of the embankment. This excavation can be performed in a manner which creates a wet storage forebay area or which increases the storage capacity over the entire length of the basin.

Basin Shape

To improve sediment trapping efficiency of the basin, the effective flow length must be twice the effective flow width. This basin shape may be attained by properly selecting the site of the basin, by excavation, or by the use of baffles. See Appendix 3.14-a for pertinent design details.



Source: Va. DSWC Plate 3.14-1

Embankment Cross-Section

For embankments of less than 10 feet, the embankment must have a minimum top width of 6 feet, and the side slopes must be 2:1 or flatter. In the case of an embankment 10 to 14 feet in height, the minimum top width shall be 8 feet and the side slopes shall be 2½:1 or flatter. For 15-foot embankments (maximum allowed under these specifications), the top width must be 10 feet with maximum 2½:1 side slopes.

Spillway Design

The outlets for the basin shall consist of a combination of principal and emergency spillways. These outlets must pass the peak runoff expected from the contributing drainage area for a 25-year storm. If, due to site conditions and basin geometry, a separate emergency spillway is not feasible, the principal spillway must pass the entire peak runoff expected from the 25-year storm. However, an attempt to provide a separate emergency spillway should always be made (refer to "Emergency Spillway" later on in this section). Runoff computations shall be based upon the soil cover conditions which are expected to prevail during the life of the basin. Refer to Chapter 5 for calculation of the peak rate of runoff. Notably, the flow through the dewatering orifice cannot be utilized when calculating the 25-year storm elevation because of its potential to become clogged; therefore, available spillway storage must begin at the principal spillway riser crest.

The spillways designed by the procedures contained in the standard and specification will not necessarily result in any reduction in the peak rate of runoff. If a reduction in peak runoff is desired, the appropriate hydrographs/storm routings should be generated to choose the basin and outlet sizes.

Principal Spillway

For maximum effectiveness, the principal spillway should consist of a vertical pipe or box of corrugated metal or reinforced concrete, with a minimum diameter of 15 inches, joined by a watertight connection to a horizontal pipe (barrel) extending through the embankment and outletting beyond the downstream toe of the fill. If the principal spillway is used in conjunction with a separate emergency spillway, the principal spillway must be designed to pass at least the peak flow expected from of 2-year storm. If no emergency spillway is used, the principal spillway must be designed to pass the entire peak flow expected from a 25-year storm (see Appendix 3.14-a for design details).

Design Elevations

The crest of the principal spillway shall be set at the elevation corresponding to the storage volume required (67 cubic yards/acre wet storage plus 67 cubic yards/acre dry storage = 134 cubic yards/acre). If the principal spillway is used in conjunction with an emergency spillway, this elevation shall be a minimum of 1.0 foot below the crest of the emergency spillway. In addition, a minimum freeboard of 1.0 foot shall be provided between the design high water (25-year) and the top of the embankment (see Plate 3.14-2). If no emergency spillway is used, the crest of the principal spillway shall be a minimum of 3 feet below the top of the embankment; also, a minimum freeboard of 2.0 feet shall be provided between the design high water and the top of the embankment.

Anti-Vortex Device and Trash Rack

An anti-vortex device and trash rack shall be attached to the top of the principal spillway to improve the flow characteristics of water into the spillway and prevent floating debris from blocking the principal spillway. The anti-vortex device shall be of the concentric type as shown in Plate 3.14-10. See Appendix 3.14-a for design procedures for the anti-vortex device and trash rack.

Dewatering

Provisions shall be made to dewater the basin down to the permanent pool elevation. Recent studies by the Washington Metropolitan Council of Governments have shown that it is necessary to provide at least a 6-hour drawdown time in the dry storage area in order to achieve up to 60% removal of sediment (28).

Dewatering of the dry storage should be done in a manner which removes the "cleaner" water without removing the potentially sediment-laden water found in the wet storage area or any appreciable quantities of floating debris. An economical and efficient device for performing the drawdown is a section of perforated vertical tubing which is connected to the principal spillway at two locations. See Plate 3.14-15 which depicts the orientation of such a device. By virtue of the potential for the dewatering device or orifice becoming clogged, no credit is given for drawdown by the device in the calculation of the principal or emergency spillway locations. The method for sizing the dewatering orifice and the associated flexible conduit is located in Appendix 3.14-a.

Base

The base of the principal spillway must be firmly anchored to prevent its floating. If the riser of the spillway is greater than 10 feet in height, computations must be made to determine the anchoring requirements. A minimum factor of safety of 1.25 shall be used (downward forces = 1.25 x upward forces).

For risers 10 feet or less in height, the anchoring may be done in one of the two following ways:

1. A concrete base 18 inches thick and twice the width of riser diameter shall be used and the riser embedded 6 inches into the concrete. See Plate 3.14-3 and Appendix 3.14-a for design details.

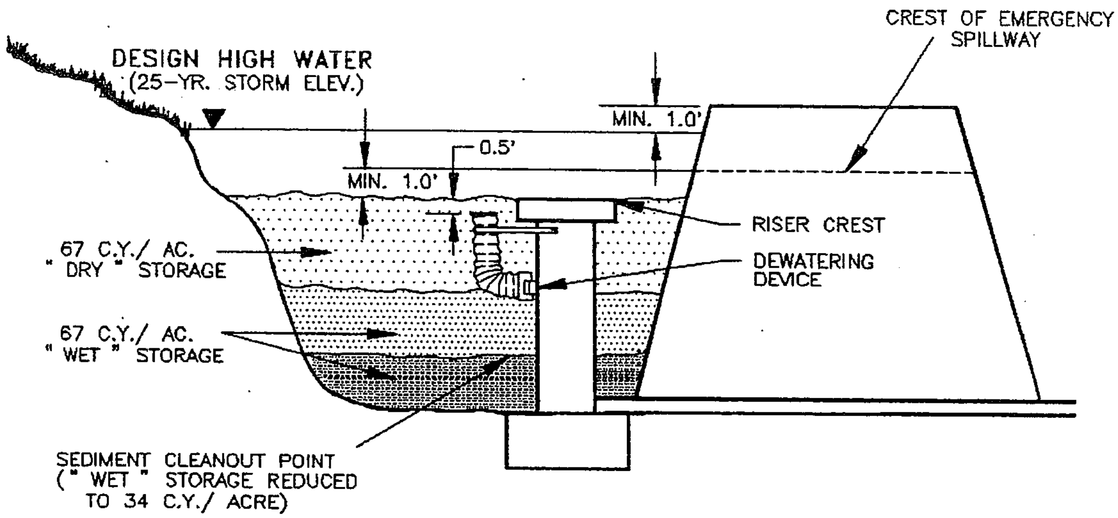
2. A square steel plate, a minimum of 1/4-inch thick and having a width equal to twice the diameter of the riser shall be used; it shall be covered with 2.5 feet of stone, gravel, or compacted soil to prevent flotation. See Plate 3.14-3 and Appendix 3.14-a for design details.

   Note: If the steel base is used, special attention should be given to compaction so that 95% compaction is achieved over the plate. Also, added precautions should be taken to ensure that material over the plate is not removed accidently during removal of sediment from basin.

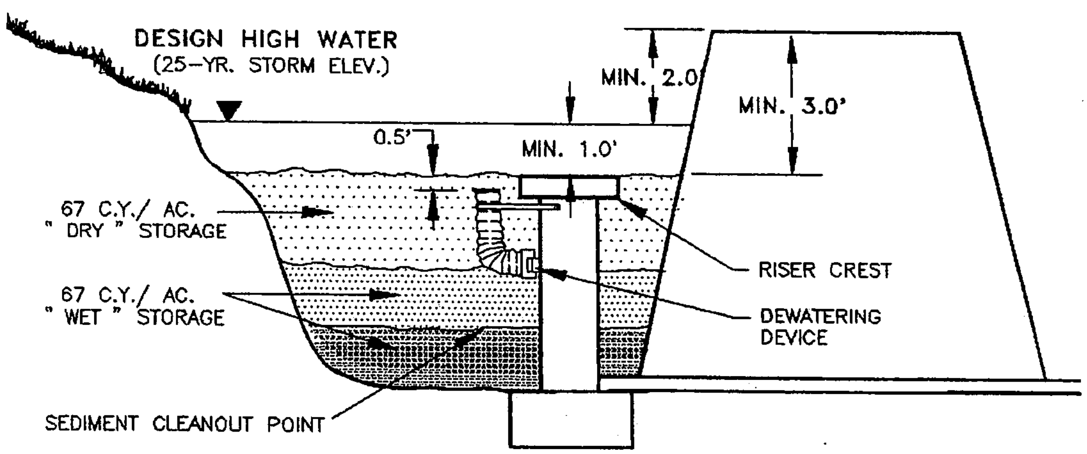
Barrel

The barrel of the principal spillway, which extends through the embankment, shall be designed to carry the flow provided by the riser of the principal spillway with the water level at the crest of the emergency spillway. The connection between the riser and the barrel must be watertight. The outlet of the barrel must be protected to prevent erosion or scour of downstream area. See Appendix 3.14-a for design details.

SEDIMENT BASIN SCHEMATIC ELEVATIONS



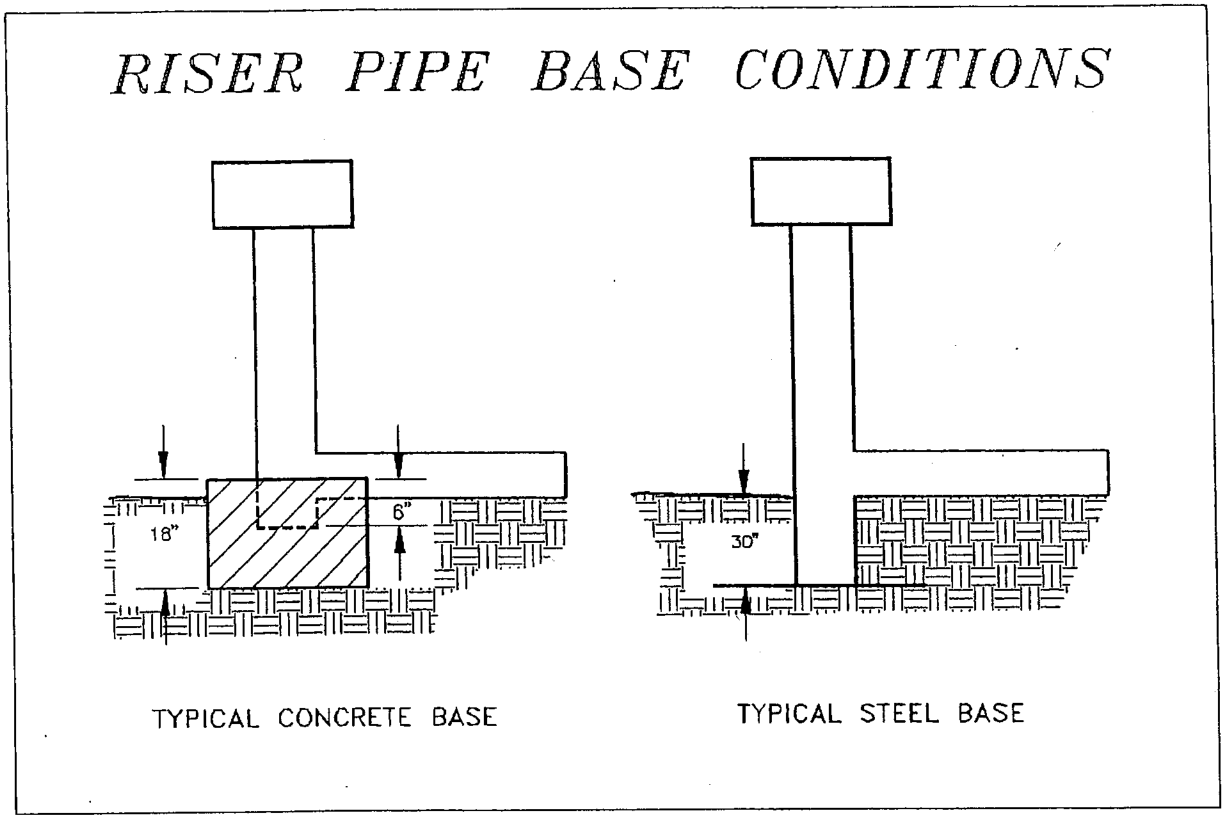
DESIGN ELEVATIONS WITH EMERGENCY SPILLWAY



DESIGN ELEVATIONS WITHOUT EMERGENCY SPILLWAY
(RISER PASSES 25-YR. EVENT)

Source: Va. DSWC

Plate 3.14-2



Source: Va. DSWC

Plate 3.14-3

Anti-Seep Collars

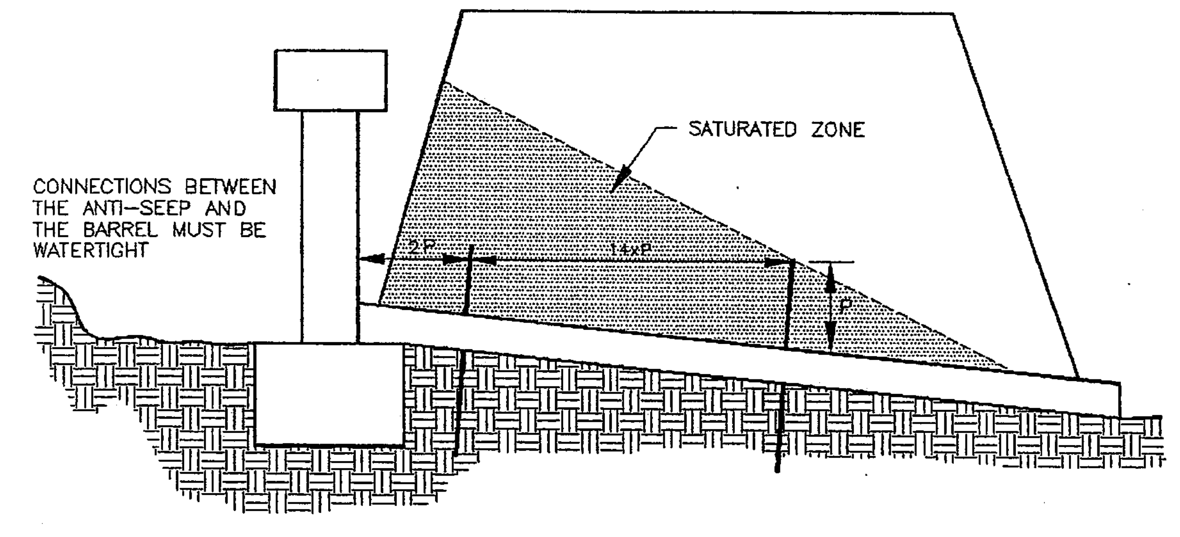
Anti-seep collars shall be used on the barrel of the principal spillway within the normal saturation zone of the embankment to increase the seepage length by at least 10%, if either of the following two conditions is met:

1. The settled height of the embankment exceeds 10 feet.

2. The embankment has a low silt-clay content (Unified Soil Classes SM or GM) and the barrel is greater than 10 inches in diameter.

The anti-seep collars shall be installed within the saturated zone. The maximum spacing between collars shall be 14 times the projection of the collars above the barrel. Collars shall not be closer than 2 feet to a pipe joint. Collars should be placed sufficiently far apart to allow space for hauling and compacting equipment. Precautions should be taken to ensure that 95% compaction is achieved around the collars. Connections between the collars and the barrel shall be watertight. See Plate 3.14-4 and Appendix 3.14-a for details and design procedure.

ANTI-SEEP COLLAR



Source: Va. DSWC

Plate 3.14-4

Alternatives to Anti-Seep Collars

Anti-seep collars are designed to control seepage and piping along the barrel by increasing the flow length and thus making any flow along the barrel travel a longer distance. However, due to the constraints that collars impose on embankment fill placement and compaction, collars may sometimes be ineffective or actually result in an increase in seepage and piping.

Alternative measures have been developed and are being incorporated into embankment designs. These measures include a structure known as a "filter diaphragm." A filter diaphragm consists of a layer of sand and fine gravel which runs through the dam embankment perpendicular to the barrel. Typically, the structure is 4 to 5 inches in width, approximately one foot in height and is located at the barrel elevation at its intersection with the upper bounds of the seepage zone. The measure controls the transport of embankment fines, which is the major concern with piping and seepage. The diaphragm channels any undesirable flow through the fine-graded material, which traps any embankment material being transported. The flow is then conveyed out of the embankment through a perforated toe drain.

The critical design element of the filter diaphragm is the grain-size distribution of the filter material which is determined by the grain-size distribution of the embankment fill material. The use and design of these measures should be based on site-specific geotechnical information and should be supervised by a qualified professional.

Emergency Spillway

The emergency spillway acts as a safety release for a sediment basin, or any impoundment-type structure, by conveying the larger, less frequent storms through the basin without damage to the embankment. The emergency spillway also acts as its name implies - in case of an emergency such as excessive sedimentation or damage to the riser which prevents flow through the principal spillway. The emergency spillway shall consist of an open channel (earthen and vegetated) constructed adjacent to the embankment over undisturbed material (not fill). Where conditions will not allow the construction of an emergency spillway on undisturbed material, a spillway may be constructed of a non-erodible material such as riprap. The spillway shall have a control section at least 20 feet in length. The control section is a level portion of the spillway channel at the highest elevation in the channel. See Plate 3.14-5 and Appendix 3.14-a for details and design procedure.

An evaluation of site and downstream conditions must be made to determine the feasibility and justification for the incorporation of an emergency spillway. In some cases, the site topography does not allow a spillway to be constructed in undisturbed material, and the temporary nature of the facility may not warrant the cost of disturbing more acreage to construct and armor a spillway. The principal spillway should then be sized to convey all the design storms. If the facility is designed as a permanent facility with downstream restrictions, the added expense of constructing and armoring an emergency spillway may be justified.

Capacity

The emergency spillway shall be designed to carry the portion of the peak rate of runoff expected from a 25-year storm which is not carried by the principal spillway. See Appendix 3.14-a for design procedure and details.

Design Elevations

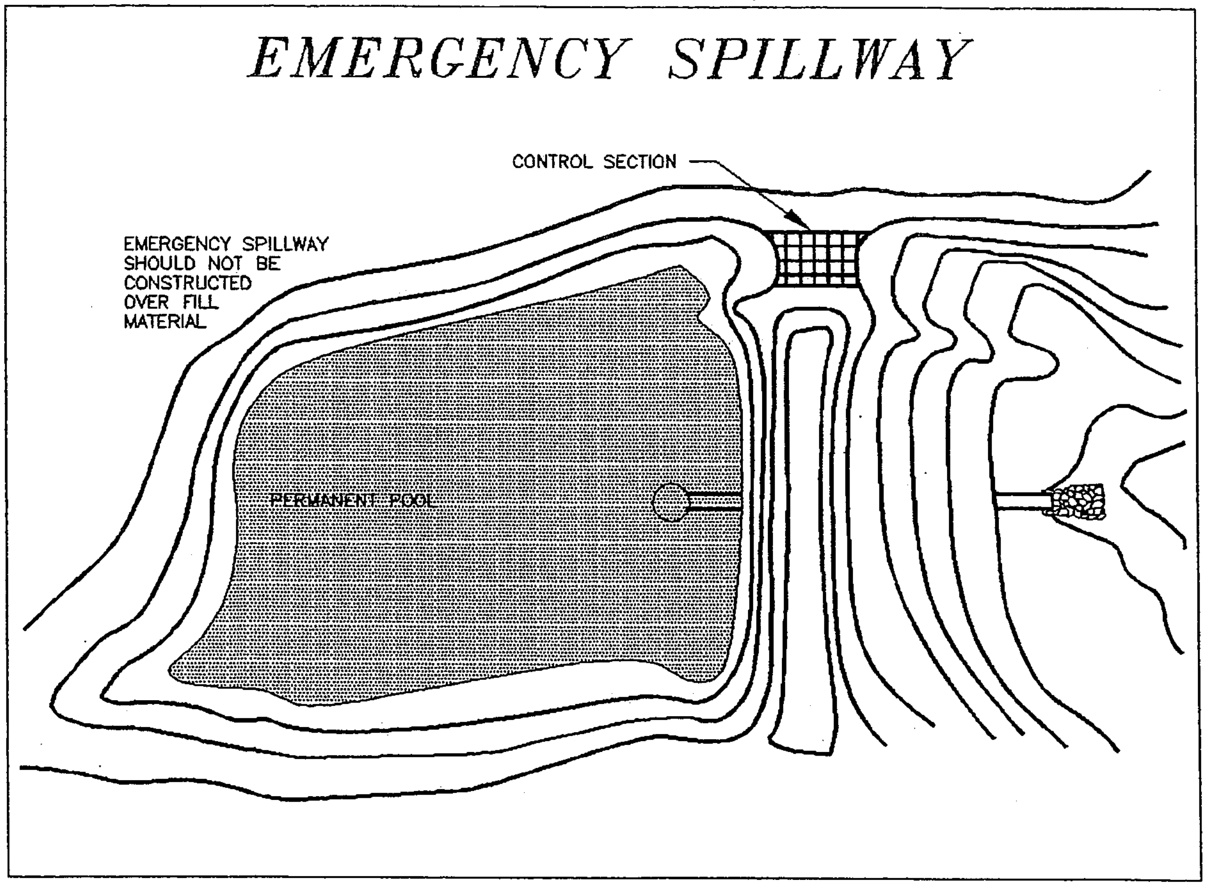
The 25-year storm elevation through the emergency spillway shall be at least 1.0 foot below the top of the embankment. The crest of the emergency spillway channel shall be at least 1.0 foot above the crest of the principal spillway.

Location

The emergency spillway channel shall be located so that it will not be constructed over fill material. The channel shall be located so as to avoid sharp turns or bends. The channel shall return the flow of water to a defined channel downstream from the embankment.

Maximum Velocities

The maximum allowable velocity in the emergency spillway channel will depend upon the type of lining used. For vegetated linings, allowable velocities are listed in Table 3.17-A (Std. & Spec. 3.17, STORMWATER CONVEYANCE CHANNELS). For non-erodible linings, such as concrete or riprap, design velocities may be increased. However, the emergency spillway channel shall return the flow to the receiving channel at a non-eroding velocity. See Appendix 3.14-a for design procedure and details.



Source: Va. DSWC Plate 3.14-5

Stabilization

The embankment of the sediment basin shall receive temporary or permanent seeding immediately after installation (see TEMPORARY SEEDING, Std. & Spec. 3.31 or PERMANENT SEEDING, Std. & Spec. 3.32). If excavation is required in the basin, side slopes should not be steeper than 1½:1.

Disposal

Sediment shall be removed from the basin when the sediment level is no higher than 1 foot below the bottom of the dewatering orifice, or one-half of the permanent pool volume, whichever is lower. Plans for the sediment basin shall indicate the methods for disposing of sediment removed from the basin. Possible alternatives are the use of the material in fill areas on-site or removal to an approved off-site location.

Sediment basin plans shall indicate the final disposition of the sediment basin after the upstream drainage area is stabilized. The plans shall include methods for the removal of excess water lying over the sediment, stabilization of the basin site, and the disposal of any excess material. Where the sediment basin has been designed as a permanent stormwater management basin, plans should also address the steps necessary for the conversion from sediment basin to a permanent detention or retention facility.

Safety

Sediment basins can be attractive to children and can be dangerous. They should, therefore, be fenced or otherwise made inaccessible to persons or animals unless this is deemed unnecessary by the plan approving authority due to the remoteness of the site or other circumstances. Strategically placed signs around the impoundment reading "DANGER-QUICKSAND" should also be installed. In any case, local ordinances and regulations regarding health and safety must be adhered to (see Std. & Spec. 3.01, SAFETY FENCE).

Construction Specifications

Site Preparation

Areas under the embankment or any structural works related to the basin shall be cleared, grubbed, and stripped of topsoil to remove trees, vegetation, roots, or other objectionable material. In order to facilitate cleanout and restoration, the area of most frequent inundation (measured from the top of the principal spillway) will be cleared of all brush and trees.

Cutoff Trench

For earth-fill embankments, a cutoff trench shall be excavated along the centerline of the dam. The trench must extend at least 1 foot into a stable, impervious layer of soil and have a minimum depth of 2 feet. The cutoff trench shall extend up both abutments to the riser crest elevation. The minimum bottom width shall be 4 feet, but also must be wide enough to permit operation of compaction equipment. The side slopes shall be no steeper than 1:1.

Compaction requirements shall be the same as those for the embankment. The trench shall be drained during the backfilling/compacting operations.

Embankment

The fill material shall be taken from approved borrow areas. It shall be clean mineral soil, free of roots, woody vegetation, stumps, sod, oversized stones, rocks, or other perishable or objectionable material. The material selected must have enough strength for the dam to remain stable and be tight enough, when properly compacted, to prevent excessive percolation of water through the dam. Fill containing particles ranging from small gravel or coarse sand to fine sand and clay in desired proportion is appropriate. Any embankment material should contain approximately 20% clay particles by weight. Using the Unified Soil Classification System, SC (clayey sand), GC (clayey gravel) and CL ("low liquid limit" clay) are among the preferred types of embankment soils. Areas on which fill is to be placed shall be scarified prior to placement of fill. The fill material should contain the proper amount of moisture to ensure that 95% compaction will be achieved. Fill material will be placed in 6-inch continuous layers over the entire length of the fill. Compaction shall be obtained by routing the hauling equipment over the fill so that the entire surface of the fill is transversed by at least one wheel or tread track of the equipment, or by using a compactor. Special care shall be taken in compacting around the anti-seep collars (compact by hand, if necessary) to avoid damage and achieve desired compaction. The embankment shall be constructed to an elevation 10% higher than the design height to allow for settlement if compaction is obtained with hauling equipment. If compactors are used for compaction, the overbuild may be reduced to not less than 5%.

Principal Spillway

The riser of the principal spillway shall be securely attached to the barrel by a watertight connection. The barrel and riser shall be placed on a firmly compacted soil foundation. The base of the riser shall be firmly anchored according to design criteria to prevent its floating. Pervious materials such as sand, gravel, or crushed stone shall not be used as backfill around the barrel or anti-seep collars. Special care shall be taken in compacting around the anti-seep collars (compact by hand, if necessary). Fill material shall be placed around the pipe in 4-inch layers and compacted until 95% compaction is achieved. A minimum of two feet of fill shall be hand-compacted over the barrel before crossing it with construction equipment.

Emergency Spillway

Vegetative emergency spillways shall not be constructed over fill material. Design elevations, widths, entrance and exit channel slopes are critical to the successful operation of the spillway and should be adhered to closely during construction.

Vegetative Stabilization

The embankment and emergency spillway of the sediment basin shall be stabilized with temporary or permanent vegetation immediately after installation of the basin (see TEMPORARY SEEDING, Std. & Spec. 3.31 or PERMANENT SEEDING, Std. & Spec. 3.32).

Erosion and Sediment Control

The construction of the sediment basin shall be carried out in a manner such that it does not result in sediment problems downstream.

Safety

All state and local requirements shall be met concerning fencing and signs warning the public of the hazards of soft, saturated sediment and flood waters (refer to Std. & Spec. 3.01, SAFETY FENCE).

Maintenance

The basin embankment should be checked regularly to ensure that it is structurally sound and has not been damaged by erosion or construction equipment.

The emergency spillway should be checked regularly to ensure that its lining is well established and erosion-resistant.

The basin should be checked after each runoff-producing rainfall for sediment cleanout. When the sediment reaches the clean-out level, it shall be removed and properly disposed of.

APPENDIX 3.14-a

Design Procedure for Temporary Sediment Basins

The following design procedure provides a step-by-step method for the design of a temporary sediment basin. The data sheet found in the back of this Appendix should be used in the erosion and sediment control plan to outline design values calculated.

I. Basin Volume

A. Determine the required basin volume. The design capacity of the basin must be at least 134 cubic yards per acre of total contributing drainage area, half of which shall be in the form of a permanent pool or wet storage, and the remaining half as a "drawdown" area or dry storage.

1. For a natural basin, the wet storage volume may be approximated as follows:

$$V_1 = 0.4 \times A_1 \times D_1$$

where,

V_1 = the wet storage volume in cubic feet

A_1 = the surface area of the flooded area at the invert of the dewatering outlet, in square feet

D_1 = the maximum depth in feet, measured from the low point in the basin to the invert of the dewatering outlet

2. For a natural basin, the dry storage volume may be approximated as follows:

$$V_2 = \frac{A_1 + A_2}{2} \times D_2$$

where,

V_2 = the dry storage volume in cubic feet

A_1 = the surface area of the flooded area at the invert of the dewatering outlet, in square feet (see #1 above)

A_2 = the surface area of the flooded area at the crest of the principal spillway

D_2 = the depth, in feet, measured from the invert of the dewatering outlet to the crest of the principal spillway

Note 1: The volumes may be computed from more precise contour information or other suitable methods.

Note 2: Conversion between cubic feet and cubic yards is as follows:

number of cubic feet x 0.037 = number of cubic yards

B. If the volume of the basin is inadequate or embankment height becomes excessive, pursue the use of excavation to obtain the required volume.

II. Basin Shape

A. The shape of the basin must be such that the length-to-width ratio is at least 2 to 1 according to the following equation:

$$Length\text{-}to\text{-}width\ Ratio = \frac{L}{We}$$

where,

We = A/L = the effective width

A = the surface area of the normal pool

L = the length of the flow path from the inflow to the outflow. If there is more than one inflow point, any inflow which carries more than 30% of the peak rate of inflow must meet these criteria.

B. The correct basin shape can be obtained by proper site selection, excavation, or the use of baffles. Baffles increase the flow length by deflecting the flow. The baffles should be placed halfway between the inflow point and the outflow. Plate 3.14-6 shows the detail for baffle construction and three situations where baffles might be used.

III. Determine whether the basin will have a separate emergency spillway.

IV. Determine the elevation of the crest of the principal spillway for the required volume (dewatering orifice at 67 cubic yards per acre and crest of principal spillway 134 cubic yards per acre).

V. Estimate the elevation of the design high water and the required height of the dam.

A. If an emergency spillway is included, the crest of the principal spillway must be at least 1.0 foot below the crest of the emergency spillway.

B. If an emergency spillway is included, the elevation of the peak flow through the emergency spillway (which will be the design high water for the 25-year storm) must be at least 1.0 foot below the top of embankment.

C. If an emergency spillway is <u>not</u> included, the crest of the principal spillway must be at least 3 feet below the top of the embankment.

D. If an emergency spillway is <u>not</u> included, the elevation of the design high water for the 25-year storm must be 2.0 feet below the top of the embankment.

VI. Using Chapter 5 of this handbook, determine the peak rate of runoff expected from the drainage area of the basin for a 25-year storm. The "C" factor or "CN" value used in the runoff calculations should be derived from analysis of the contributing drainage area at the peak of land disturbance (condition which will create greatest peak runoff).

VII. Principal Spillway Design

A. If an emergency spillway is included, the principal spillway must at least pass the peak rate of runoff from the basin drainage area for a 2-year storm.

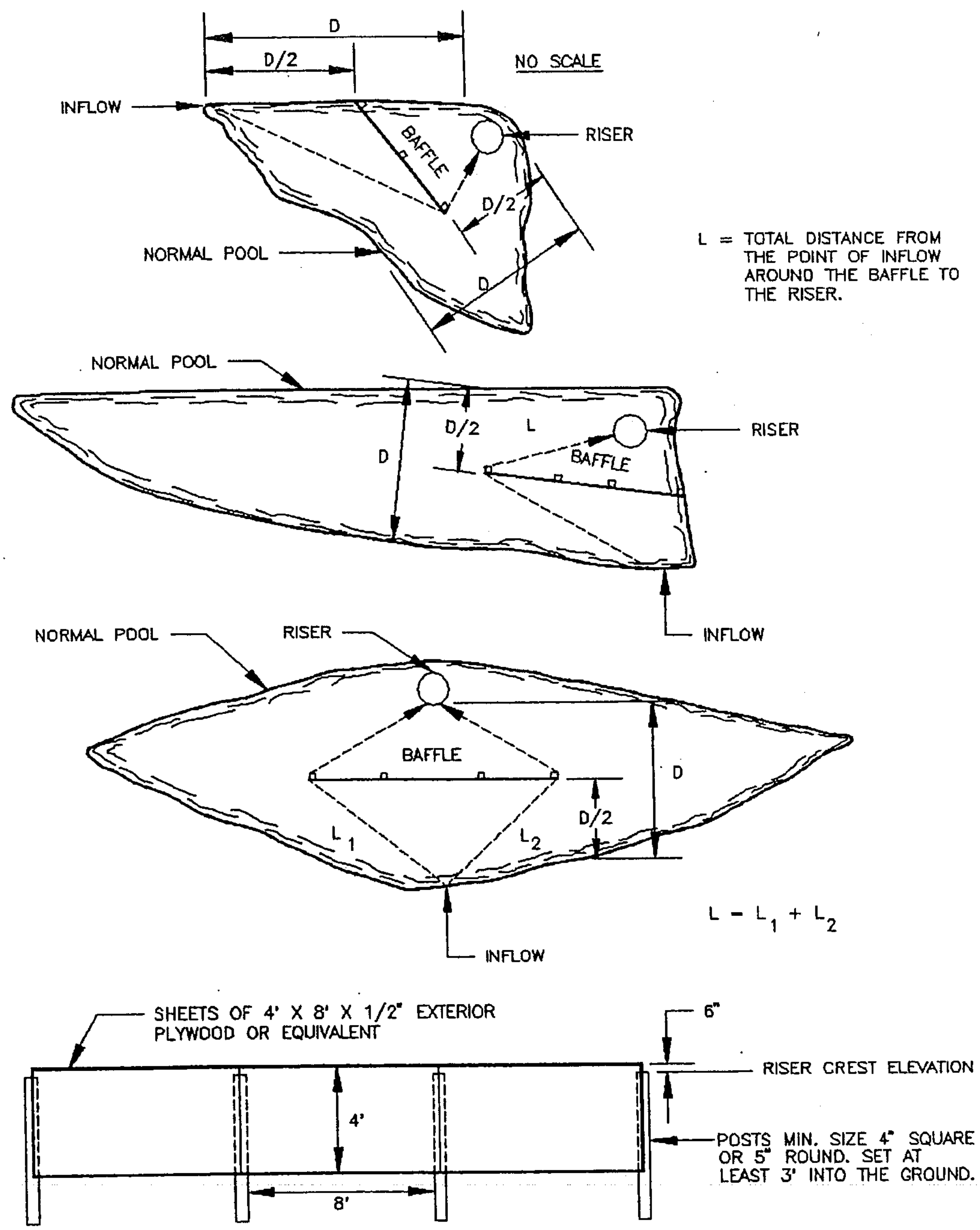
1. Q_p = the 2-year peak rate of runoff.

B. If an emergency spillway is <u>not</u> included, the principal spillway must pass the peak rate of runoff from the basin drainage area for a 25-year storm.

1. Therefore,

Q_p = the 25-year peak rate of runoff.

EXAMPLE PLAN VIEWS OF BAFFLE LOCATIONS IN SEDIMENT BASINS



Source: USDA-SCS

Plate 3.14-6

C. Refer to Plate 3.14-7, where h is the difference between the elevation of the crest of the principal spillway and the elevation of the crest of the emergency spillway.

D. Enter Plate 3.14-8 with Q_p. Choose the smallest riser which will pass the required flow with the available head, h.

E. Refer to Plate 3.14-7, where H is the difference in elevation of the centerline of the outlet of the barrel and the crest of the emergency spillway. L is the length of the barrel through the embankment.

F. Enter Table 3.14-A or Table 3.14-B with H. Choose the smallest size barrel which will pass the flow provided by the riser. If L is other than 70 feet, make the necessary correction.

VIII. Emergency Spillway Design

A. The emergency spillway must pass the remainder of the 25-year peak rate of runoff not carried by the principal spillway.

B. Compute, $Q_e = Q_{25} - Q_p$

C. Refer to Plate 3.14-9 and Table 3.14-C.

D. Determine approximate permissible values for b, the bottom width; s, the slope of the exit channel; and X, minimum length of the exit channel.

E. Enter Table 3.14-C and choose an exit channel cross-section which passes the required flow and meets the other constraints of the site.

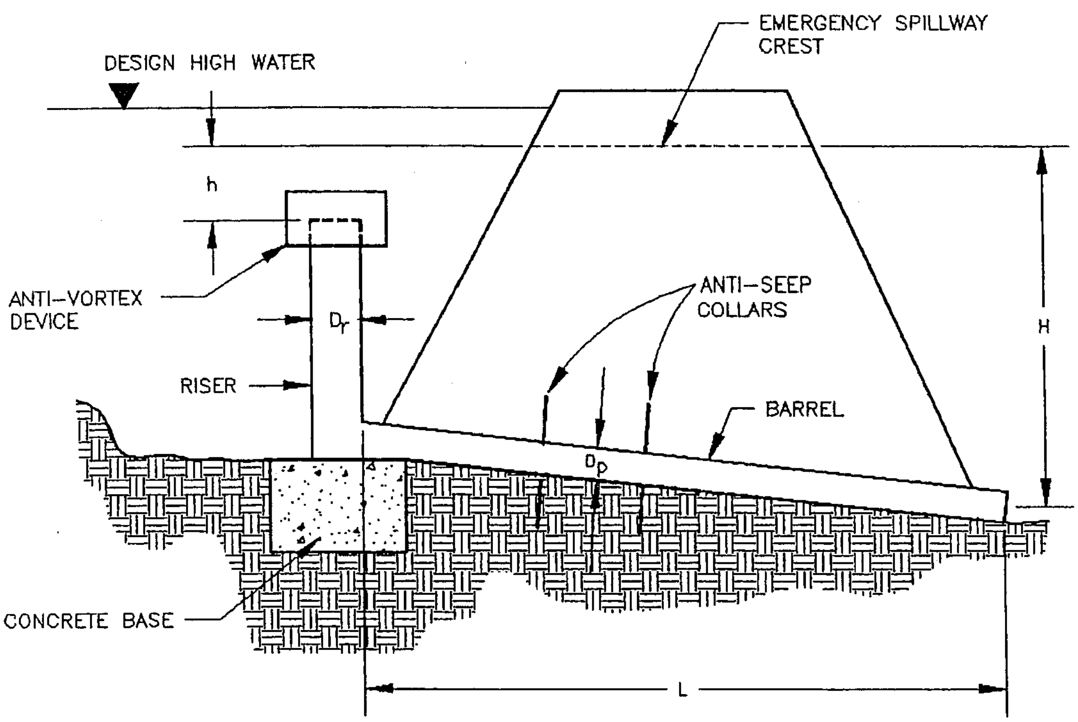
F. <u>Note</u>:

1. The maximum permissible velocity for vegetated waterways must be considered when designing an exit channel.

2. For a given Hp, a decrease in the exit slope from S as given in the table decreases spillway discharge, but increasing the exit slope from S does not increase discharge. If an exit slope (Se) steeper than S is used, then design procedures found in "Open Channel Flow" in Chapter 5 should be used to verify the adequacy of the exit channel.

3. Data to the right of heavy vertical lines should be used with caution, as the resulting sections will be either poorly proportioned or have excessive velocities.

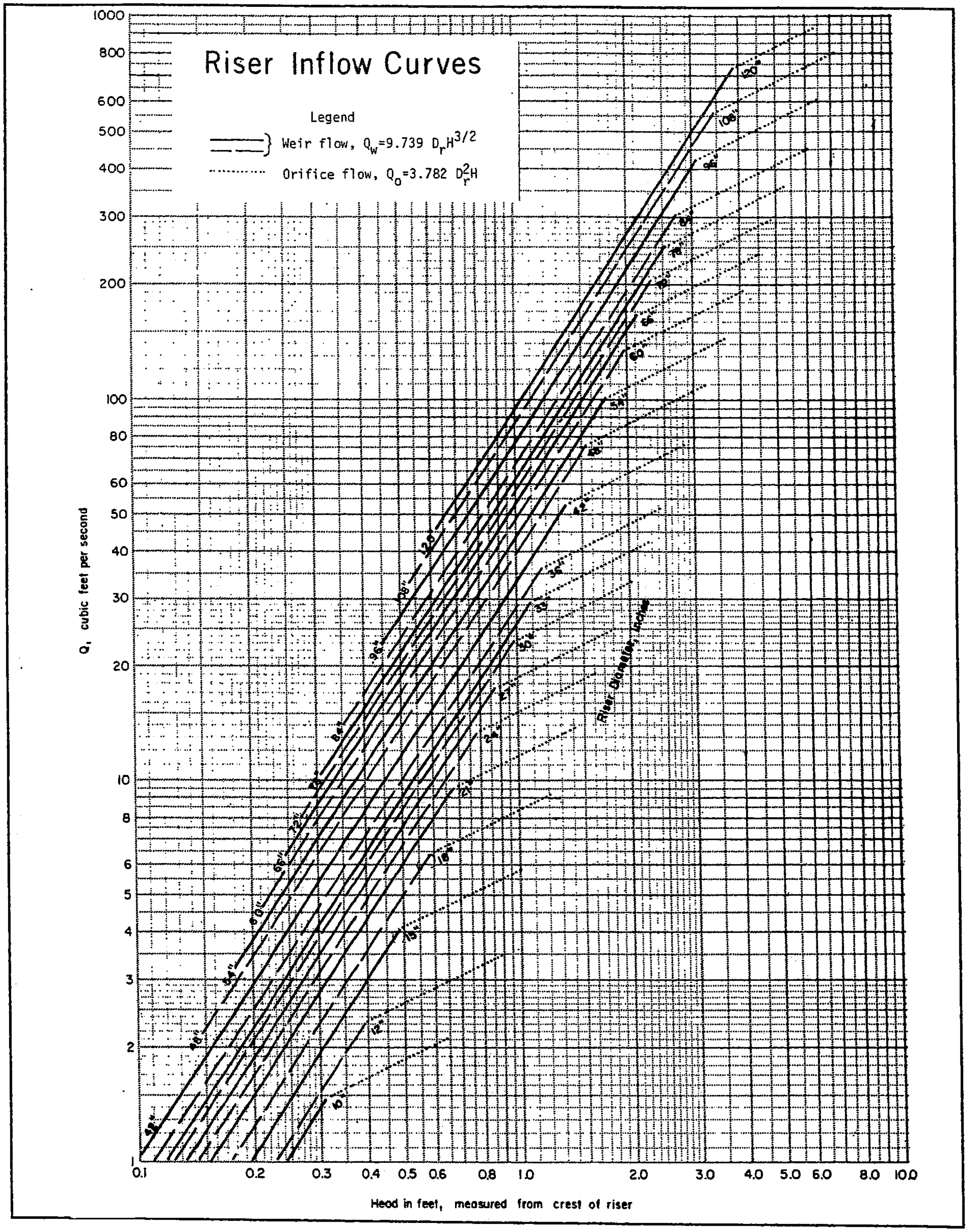
PRINCIPAL SPILLWAY DESIGN



H = HEAD ON PIPE THROUGH EMBANKMENT
h = HEAD OVER RISER CREST
L = LENGTH OF PIPE THROUGH EMBANKMENT
D_p = DIAMETER OF PIPE THROUGH EMBANKMENT
D_r = DIAMETER OF RISER

Source: Va. DSWC

Plate 3.14-7



Source: USDA-SCS

Plate 3.14-8

TABLE 3.14-A
PIPE FLOW CHART, n = 0.025

FOR CORRUGATED METAL PIPE INLET $K_m = K_e + K_b = 1.0$ AND 70 FEET OF CORRUGATED METAL PIPE CONDUIT (full flow assumed)
Note correction factors for pipe lengths other than 70 feet

diameter of pipe in inches

H, in feet	6"	8"	10"	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
1	0.33	0.70	1.25	1.98	3.48	5.47	7.99	11.0	18.8	28.8	41.1	55.7	72.6	91.8	113	137	163	191	222	255	290
2	0.47	0.99	1.76	2.80	4.92	7.74	11.3	15.6	26.6	40.8	58.2	78.8	103	130	160	194	231	271	314	360	410
3	0.58	1.22	2.16	3.43	6.02	9.48	13.8	19.1	32.6	49.9	71.2	96.5	126	159	196	237	282	331	384	441	502
4	0.67	1.40	2.49	3.97	6.96	10.9	16.0	22.1	37.6	57.7	82.3	111	145	184	226	274	326	383	444	510	580
5	0.74	1.57	2.79	4.43	7.78	12.2	17.9	24.7	42.1	64.5	92.0	125	162	205	253	306	365	428	496	570	648
6	0.82	1.72	3.05	4.86	8.52	13.4	19.6	27.0	46.1	70.6	101	136	178	225	277	336	399	469	544	624	710
7	0.88	1.86	3.30	5.25	9.20	14.5	21.1	29.2	49.8	76.3	109	147	192	243	300	362	431	506	587	674	767
8	0.94	1.99	3.53	5.61	9.84	15.5	22.6	31.2	53.2	81.5	116	158	205	260	320	388	461	541	628	721	820
9	1.00	2.11	3.74	5.95	10.4	16.4	24.0	33.1	56.4	86.5	123	167	218	275	340	411	489	574	666	764	870
10	1.05	2.22	3.94	6.27	11.0	17.3	25.3	34.9	59.5	91.2	130	176	230	290	358	433	516	605	702	806	917
11	1.10	2.33	4.13	6.58	11.5	18.2	26.5	36.6	62.4	95.6	136	185	241	304	376	454	541	635	736	845	962
12	1.15	2.43	4.32	6.87	12.1	19.0	27.7	38.2	65.2	99.9	142	193	252	318	392	475	565	663	769	883	1004
13	1.20	2.53	4.49	7.15	12.6	19.7	28.8	39.8	67.8	104	148	201	262	331	408	494	588	690	800	919	1045
14	1.25	2.63	4.66	7.42	13.0	20.5	29.9	41.3	70.4	108	154	208	272	343	424	513	610	716	830	953	1085
15	1.29	2.72	4.83	7.68	13.5	21.2	30.9	42.8	72.8	112	159	216	281	355	439	531	631	741	860	987	1123
16	1.33	2.81	4.99	7.93	13.9	21.9	32.0	44.2	75.2	115	165	223	290	367	453	548	652	765	888	1019	1160
17	1.37	2.90	5.14	8.18	14.3	22.6	32.9	45.5	77.5	119	170	230	229	378	467	565	672	789	915	1051	1195
18	1.41	2.98	5.29	8.41	14.8	23.2	33.9	46.8	79.8	120	174	236	308	389	480	581	692	812	942	1081	1230
19	1.45	3.06	5.43	8.64	15.2	23.9	34.8	48.1	82.0	126	179	243	316	400	494	597	711	834	967	1111	1264
20	1.49	3.14	5.57	8.87	15.6	24.5	35.7	49.4	84.1	129	184	249	325	410	506	613	729	856	993	1139	1297
21	1.53	3.22	5.71	9.09	15.9	25.1	36.6	50.6	86.2	132	188	255	333	421	519	628	747	877	1017	1168	1329
22	1.56	3.29	5.85	9.30	16.3	25.7	37.5	51.8	88.2	135	193	261	341	430	531	643	765	898	1041	1195	1360
23	1.60	3.37	5.98	9.51	16.7	26.2	38.3	53.0	90.2	138	197	267	348	440	543	657	782	918	1064	1222	1390
24	1.63	3.44	6.11	9.72	17.0	26.8	39.1	54.1	92.1	141	201	273	356	450	555	671	799	937	1087	1248	1420
25	1.66	3.51	6.23	9.92	17.4	27.4	39.9	55.2	94.0	144	206	279	363	459	566	685	815	957	1110	1274	1450
26	1.70	3.58	6.36	10.1	17.7	27.9	40.7	56.3	95.9	147	210	284	370	468	577	699	831	976	1132	1299	1478
27	1.73	3.65	6.48	10.3	18.1	28.4	41.5	57.4	97.7	150	214	290	377	477	588	712	847	994	1153	1324	1507
28	1.76	3.72	6.60	10.5	18.4	29.0	42.3	58.4	99.5	153	218	295	384	486	599	725	863	1013	1174	1348	1534
29	1.79	3.78	6.71	10.7	18.7	29.5	43.0	59.5	101	155	221	300	391	494	610	738	878	1030	1195	1372	1561
30	1.82	3.85	6.83	10.9	19.1	30.0	43.7	60.5	103	158	225	305	398	503	620	750	893	1048	1216	1396	1588

Correction Factors For Other Pipe Lengths

L, in feet	6"	8"	10"	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
20	1.69	1.63	1.58	1.53	1.47	1.42	1.37	1.34	1.28	1.24	1.20	1.18	1.16	1.14	1.13	1.11	1.10	1.10	1.09	1.08	1.08
30	1.44	1.41	1.39	1.36	1.32	1.29	1.27	1.24	1.21	1.18	1.15	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.07	1.06	1.06
40	1.28	1.27	1.25	1.23	1.21	1.20	1.18	1.17	1.14	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.05	1.04
50	1.16	1.16	1.15	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.03
60	1.07	1.07	1.07	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	.94	.94	.95	.95	.95	.95	.96	.96	.96	.97	.97	.97	.98	.98	.98	.98	.98	.98	.99	.99	.99
90	.89	.89	.90	.90	.91	.91	.92	.92	.93	.94	.94	.95	.95	.96	.96	.96	.97	.97	.97	.97	.94
100	.85	.85	.86	.86	.87	.88	.89	.89	.90	.91	.92	.93	.93	.94	.94	.95	.95	.95	.96	.96	.94
120	.78	.79	.79	.90	.81	.82	.83	.83	.85	.86	.87	.89	.89	.90	.91	.89	.92	.93	.93	.94	.92
140	.72	.73	.74	.75	.76	.77	.78	.79	.81	.82	.84	.85	.86	.87	.88	.86	.89	.90	.91	.91	.90
160	.68	.69	.69	.70	.71	.73	.74	.75	.77	.79	.80	.82	.83	.84	.85	.92	.87	.88	.89	.89	

Source: USDA-SCS

TABLE 3.14-B
PIPE FLOW CHART, n = 0.013

FOR REINFORCED CONCRETE PIPE INLET $K_m = K_e + K_b = 0.65$ AND 70 FEET OF REINFORCED CONCRETE PIPE CONDUIT (full flow assumed)

Note correction factors for pipe lengths other than 70 feet

H, in feet	diameter of pipe in inches															
	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
1	3.22	5.44	8.29	11.8	15.9	26.0	38.6	53.8	71.4	91.5	114	139	167	197	229	264	302	342
2	4.55	7.69	11.7	16.7	22.5	36.8	54.6	76.0	101	129	161	197	236	278	324	374	427	483
3	5.57	9.42	14.4	20.4	27.5	45.0	66.9	93.1	124	159	198	241	289	341	397	458	523	592
4	6.43	10.9	16.6	23.5	31.8	52.0	77.3	108	143	183	228	278	334	394	459	529	604	683
5	7.19	12.2	18.5	26.3	35.5	58.1	86.4	120	160	205	255	311	373	440	513	591	675	764
6	7.88	13.3	20.3	28.8	38.9	63.7	94.6	132	175	224	280	341	409	482	562	647	739	837
7	8.51	14.4	21.9	31.1	42.0	68.8	102	142	189	242	302	368	441	521	607	699	798	904
8	9.10	15.4	23.5	33.3	44.9	73.5	109	152	202	259	323	394	472	557	685	748	854	966
9	9.65	16.3	24.9	35.3	47.7	78.0	116	161	214	275	342	418	500	590	688	793	905	1025
10	10.2	17.2	26.2	37.2	50.2	82.2	122	170	226	289	361	440	527	622	725	836	954	1080
11	10.7	18.0	27.5	39.0	52.7	86.2	128	178	237	304	379	462	553	653	761	877	1001	1133
12	11.1	18.9	28.7	40.8	55.0	90.1	134	186	247	317	395	482	578	682	794	916	1045	1184
13	11.6	19.6	29.9	42.4	57.3	93.7	139	194	257	330	411	502	601	710	827	953	1088	1232
14	12.0	20.4	31.0	44.1	59.4	97.3	145	201	267	342	427	521	624	736	858	989	1129	1278
15	12.5	21.1	32.1	45.6	61.5	101	150	208	277	354	442	539	646	762	888	1024	1169	1323
16	12.9	21.8	33.2	47.1	63.5	104	155	215	286	366	457	557	667	787	917	1057	1207	1367
17	13.3	22.4	34.2	48.5	65.5	107	159	222	294	377	471	574	688	812	946	1090	1244	1409
18	13.7	23.1	35.2	49.9	67.4	110	164	228	303	388	484	591	708	835	973	1121	1280	1450
19	14.0	23.7	36.1	51.3	69.2	113	168	234	311	399	497	607	727	858	1000	1152	1315	1489
20	14.4	24.3	37.1	52.6	71.0	116	173	240	319	409	510	623	746	880	1026	1182	1350	1528
21	14.7	24.9	38.0	53.9	72.8	119	177	246	327	419	523	638	764	902	1051	1211	1383	1566
22	15.1	25.5	38.9	55.2	74.5	122	181	252	335	429	535	653	782	923	1076	1240	1415	1603
23	15.4	26.1	39.8	56.5	76.2	125	186	258	342	439	547	668	800	944	1100	1268	1447	1639
24	15.8	26.7	40.6	57.7	77.8	127	189	263	350	448	559	682	817	964	1123	1295	1478	1674
25	16.1	27.2	41.5	58.9	79.4	130	193	269	357	458	571	696	834	984	1147	1322	1509	1708
26	16.4	27.7	42.3	60.0	81.0	133	197	274	364	467	582	710	850	1004	1169	1348	1539	1742
27	16.7	28.3	43.1	61.2	82.5	135	201	279	371	476	593	723	867	1023	1192	1373	1568	1775
28	17.0	28.8	43.9	62.3	84.1	138	204	285	378	484	604	737	883	1041	1214	1399	1597	1808
29	17.3	29.3	44.7	63.4	85.5	140	208	290	384	493	615	750	898	1060	1235	1423	1625	1840
30	17.6	29.8	45.4	64.5	87.0	142	212	294	391	501	625	763	913	1078	1256	1448	1653	1871

L, in feet	Correction Factors For Other Pipe Lengths																	
20	1.30	1.24	1.21	1.18	1.15	1.12	1.10	1.08	1.07	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.03
30	1.22	1.18	1.15	1.13	1.12	1.09	1.08	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02
40	1.15	1.13	1.11	1.10	1.08	1.07	1.05	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02
50	1.09	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01
60	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	.96	.97	.97	.97	.98	.98	.98	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99
90	.93	.94	.94	.95	.95	.96	.97	.97	.98	.98	.98	.98	.98	.99	.99	.99	.99	.99
100	.90	.91	.92	.93	.93	.95	.95	.96	.97	.97	.97	.98	.98	.98	.98	.98	.98	.99
120	.84	.86	.87	.89	.90	.91	.93	.94	.94	.95	.96	.96	.96	.97	.97	.97	.97	.98
140	.80	.82	.83	.85	.86	.88	.90	.91	.92	.93	.94	.94	.95	.95	.96	.96	.96	.97
160	.76	.78	.80	.82	.83	.86	.88	.89	.90	.91	.92	.93	.94	.94	.95	.95	.95	.96

Source: USDA-SCS

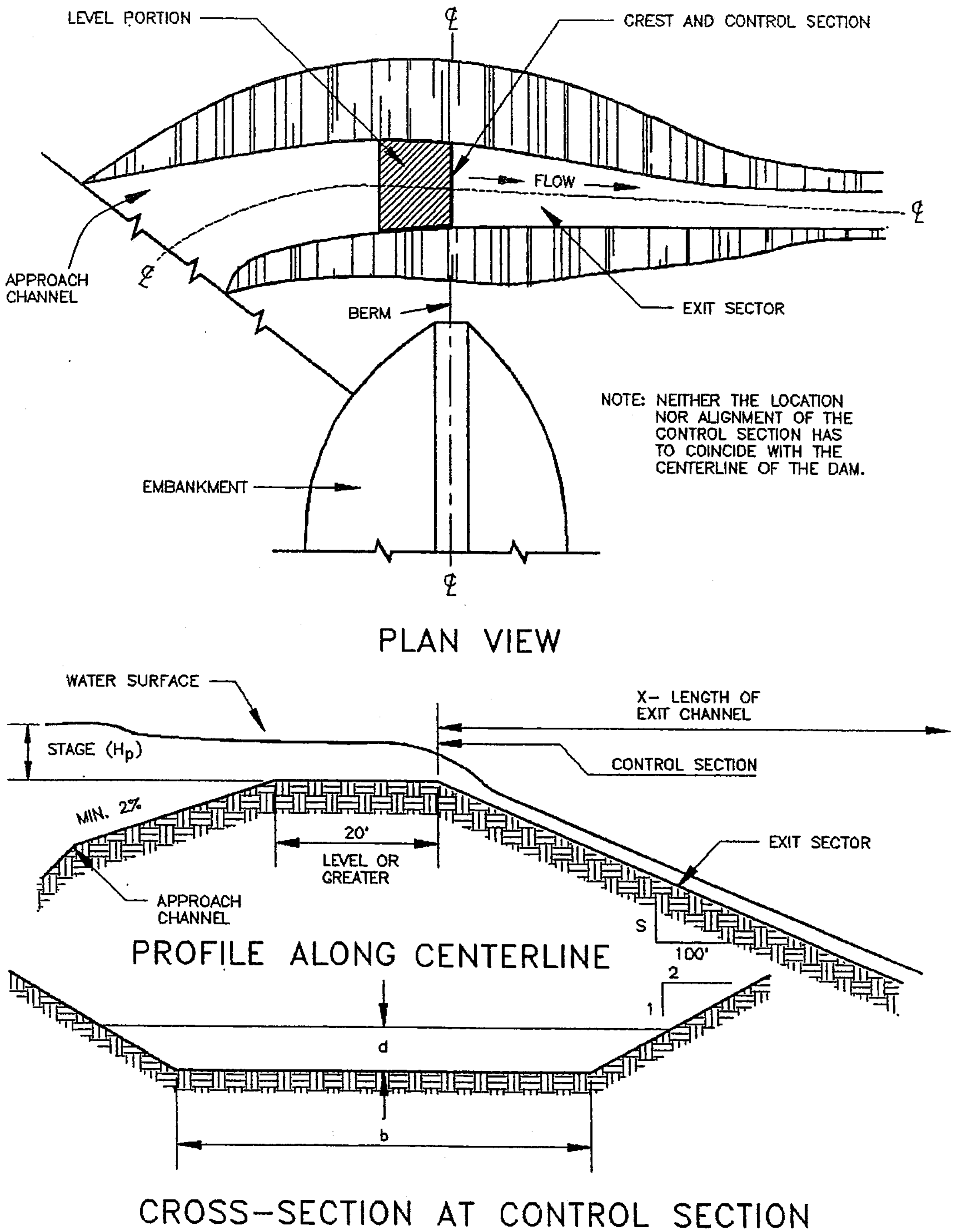
TABLE 3.14-C

DESIGN DATA FOR EARTH SPILLWAYS

STAGE (Hp) IN FEET	SPILLWAY VARIABLES	BOTTOM WIDTH (b) IN FEET																
		8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
0.5	Q	6	7	8	10	11	13	14	15	17	18	20	21	22	24	25	27	28
	V	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	S	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	X	32	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
0.6	Q	8	10	12	14	16	18	20	22	24	26	28	30	32	34	35	37	39
	V	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	S	3.7	3.7	3.7	3.7	3.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	X	36	36	36	36	36	36	37	37	37	37	37	37	37	37	37	37	37
0.7	Q	11	13	16	18	20	23	25	28	30	33	35	38	41	43	44	46	48
	V	3.2	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
	S	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	X	39	40	40	40	41	41	41	41	41	41	41	41	41	41	41	41	41
0.8	Q	13	16	19	22	26	29	32	35	38	42	45	46	48	51	54	57	60
	V	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	S	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	X	44	44	44	44	45	45	45	45	45	45	45	45	45	45	45	45	45
0.9	Q	17	20	24	28	32	35	39	43	47	51	53	57	60	64	68	71	75
	V	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	S	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	X	47	47	48	48	48	48	48	48	48	48	49	49	49	49	49	49	49
1.0	Q	20	24	29	33	38	42	47	51	56	61	63	68	72	77	81	86	90
	V	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	S	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	X	51	51	51	51	52	52	52	52	52	52	52	52	52	52	52	52	52
1.1	Q	23	28	34	39	44	49	54	60	65	70	74	79	84	89	95	100	105
	V	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	S	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	55	55	55	55	55	55	55	56	56	56	56	56	56	56	56	56	56
1.2	Q	28	33	40	45	51	58	64	69	76	80	86	92	98	104	110	116	122
	V	4.4	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	S	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	58	58	59	59	59	59	59	59	60	60	60	60	60	60	60	60	60
1.3	Q	32	38	46	53	58	65	73	80	86	91	99	106	112	119	125	133	140
	V	4.5	4.6	4.6	4.6	4.6	4.6	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
	S	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	X	62	62	62	63	63	63	63	63	63	63	63	64	64	64	64	64	64
1.4	Q	37	44	51	59	66	74	82	90	96	103	111	119	127	134	142	150	158
	V	4.7	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	S	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	X	65	66	66	66	66	67	67	67	67	67	67	68	68	68	68	68	69
1.5	Q	41	50	58	66	75	85	92	101	108	116	125	133	142	150	160	169	178
	V	4.8	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	5.1	5.1
	S	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.5	2.5
	X	69	69	70	70	71	71	71	71	71	71	71	72	72	72	72	72	72
1.6	Q	46	56	65	75	84	94	104	112	122	132	142	149	158	168	178	187	197
	V	5.0	5.1	5.1	5.1	5.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
	S	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	72	74	74	75	75	76	76	76	76	76	76	76	76	76	76	76	76
1.7	Q	52	62	72	83	94	105	115	126	135	145	156	167	175	187	196	206	217
	V	5.2	5.2	5.2	5.3	5.3	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
	S	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	76	78	79	80	80	80	80	80	80	80	80	80	80	80	80	80	80
1.8	Q	58	69	81	93	104	116	127	138	150	160	171	182	194	204	214	226	233
	V	5.3	5.4	5.4	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.6	5.6	5.6	5.6	5.6	5.6
	S	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	80	82	83	84	84	84	84	84	84	84	84	84	84	84	84	84	84
1.9	Q	64	76	88	102	114	127	140	152	164	175	188	201	213	225	235	248	260
	V	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
	S	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	84	85	86	87	88	88	88	88	88	88	88	88	88	88	88	88	88
2.0	Q	71	83	97	111	125	138	153	164	178	193	204	218	232	245	256	269	283
	V	5.6	5.7	5.7	5.7	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.9	5.9	5.9	5.9	5.9
	S	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	88	90	91	91	91	91	92	92	92	92	92	92	92	92	92	92	92
2.1	Q	77	91	107	122	135	149	162	177	192	207	220	234	250	267	276	291	305
	V	5.7	5.8	5.9	5.9	5.9	5.9	5.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	S	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	92	93	95	95	95	95	95	95	95	96	96	96	96	96	96	96	96
2.2	Q	84	100	116	131	146	163	177	194	210	224	238	253	269	288	301	314	330
	V	5.9	5.9	6.0	6.0	6.0	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.2	6.2	6.2	6.2
	S	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	96	98	99	99	99	99	99	100	100	100	100	100	100	100	100	100	100
2.3	Q	90	108	124	140	158	175	193	208	226	243	258	275	292	306	323	341	354
	V	6.0	6.1	6.1	6.1	6.2	6.2	6.2	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	S	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
	X	100	102	102	103	103	103	104	104	104	105	105	105	105	105	105	105	105
2.4	Q	99	116	136	152	170	189	206	224	241	260	275	294	312	327	346	364	378
	V	6.1	6.2	6.2	6.3	6.3	6.3	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
	S	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
	X	105	105	106	107	107	108	108	108	108	109	109	109	109	109	109	109	109

Source: USDA-SCS

EXCAVATED EARTH SPILLWAY



Source: USDA-SCS

Plate 3.14-9

IX. Re-estimate the elevation of the design high water and the top of the dam based upon the design of the principal spillway and the emergency spillway.

X. Anti-Vortex Device and Trash Rack

A. This design procedure for the anti-vortex device and trash rack refers only to riser pipes of corrugated metal. There are numerous ways to provide protection for concrete pipe; these include various hoods and grates and rebar configurations which should be a part of project-specific design and will frequently be a part of a permanent structure.

B. Refer to Plate 3.14-10 and Table 3.14-D. Choose cylinder size, support bars, and top requirements from Table 3.14-D based on the diameter of the riser pipe.

XI. Anti-Seep Collars

A. Anti-seep collars must be used under the conditions specified in the Design Criteria.

B. Anti-seep collars are used to increase the seepage length along the barrel by 10%.

C. Determine the length of the barrel within the saturated zone. This may be done graphically as in Plate 3.14-11 or by solving the following equation:

$$Ls = Y(Z + 4)\left(1 + \frac{S}{0.25 - S}\right)$$

where:

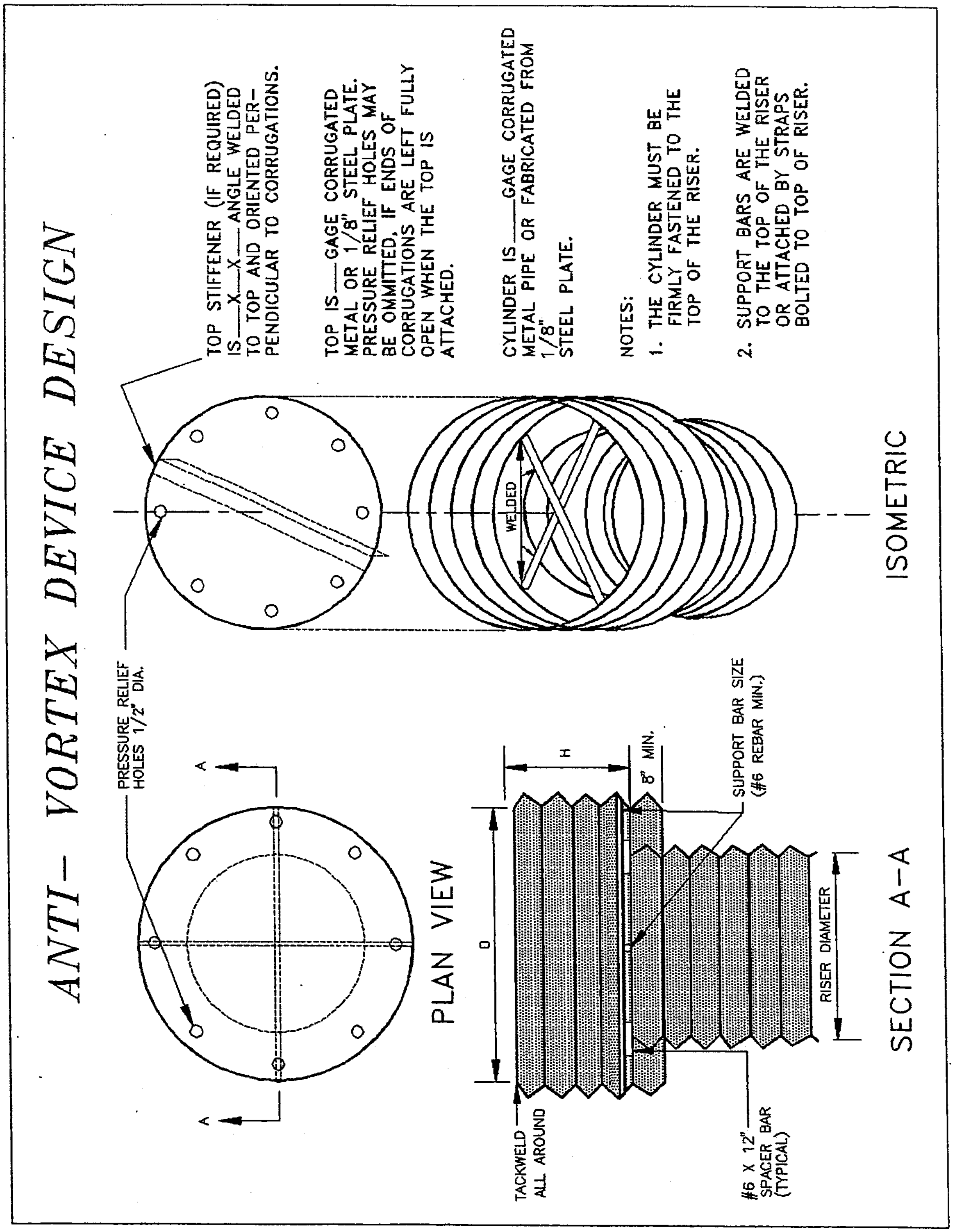
Ls = length of barrel in the saturated zone, feet

Y = the depth of water at the principal spillway crest, feet

Z = slope of the upstream face of embankment in Z feet horizontal to one vertical

S = slope of the barrel in feet per foot

D. Enter Plate 3.14-12 with Ls. Move horizontally right until one of the lines is intersected. Move vertically until the correct line for barrel diameter is intersected. Move horizontally right to read P, the size of the anti-seep collar.



Source: USDA-SCS

Plate 3.14-10

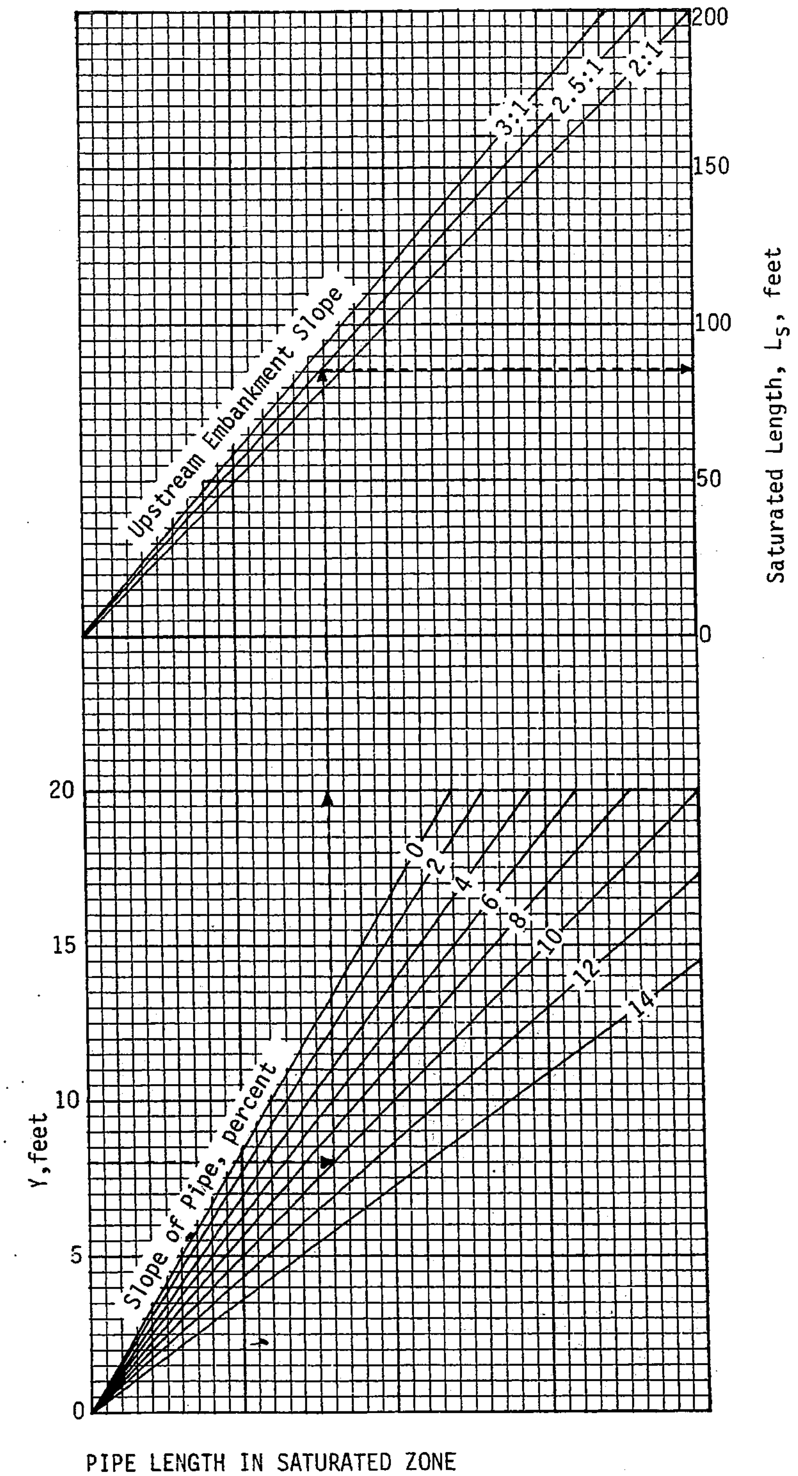
TABLE 3.14-D

CONCENTRIC TRASH RACK AND ANTI-VORTEX DEVICE DESIGN TABLE

Riser Diam., in.	Cylinder		Height, inches	Minimum Size Support Bar	Minimum Top	
	Diameter, inches	Thickness, gage			Thickness	Stiffener
12	18	16	6	#6 Rebar or 1½ x 1½ x 3/16 angle	16 ga. (F&C)	-
15	21	16	7	" "	" "	-
18	27	16	8	" "	" "	-
21	30	16	11	" "	16 ga.(C), 14 ga.(F)	-
24	36	16	13	" "	" "	-
27	42	16	15	" "	" "	-
36	54	14	17	#8 Rebar	14 ga.(C), 12 ga.(F)	-
42	60	16	19	" "	" "	-
48	72	16	21	1¼" pipe or 1¼ x 1¼ x ¼ angle	14 ga.(C), 10 ga.(F)	-
54	78	16	25	" "	" "	-
60	90	14	29	1½" pipe or 1½ x 1½ x ¼ angle	12 ga.(C), 8 ga.(F)	-
66	96	14	33	2" pipe or 2 x 2 x 3/16 angle	12 ga.(C), 8 ga.(F) w/stiffener	2 x 2 x ¼ angle
72	102	14	36	" "	" "	2½ x 2½ x ¼ angle
78	114	14	39	2½" pipe or 2 x 2 x ¼ angle	" "	" "
84	120	12	42	2½" pipe or 2½ x 2½ x ¼ angle	" "	2½ x 2½ x 5/16 angle

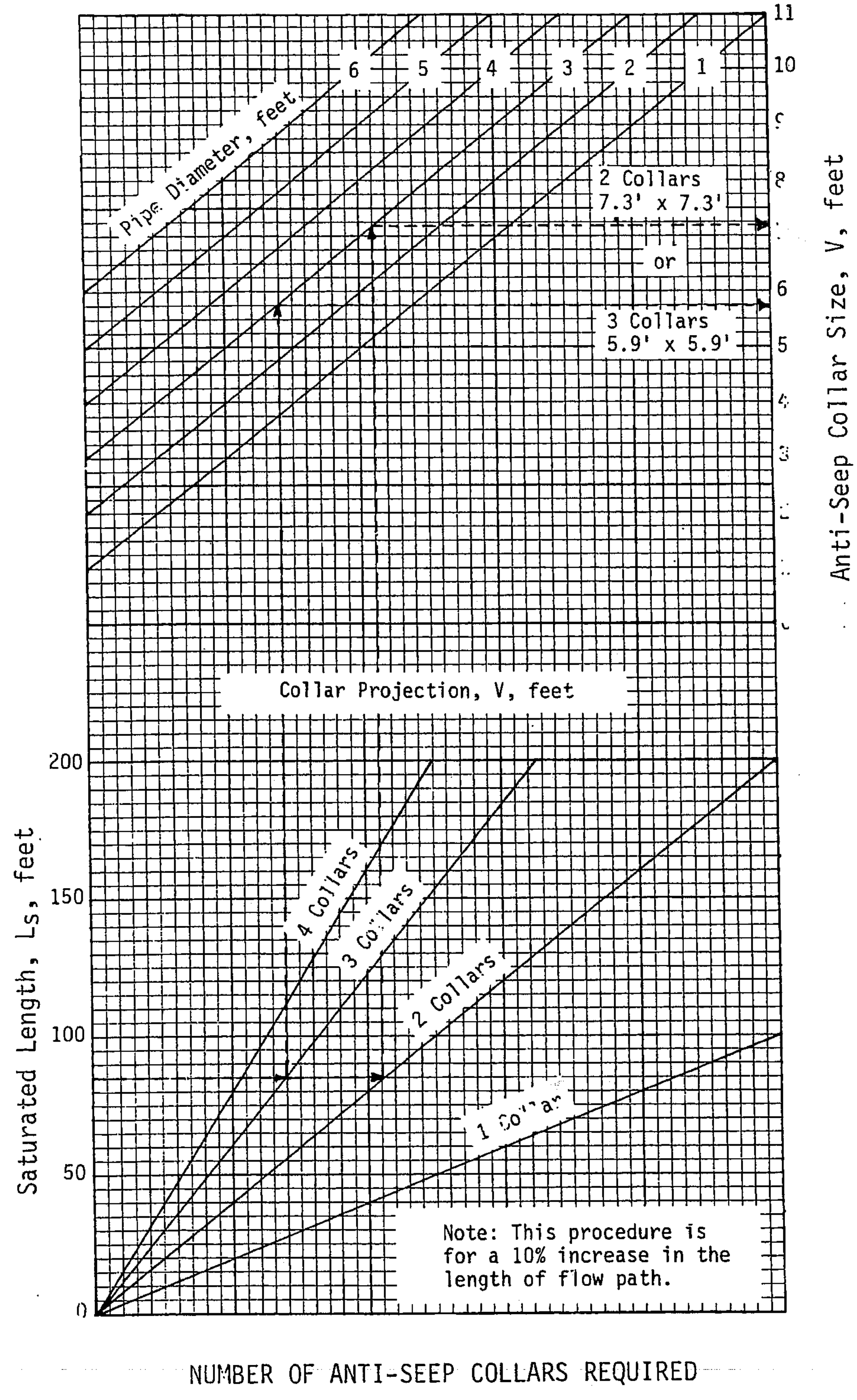
$Note_1$: The criterion for sizing the cylinder is that the area between the inside of the cylinder and the outside of the riser is equal to or greater than the area inside the riser. Therefore, the above table is invalid for use with concrete pipe risers.
$Note_2$: Corrugation for 12"-36" pipe measures 2⅔" x ½"; for 42" -84" the corrugation measures 5" x 1" or 8" x 1".
$Note_3$: C = corrugated; F = flat.

Source: Adapted from USDA-SCS and Carl M. Henshaw Drainage Products Information.



Source: USDA-SCS

Plate 3.14-11



Source: USDA-SCS

Plate 3.14-12

E. If more than one collar is used, the spacing between collars should be 14 times the projection of the collar above the barrel.

F. Collars should not be located closer than 2 feet to a pipe joint.

G. See Plate 3.14-13 for details of the anti-seep collar.

XII. Anchoring the Principal Spillway

A. The principal spillway must be firmly anchored to prevent its floating.

B. If the riser is over 10 feet high, the forces acting on the spillway must be calculated. A method of anchoring the spillway which provides a safety factor of 1.25 must be used (downward forces = 1.25 x upward forces).

C. If the riser is 10 feet or less in height, choose one of the two methods in Plate 3.14-14 to anchor the principal spillway.

XIII. Dewatering

A. Refer to Plate 3.14-15 for details and orientation.

B. <u>Calculation of the diameter of the dewatering orifice</u>:

Use a modified version of the discharge equation for a vertical orifice and a basic equation for the area of a circular orifice.

Naming the variables:

A = flow area of orifice, in square feet

d = diameter of circular orifice, in feet

h = average driving head (maximum possible head measured from radius of orifice to crest of principal spillway <u>divided by</u> 2), in feet

Q = volumetric flowrate through orifice needed to achieve approximate 6-hour drawdown, cubic feet per second

S = total storage available in dry storage area, cubic feet

Q = S / 21,600 seconds

Use S for basin and find Q. Then substitute in calculated Q and find A:

$$A = \frac{Q}{\left(64.32 \;x\; \mathrm{h}\right)^{\frac{1}{2}} (0.6)}$$

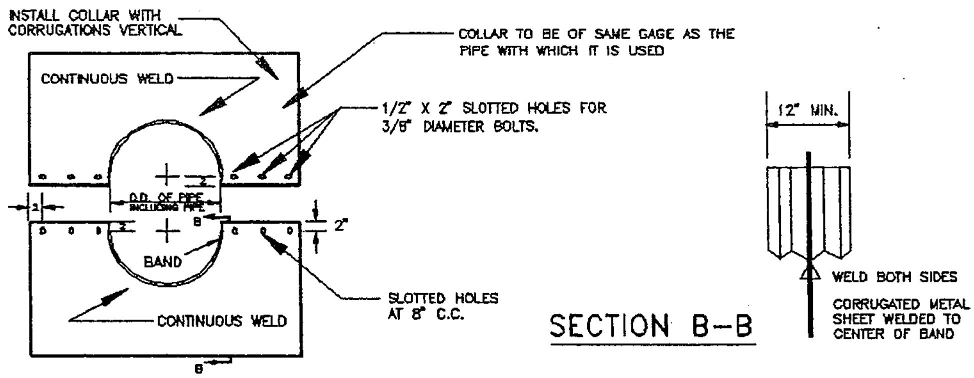
Then, substitute in calculated A and find d:

$$d* = 2 \;x \left(\frac{A}{3.14}\right)^{\frac{1}{2}}$$

* Diameter of dewatering orifice should never be less than 3 inches in order to help prevent clogging by soil or debris.

Note: Flexible tubing used should be at least 2 inches larger in diameter than the calculated orifice to promote improved flow characteristics.

DETAILS OF CORRUGATED METAL ANTI-SEEP COLLAR



SECTION B–B

ELEVATION OF UNASSEMBLED COLLAR

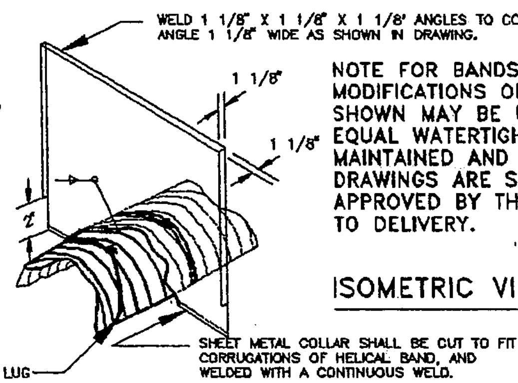
NOTES FOR COLLARS:

1. ALL MATERIALS TO BE IN ACCORDANCE WITH CONSTRUCTION AND CONSTRUCTION MATERIAL SPECIFICATIONS.
2. WHEN SPECIFIED ON THE PLANS, COATING OF COLLARS SHALL BE IN ACCORDANCE WITH CONSTRUCTION AND CONSTRUCTION MATERIAL SPECIFICATIONS.
3. UNASSEMBLED COLLARS SHALL BE MARKED BY PAINTING OR TAGGING TO IDENTIFY MATCHING PAIRS.
4. THE LAP BETWEEN THE TWO HALF SECTIONS AND BETWEEN THE PIPE AND CONNECTING BAND SHALL BE CAULKED WITH ASPHALT MASTIC AT TIME OF INSTALLATION.
5. EACH COLLAR SHALL BE FURNISHED WITH TWO 1/2" DIAMETER RODS WITH STANDARD TANK LUGS FOR CONNECTING COLLARS TO PIPE.

DETAIL OF HELICAL PIPE ANTI-SEEP COLLAR

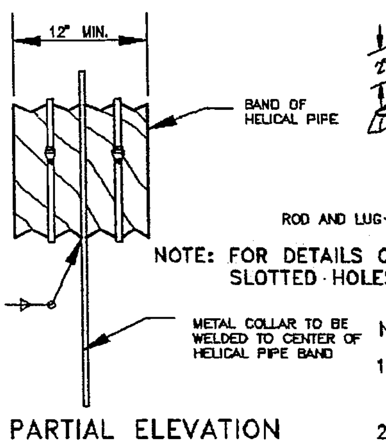
SIZE AND SPACING OF SLOTTED OPENINGS SHALL BE THE SAME AS SHOWN FOR CM COLLAR.

USE RODS AND LUGS TO CLAMP BANDS SECURELY TO PIPE.



NOTE FOR BANDS AND COLLARS: MODIFICATIONS OF THE DETAILS SHOWN MAY BE USED PROVIDING EQUAL WATERTIGHTNESS IS MAINTAINED AND DETAILED DRAWINGS ARE SUBMITTED AND APPROVED BY THE ENGINEER PRIOR TO DELIVERY.

ISOMETRIC VIEW



NOTE: FOR DETAILS OF FABRICATION DIMENSIONS, MINIMUM GAGES, SLOTTED HOLES, AND NOTES, SEE DETAIL ABOVE.

NOTE: TWO OTHER TYPES OF ANTI-SEEP COLLARS ARE:

1. CORRUGATED METAL, SIMILAR TO UPPER, EXCEPT SHOP WELDED TO A SHORT (4FT.) SECTION OF THE PIPE AND CONNECTED WITH CONNECTING BANDS TO THE PIPE.
2. CONCRETE, SIX INCHES THICK FORMED AROUND THE PIPE WITH #3 REBAR SPACED 15" HORIZONTALLY AND VERTICALLY.

PARTIAL ELEVATION

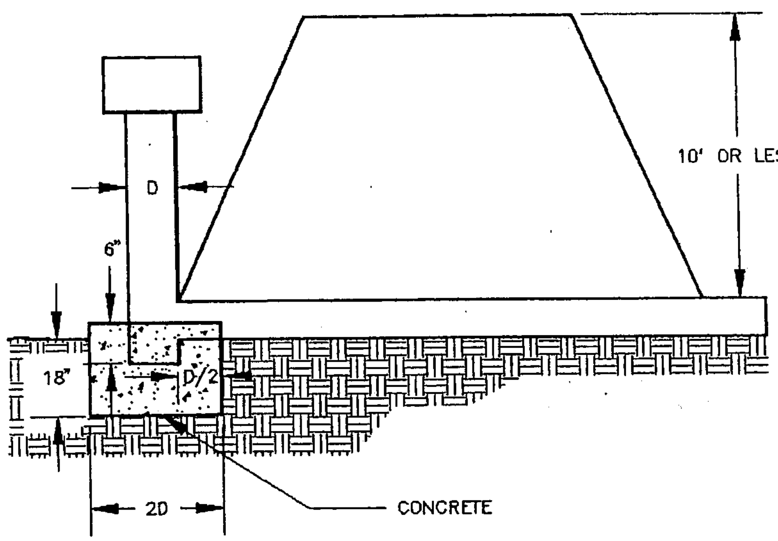
REF: ENGR. FIELD MANUAL

Source: USDA-SCS

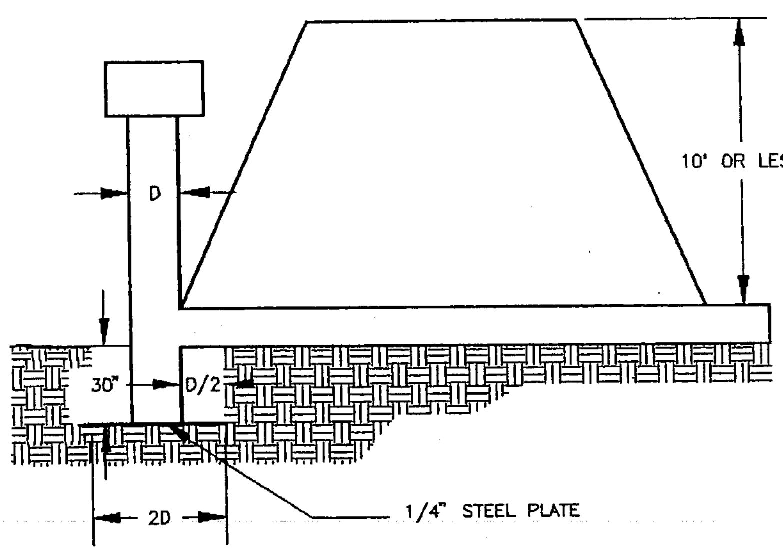
Plate 3.14-13

RISER PIPE BASE CONDITIONS FOR EMBANKMENTS LESS THAN 10' HIGH

CONCRETE BASE FOR EMBANKMENT 10' OR LESS IN HEIGHT



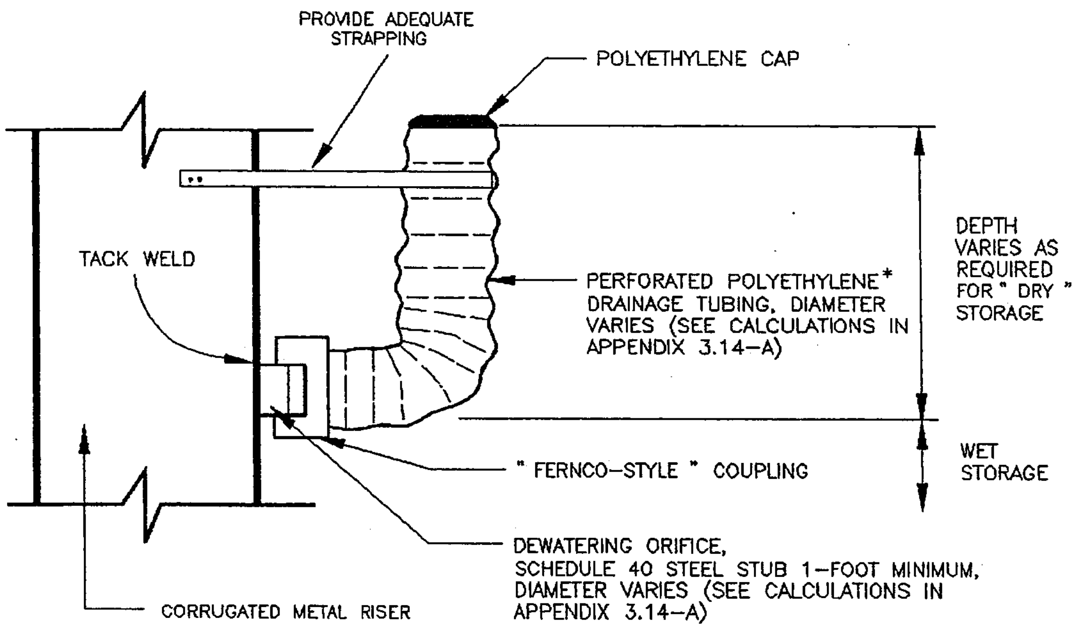
STEEL BASE FOR EMBANKMENT 10' OR LESS IN HEIGHT



Source: Va. DSWC

Plate 3.14-14

RECOMMENDED DEWATERING SYSTEM FOR SEDIMENT BASINS



NOTE: WITH CONCRETE RISER, USE PVC SCHEDULE 40 STUB FOR DEWATERING ORIFICE

*DRAINAGE TUBING SHALL COMPLY WITH ASTM F667 AND AASHTO M294

Source: Va. DSWC

Plate 3.14-15

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET

(with or without an emergency spillway)

Project ____

Basin # ________________ Location __________________________

Total area draining to basin: _______ acres.

Basin Volume Design

Wet Storage:

1. Minimum required volume = 67 cu. yds. x Total Drainage Area (acres).

   67 cu. yds. x ______ acres = ______ cu. yds.

2. Available basin volume = _______ cu. yds. at elevation _______. (From storage - elevation curve)

3. Excavate ______ cu. yds. to obtain required volume*.

   * Elevation corresponding to required volume = invert of the dewatering orifice.

4. Available volume before cleanout required.

   33 cu. yds. x _____ acres = _____ cu. yds.

5. Elevation corresponding to cleanout level = _________.

   (From Storage - Elevation Curve)

6. Distance from invert of the dewatering orifice to cleanout level = _____ ft. (Min. = 1.0 ft.)

Dry Storage:

7. Minimum required volume = 67 cu. yds. x Total Drainage Area (acres).

   67 cu. yds. x ______ acres = ______ cu. yds.

8. Total available basin volume at crest of riser* = ________ cu. yds. at elevation _______. (From Storage - Elevation Curve)

   * Minimum = 134 cu. yds./acre of total drainage area.

9. Diameter of dewatering orifice = _______________in.

10. Diameter of flexible tubing = ___________in. (diameter of dewatering orifice plus 2 inches).

Preliminary Design Elevations

11. Crest of Riser = ____________

    Top of Dam = ____________

    Design High Water = ____________

    Upstream Toe of Dam = ____________

Basin Shape

12. $\frac{\text{Length of Flow}}{\text{Effective Width}} \quad \frac{L}{We} =$ ________

    If > 2, baffles are not required ______________

    If < 2, baffles are required ______________

Runoff

13. Q_2 = ________ cfs (From Chapter 5)

14. Q_{25} = ________ cfs (From Chapter 5)

Principal Spillway Design

15. With emergency spillway, required spillway capacity $Q_p = Q_2 =$ ______ cfs. (riser and barrel)

    Without emergency spillway, required spillway capacity $Q_p = Q_{25} =$ _____ cfs. (riser and barrel)

16. With emergency spillway:

    Assumed available head (h) = ____________ ft. (Using Q_2)

    h = Crest of Emergency Spillway Elevation - Crest of Riser Elevation

    Without emergency spillway:

    Assumed available head (h) = ____________ ft. (Using Q_{25})

    h = Design High Water Elevation - Crest of Riser Elevation

17. Riser diameter (D_r) = _______ in. Actual head (h) = _____ ft.

    (From Plate 3.14-8.)

    Note: Avoid orifice flow conditions.

18. Barrel length (l) = ________ ft.

    Head (H) on barrel through embankment = ________ft.

    (From Plate 3.14-7).

19. Barrel diameter = __________ in.

    (From Plate 3.14-B [concrete pipe] or Plate 3.14-A [corrugated pipe]).

20. Trash rack and anti-vortex device

    Diameter = ________ inches.

    Height = _______ inches.

    (From Table 3.14-D).

Emergency Spillway Design

21. Required spillway capacity $Q_e = Q_{25} - Q_p$ = ____________cfs.

22. Bottom width (b) = ________ ft.; the slope of the exit channel (s) = ________ ft./foot; and the minimum length of the exit channel (x) = ________ ft.
    (From Table 3.14-C).

Anti-Seep Collar Design

23. Depth of water at principal spillway crest (Y) = ____ ft.

Slope of upstream face of embankment (Z) = _______:1.

Slope of principal spillway barrel (S_b) = _________%

Length of barrel in saturated zone (L_s) = ________ ft.

24. Number of collars required = ______ dimensions = _________

(from Plate 3.14-12).

Final Design Elevations

25. Top of Dam = ________

Design High Water = ________

Emergency Spillway Crest = ________

Principal Spillway Crest = ________

Dewatering Orifice Invert = ________

Cleanout Elevation = ________

Elevation of Upstream Toe of Dam or Excavated Bottom of "Wet Storage Area" (if excavation was performed) = ________

STD & SPEC 3.15

TEMPORARY SLOPE DRAIN

TSD

Definition

A flexible tubing or conduit extending from the top to the bottom of a cut or fill slope.

Purpose

To temporarily conduct concentrated stormwater runoff safely down the face of a cut or fill slope without causing erosion on or below the slope.

Conditions Where Practice Applies

On cut or fill slopes where there is a potential for upslope flows to move over the face of the slope causing erosion and preventing adequate stabilization.

Planning Considerations

There is often a significant lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. This situation also occurs on slope construction which is temporarily delayed before final grade is reached. Temporary slope drains can provide valuable protection of exposed slopes until permanent drainage structures can be installed or vegetation can be established.

Temporary slope drains can be used in conjunction with diversion dikes to convey runoff from the entire drainage area above a slope to the base of the slope without erosion. It is very important that these temporary structures be installed properly, since their failure will often result in severe gully erosion on the site and sedimentation below the slope. The entrance section must be securely entrenched, all connections must be watertight, and the conduit must be staked securely.

Design Criteria

Drainage Area

The maximum allowable drainage area per slope drain is 5 acres.

Flexible Conduit

The slope drain shall consist of heavy-duty, flexible material designed for this purpose. The diameter of the slope drain shall be equal over its entire length. Reinforced hold-down grommets shall be spaced at 10-foot (or less) intervals. Slope drains shall be sized as listed in Table 3.15-A.

Entrance Sections

The entrance to the slope drain shall consist of a standard VDOT flared end-section for metal pipe culverts (see Plates 3.15-2 and 3.15-3) with appropriate inlet protection as set forth in CULVERT INLET PROTECTION, Std. & Spec. 3.08. If ponding will cause a problem at the entrance and make such protection impractical, appropriate sediment-removing measures shall be taken at the outlet of the pipe. Extension collars shall consist of 12-inch long corrugated metal pipe. Watertight fittings shall be provided (see Plate 3.15-1).

Note: End-sections made of heavy-duty, flexible material may be utilized if determined by the Plan-Approving Authority to provide a stable inlet or outlet section.

TABLE 3.15-A

SIZE OF SLOPE DRAIN

Maximum Drainage Area (acres)	Pipe Diameter (inches)
0.5	12
1.5	18
2.5	21
3.5	24
5.0	30

Source: Va. DSWC

Dike Design

An earthen dike shall be used to direct stormwater runoff into the temporary slope drain and shall be constructed as set forth in DIVERSION, Std. & Spec. 3.12. See Plate 3.15-1 for placement of dike in relation to the slope drain.

The height of the dike at the centerline of the inlet shall be equal to the diameter of the pipe plus 6 inches. Where the dike height is greater than 18 inches at the inlet, it shall be sloped at the rate of 3:1 or flatter to connect with the remainder of the dike (see Plate 3.15-1).

Outlet Protection

The outlet of the slope drain must be protected from erosion as set forth in OUTLET PROTECTION, Std. & Spec. 3.18.

Construction Specifications

1. The measure shall be placed on undisturbed soil or well-compacted fill.

2. The entrance section shall slope toward the slope drain at the minimum rate of 1/2-inch per foot.

3. The soil around and under the entrance section shall be hand-tamped in 8-inch lifts to the top of the dike to prevent piping failure around the inlet.

4. The slope drain shall be securely staked to the slope at the grommets provided.

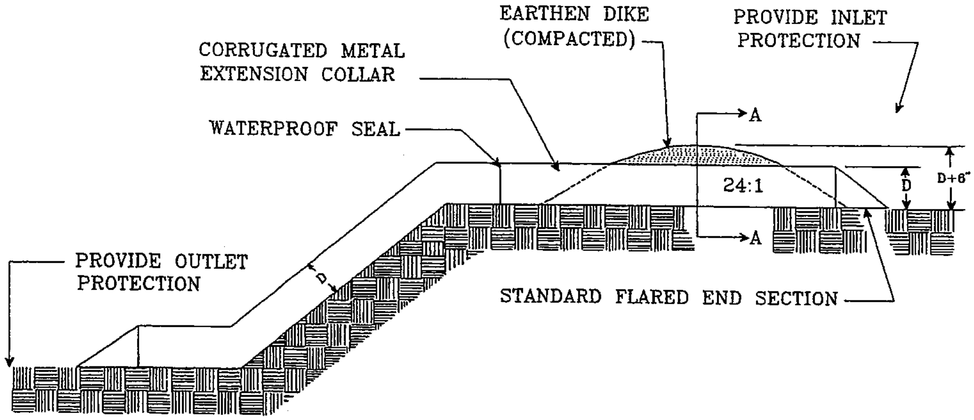
5. The slope drain sections shall be securely fastened together and have watertight fittings.

6. Install CULVERT INLET PROTECTION and OUTLET PROTECTION as per Std. & Spec.'s 3.08 and 3.18, respectively.

Maintenance

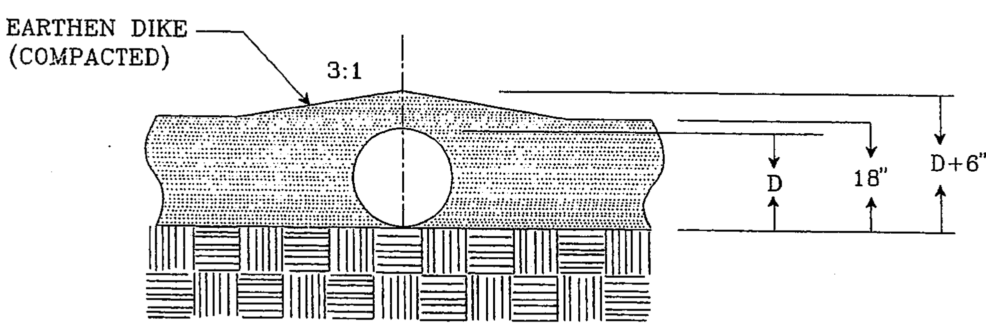
The slope drain structure shall be inspected weekly and after every storm, and repairs made if necessary. The contractor should avoid the placement of any material on and prevent construction traffic across the slope drain.

TEMPORARY SLOPE DRAIN



SECTION VIEW

NOTE: SEDIMENT MAY BE CONTROLLED AT OUTLET IF UPLAND PONDING WILL CREATE PROBLEMS

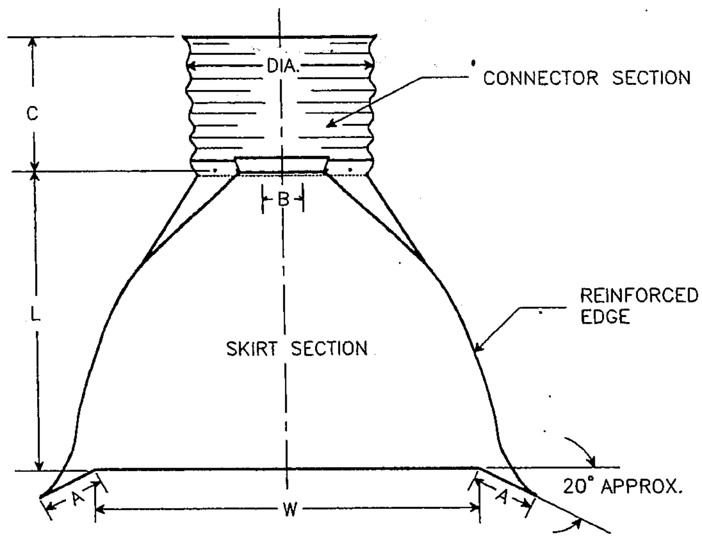


SECTION A – A

Source: Va. DSWC

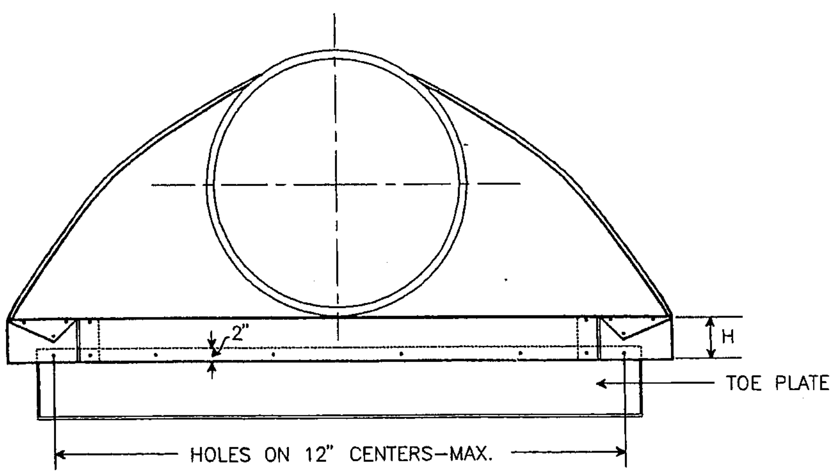
Plate 3.15-1

FLARED END-SECTION



PLAN

WHERE FLARED END-SECTIONS ARE TO BE USED WITH BITUMINOUS COATED AND PAVED METAL PIPE, THEY ARE TO BE GALVANIZED ONLY.

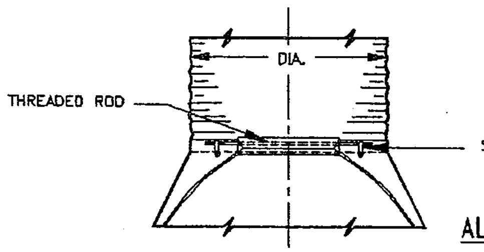


ELEVATION

Source: VDOT Road and Bridge Standards

Plate 3.15-2

FLARED END-SECTION
(CONTINUED)



ALTERNATE CONNECTION

TOE PLATE, WHERE NEEDED, TO BE PUNCHED TO MATCH IN SKIRT LIP. 3/8" GALV. BOLTS TO BE FURNISHED. LENGTH OF TOE PLATE IS W + 10" FOR 12" TO 30" DIA. PIPE AND W + 22" FOR 36" TO 60" DIA. PIPE.

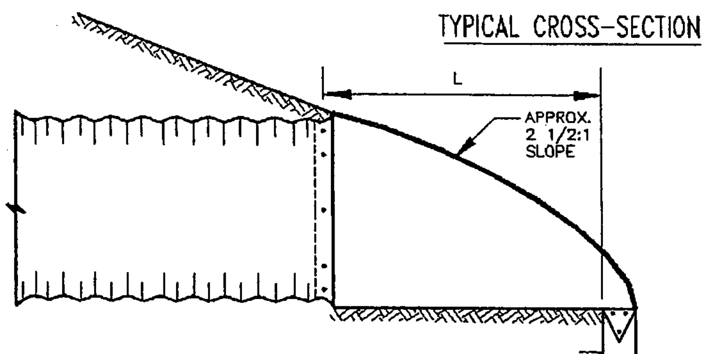
SKIRT SECTION FOR 12" TO 30" DIA. PIPE TO BE MADE IN ONE PIECE.

SKIRT SECTION FOR 36" TO 54" DIA. PIPE MAY BE MADE FROM TWO SHEETS JOINED BY RIVETING OR BOLTING ON CENTER LINE. 60" MAY BE CONSTRUCTED IN 3 PIECES.

CONNECTOR SECTION, CORNER PLATE AND TOE PLATE TO BE SAME SHEET THICKNESS AS SKIRT.

END-SECTIONS AND FITTINGS ARE TO BE GALVANIZED STEEL OR ALUMINUM ALLOY FOR USE WITH LIKE PIPE.

TYPICAL CROSS-SECTION

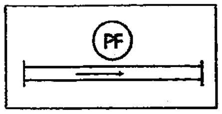


PIPE DIA.	SHEET THICKNESS		DIMENSIONS					
	STEEL	ALUMINUM	A 1" TOL.	B MAX.	H 1" TOL.	L 1 1/2" TOL.	W 2" TOL.	C
12"	.064"	.060"	6"	6"	6"	21"	24"	24"
15"	.064"	.060"	7"	8"	6"	26"	30"	24"
18"	.064"	.060"	8"	10"	6"	31"	36"	24"
21"	.064"	.060"	10"	12"	6"	36"	42"	24"
24"	.064"	.060"	10"	13"	6"	41"	48"	24"
27"/30"	.064"	.075"	12"	16"	8"	51"	60"	24"
36"	.064"	.075"	14"	19"	9"	60"	72"	36"
42"	.064"	.105"	16"	22"	11"	69"	84"	36"
48"	.064"	.105"	18"	27"	12"	78"	90"	24"
54"	.064"/.079"	.105"	18"	30"	12"	84"	102"	36"
60"	.064"/.109"	.105"/.135"	18"	33"	12"	87"	114"	36"

Source: VDOT Road and Bridge Standards

Plate 3.15-3

STD & SPEC 3.16



PAVED FLUME

PF

Definition

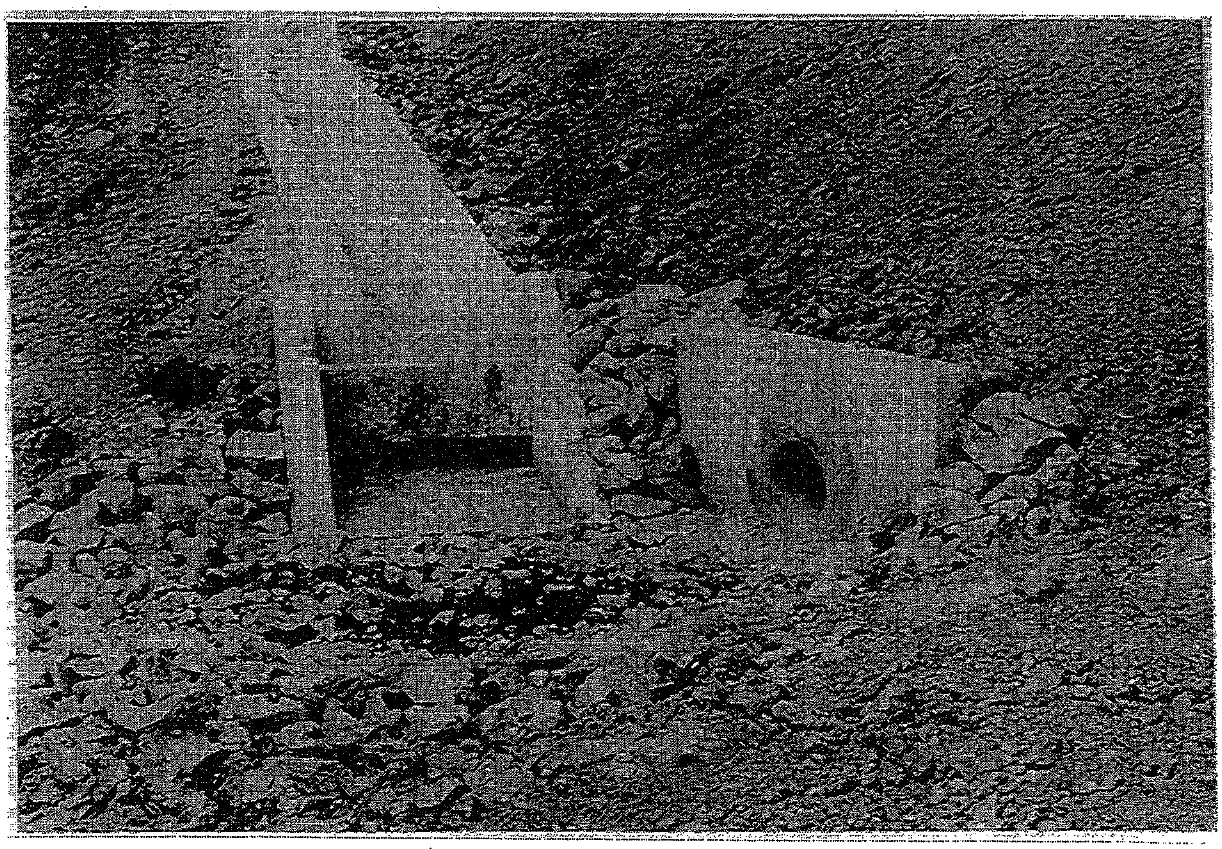
A permanent paved channel constructed on a slope.

Purpose

To conduct stormwater runoff safely down the face of a slope without causing erosion problems on or below the slope.

Conditions Where Practice Applies

Wherever concentrated stormwater runoff must be conveyed from the top to the bottom of cut or fill slopes on a permanent basis and a riprap-lined channel is not capable of conveying the runoff without erosion.



Planning Considerations

Paved flumes are used routinely on highway cuts and fills to convey concentrated stormwater runoff from the top to the bottom of the slope without erosion. VDOT has developed standards and specifications for these structures which apply to all secondary and primary highway construction projects.

Fortunately, these structures have equal applicability to cut-and-fill slopes for construction projects other than highways. Therefore, for the sake of continuity and to prevent possible conflicts, the standards and specifications for paved flumes contained in this practice correspond to those of VDOT.

Consideration must be given to protecting structures against buoyancy failures. The potential for buoyancy failures due to hydrostatic uplift forces exists in channels constructed in periodically saturated areas (basically all channels will experience saturation of the subgrade by virtue of the function of the channel) and especially if a submerged outfall condition exists.

Paved flumes should be utilized and constructed carefully. Field experience has shown a significant amount of post-construction problems with these controls. If the base contains some unsuitable material or is too "soft," the flume will subject to undermining and fracturing. There are also many cases where the outlet velocities and flow rates of stormwater which travels in a paved flume are so great that erosion and flooding at the end of the structure are inevitable, no matter what type of treatment is installed at the outlet. In these cases, strong consideration should be given to a riprapped channel or to a system of inlets, manholes, and pipe to safely convey the stormwater to the receiving channel or drainage structure.

Design Criteria

VDOT Design

Paved flumes shall be designed and constructed in accordance with criteria established by VDOT for "Paved Flumes." Design criteria and construction specifications contained herein are extracted and summarized from the latest edition of the following VDOT publications:

Road and Bridge Specifications
Road and Bridge Standards
Drainage Manual

Users of this handbook should refer to the above publications for additional information or clarification, if needed.

Capacity

Paved flumes shall be capable of passing the peak flow expected from a 10-year frequency storm.

Cross-Sections

Plate 3.16-1 illustrates a typical trapezoidal cross-section of a VDOT "Standard Paved Flume (PG-4)." Where additional flow capacity is required, larger trapezoidal cross-sections may be designed. The following criteria apply to all trapezoidal flume designs:

1. The maximum slope of the structure shall be 1.5:1 (67%).

2. Curtain Walls shall be provided at the beginning and end of all paved flumes not abutted to another structure. The curtain wall shall be as wide as the flume channel, extend at least 18 inches into the soil below the channel, and have a thickness of 6 inches. Curtain walls shall be reinforced with #4 reinforcing steel bars placed on 6-inch centers.

3. Anchor Lugs shall be spaced at a maximum of 10 feet on center for the length of the flume. Where no curtain wall is required, an anchor lug shall be installed within 2 feet of the end of the flume. Anchor lugs are to be as wide as the bottom of the flume channel, extend at least 1 foot into the soil below the channel, and have a thickness of 6 inches. Anchor lugs shall be reinforced with #4 reinforcing steel bars placed on 4-inch centers.

4. The flume channel shall have at least a 4-inch thickness of class A-3 concrete with welded wire fabric (6 X 6 - W2.1 x W2.1) in the center for reinforcement.

5. Expansion Joints shall be provided approximately every 90 feet. Eighteen-inch dowels of #4 reinforcing steel placed on 5-inch centers shall be located at all required joints.

Outlet

Outlets of paved flumes should be protected from erosion. The use of an energy dissipator with OUTLET PROTECTION (Std. & Spec. 3.18) is recommended in order to temporarily reduce the existing velocity of the flow, thus preventing undermining of the structure and providing a stable transition zone between the flume and the receiving channel or drainage structure at the base of the slope. Plates 3.16-2 and 3.16-3 show a "Standard Energy Dissipator (EG-1)," which is designed for use in conjunction with the "Standard Paved Flume (PG-4)." OUTLET PROTECTION should still be utilized with the use of an "EG-1" structure to further dissipate flow energy and to provide a smooth transition into the receiving channel. Larger energy dissipator systems may be similarly designed for larger flume cross-sections.

Construction Specifications

1. The subgrade shall be constructed to the required elevations. All soft sections and unsuitable material shall be removed and replaced with suitable material. The subgrade shall be thoroughly compacted and shaped to a smooth, uniform surface. The subgrade shall be moist at the time the concrete is poured.

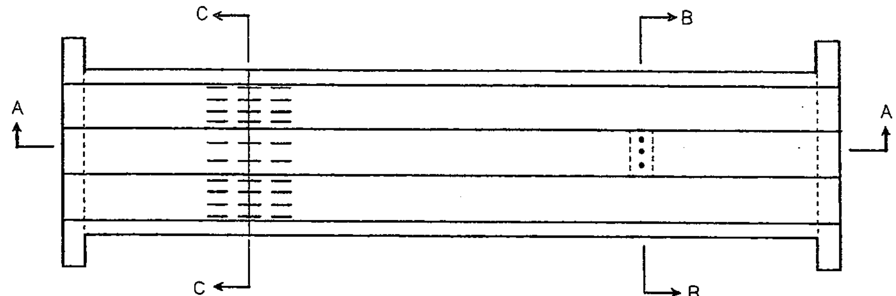
2. Anchor lugs and curtain walls shall be formed to be continuous with the channel lining.

3. Traverse joints for crack control should be provided at approximately 20-foot intervals and when more than 45 minutes elapses between consecutive concrete placements. All sections should be at least 6 feet long. Crack control joints may be formed by using a 1/8-inch thick removable template, by scoring or sawing to a depth of at least 3/4 inch or by an approved "leave-in" type insert.

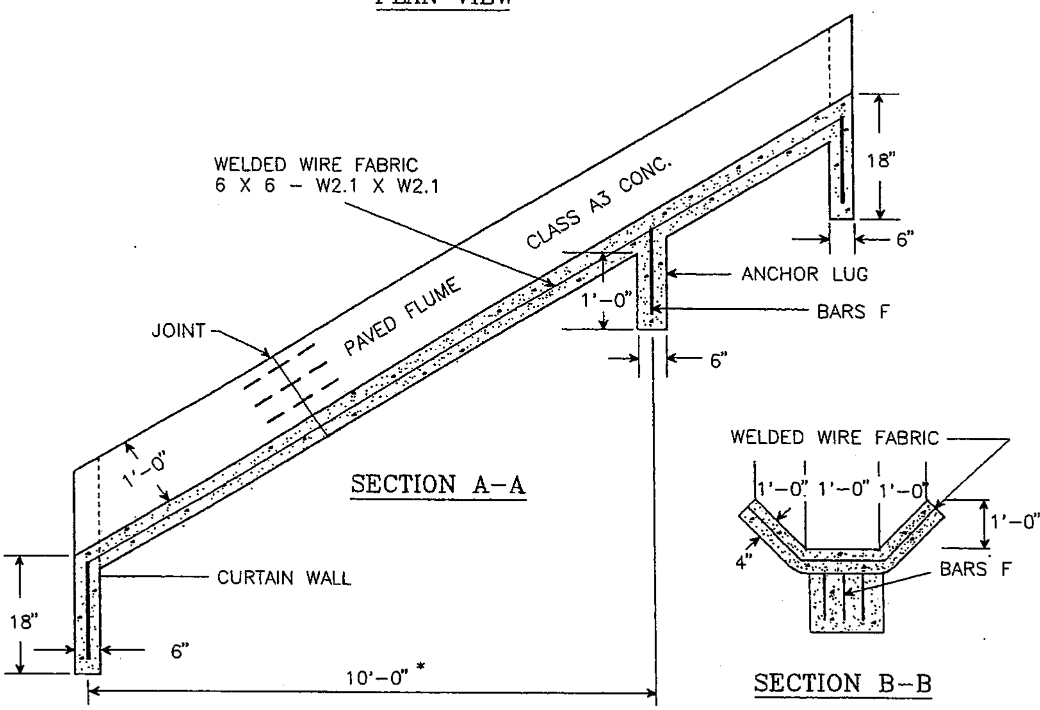
Maintenance

Prior to permanent stabilization of the slope, the structure should be inspected after each rainfall. Damages to the slope, flume or outlet area must be repaired immediately. After the slope is stabilized, the structure should be inspected to ensure continued adequate functioning (see potential problems noted in Planning Considerations).

PAVED FLUME



PLAN VIEW



SECTION A–A

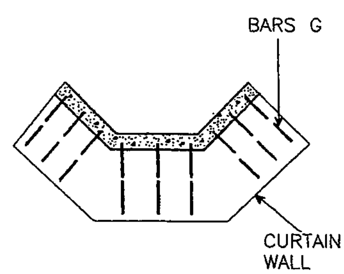
SECTION B–B

* 10'–0" C–C MAXIMUM TYPICAL SPACING BETWEEN ANCHOR LUGS. WHERE CURTAIN WALL IS NOT REQUIRED ANCHOR LUG IS TO BE A MAXIMUM OF 2' FROM END OF CHANNEL.

SCHEDULE OF REINFORCING STEEL

MARK	NO.	LENGTH 2:1	LENGTH 1 1/2:1	SIZE	SPACING C–C	SHAPE
F	3	1'–2"	1'–2"	4	4"	STRAIGHT
G	9	1'–5"	1'–5"	4	6"	STRAIGHT
DOWELS	10	1'–6"	1'–6"	4	5"	STRAIGHT

NO. SHOWN ARE FOR ONE ANCHOR LUG, CURTAIN WALL AND JOINT

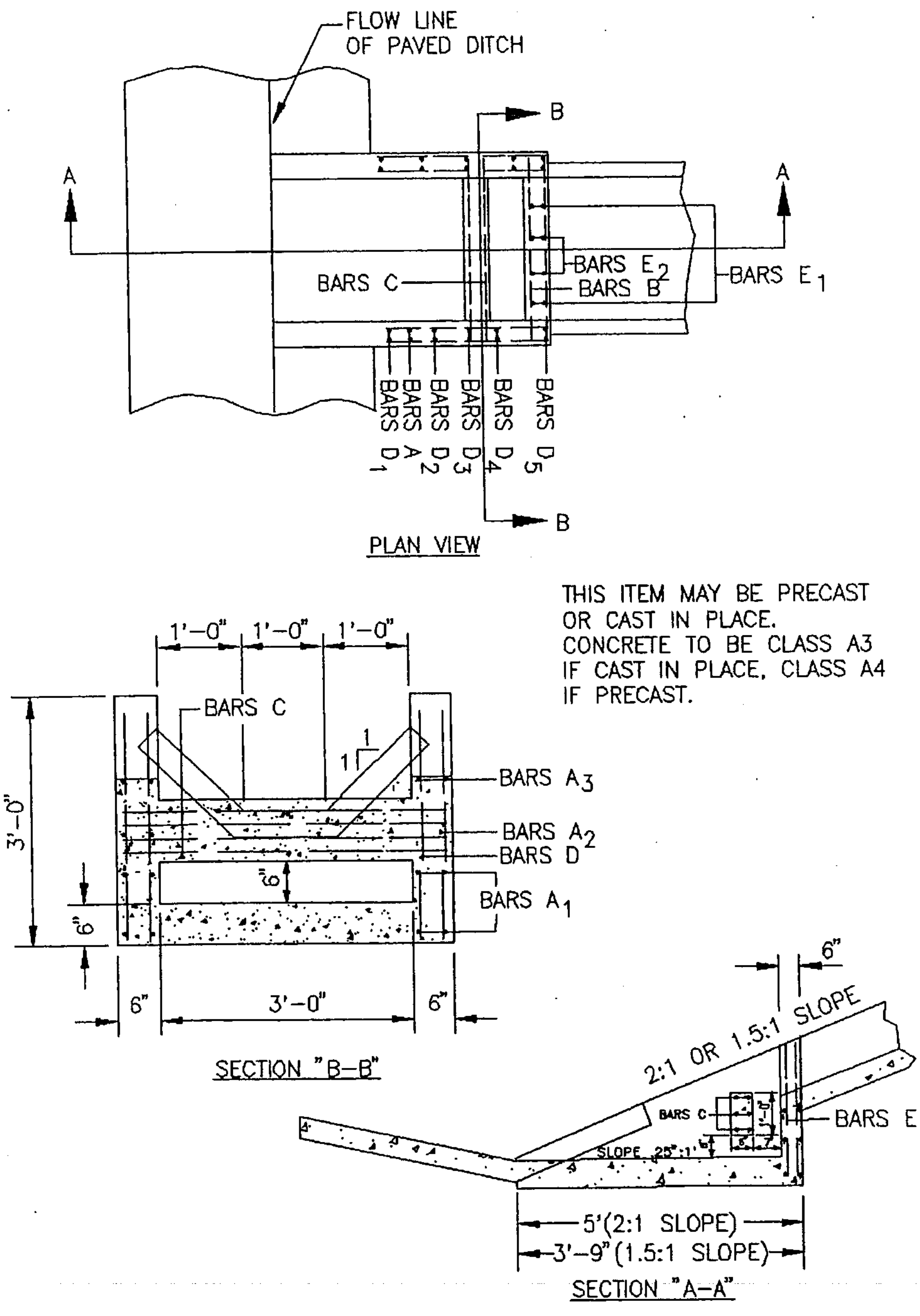


SECTION C–C

Source: VDOT Road and Bridge Specifications

Plate 3.16-1

ENERGY DISSIPATOR

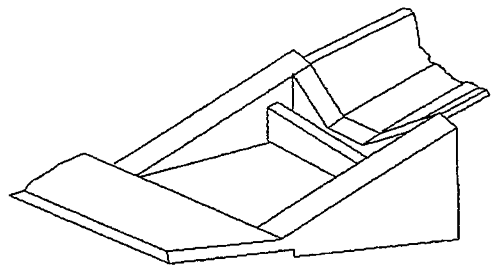


THIS ITEM MAY BE PRECAST OR CAST IN PLACE. CONCRETE TO BE CLASS A3 IF CAST IN PLACE, CLASS A4 IF PRECAST.

Source: VDOT Road and Bridge Specifications

Plate 3.16-2

ENERGY DISSIPATOR
(CONTINUED)



ISOMETRIC

SCHEDULE OF REINFORCING STEEL

MARK	NO.	LENGTH		SIZE	SPACING C–C	SHAPE
		2:1	1.5:1			
A_1	8	2'–10"	2'–10"	3	8"	STRAIGHT
A_2	4	2'–6 1/4"	1'–10"	3	8"	STRAIGHT
A_3	4	1'–0 3/4"	0'–10"	3	8"	STRAIGHT
B	6	3'–9"	3'–9"	3	8"	STRAIGHT
C	8	3'–8"	3'–8"	3	2 1/2"	STRAIGHT
D_1	4	1'–2 1/2"	0'–8"	3	8"	STRAIGHT
D_2	4	1'–6 1/2"	1'–1 1/2"	3	8"	STRAIGHT
D_3	4	1'–10 1/2"	1'–7"	3	8"	STRAIGHT
D_4	4	2'–2 1/2"	2'–0 1/2"	3	8"	STRAIGHT
D_5	4	2'–6 1/2"	2'–6"	3	8"	STRAIGHT
E_1	4	1'–11 1/2"	1'–11 1/2"	3	8"	STRAIGHT
E_2	4	1'–5 1/2"	1'–5 1/2"	3	8"	STRAIGHT

APPROXIMATE QUANTITIES			
		CONCRETE	REINFORCING STEEL
		CU. YDS.	LBS.
ENERGY DISSIPATOR	2:1	0.7479	61.20
	1.5:1	0.5921	57.63

Source: VDOT Road and Bridge Standards

Plate 3.16-3

STD & SPEC 3.17

STORMWATER CONVEYANCE CHANNEL

SCC

Definition

A permanent, designed waterway, shaped, sized, and lined with appropriate vegetation or structural material used to safely convey stormwater runoff within or away from a developing area.

Purpose

To provide for the conveyance of concentrated surface runoff water to a receiving channel or system without damage from erosion.

Conditions Where Practice Applies

Generally applicable to man-made channels, including roadside ditches and intermittent natural channels, that are constructed or are modified to accommodate flows generated by land development. The implementation of this control should come only after a channel adequacy analysis for capacity and velocity has been performed as per methods noted in Chapter 5, Engineering Calculations. The measure should be installed and stabilized prior to the introduction of post-development flows. This practice is not generally applicable to continuous flowing natural streams. Major streams need full design considerations and calculations. Provisions for protecting the banks of such streams are described in VEGETATIVE STREAMBANK STABILIZATION, Std. & Spec. 3.22 and STRUCTURAL STREAMBANK STABILIZATION, Std. & Spec. 3.23.

Planning Considerations

The design of a channel cross-section and lining is based primarily upon the volume and velocity of flow expected in the channel. If conditions are appropriate, grass or riprap channels are preferred over concrete. While concrete channels are efficient and easy to maintain, they remove runoff so quickly that channel erosion and flooding often result downstream. Grass or riprap channels reduce this problem by more closely duplicating a natural system.

Besides the primary design considerations of capacity and velocity, a number of other important factors should be taken into account when selecting a cross-section and lining. These factors include land availability, compatibility with land use and surrounding environment, safety, maintenance requirements, outlet conditions, and soil erodibility factor. If the riprap design is chosen, filter fabric must be used to act as a separator and stabilizer between the stone and the earth.

Cross-section design:

Vee-shaped ditches are generally used where the quantity of water to be handled is relatively small, such as roadside ditches. A grass or sod lining will suffice where velocities in the ditch are low. For steeper slopes where high velocities are encountered, a riprap, concrete or bituminous concrete lining may be appropriate.

Parabolic channels are often used where the quantity of water to be handled is larger and where space is available for a wide, shallow channel with low velocity flow. Riprap should be used where higher velocities are expected and where some dissipation of energy (velocity) is desired. Combinations of grass and riprap are also useful where there is a continuous low flow in the channel.

Trapezoidal channels are often used where the quantity of water to be carried is large and conditions require that it be carried at a relatively high velocity. Trapezoidal ditches are generally lined with concrete or riprap.

Plates 3.17-1 and 3.17-2 illustrate the various types of cross-sections and channel linings.

Outlet design:

Outlet conditions for all channels must be considered. This is particularly important for the transition from a man-made lining, such as concrete and riprap, to a vegetated or non-vegetated lining. Appropriate measures must be taken to dissipate the energy of the flow to prevent scour of the receiving channel. (See OUTLET PROTECTION, Std. & Spec. 3.18).

Capacity

All channels shall be designed in a manner which satisfies MS #19 of the Virginia Erosion and Sediment Control Regulations. If channel modifications are necessary, the capacity of the channel must be sufficient to convey the 10-year frequency design storm (24-hour duration) without overtopping the banks. If pre-development flooding problems exist, the consequences of flooding are severe, or drainage systems which convey larger storms converge with the channel in question, consideration should be given to increasing the capacity beyond the 10-year frequency storm capacity.

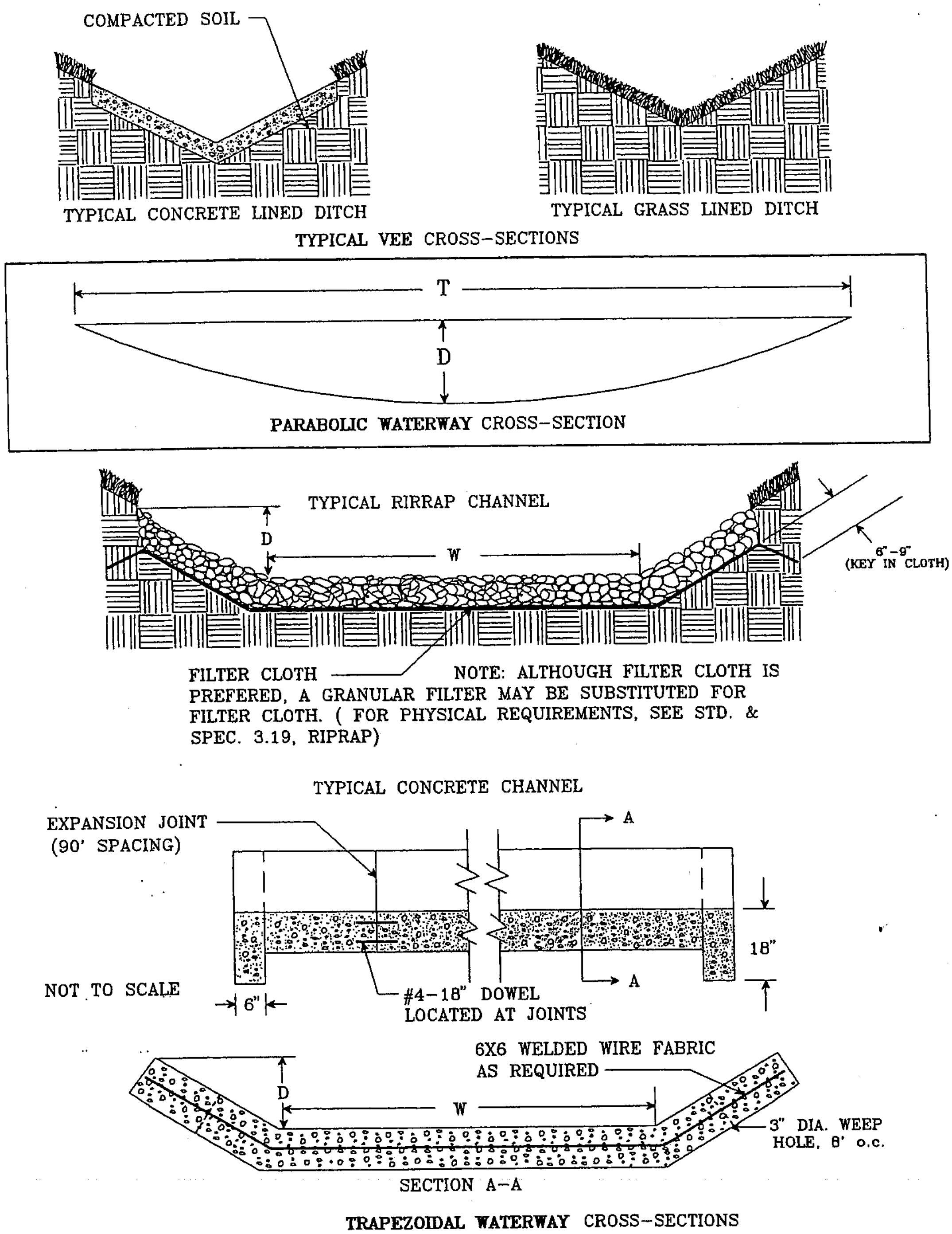
Velocity

Channels should be designed so that the velocity of flow expected from a 2-year frequency storm shall not exceed the permissible velocity for the type of lining used.

While concrete-lined channels can usually be smaller than grass-lined channels, the increased velocity will produce more erosion and flooding downstream. Chapter 5 contains information on engineering calculations for channel design. The VDOT Drainage Manual may be referenced for additional information on channel and culvert design.

Grass-lined channels provide good protection against erosion, while they provide an aesthetic setting for conveyance of runoff. However, the velocities that grass linings can handle are much lower than those which can be withstood by riprap or concrete-lined channels. For grass linings, the type of vegetation chosen shall be appropriate for the site conditions: i.e., drainage tolerance, shade tolerance, maintenance requirements, etc. (See PERMANENT SEEDING, Std. & Spec. 3.32 and SODDING, Std. & Spec. 3.33). Where there will be a base flow in grass-lined channels, a stone center, a subsurface drain, or other suitable means to handle the base flow shall be provided. Plate 3.17-2 shows typical cross-sections for stone center channels. Refer to RIPRAP, Std. & Spec. 3.19 to choose the correct stone size and for filter fabric specifications. Permissible velocities for grass-lined channels are shown in Table 3.17-A.

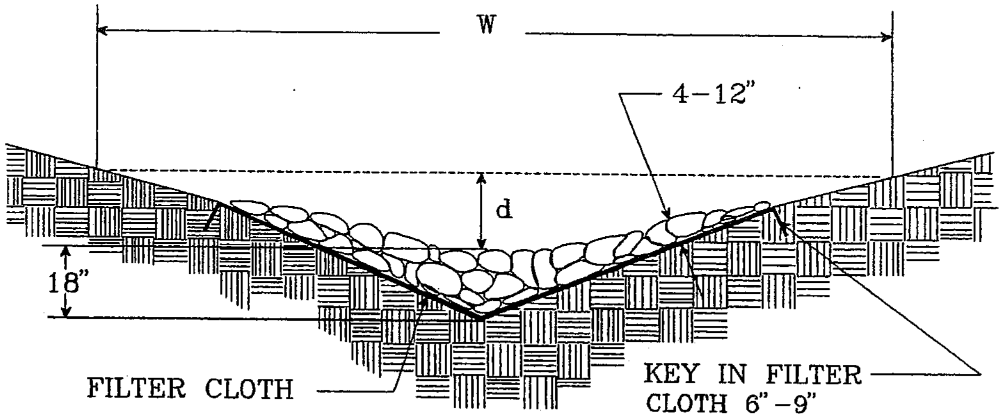
TYPICAL WATERWAY CROSS-SECTIONS



Source: Va. DSWC

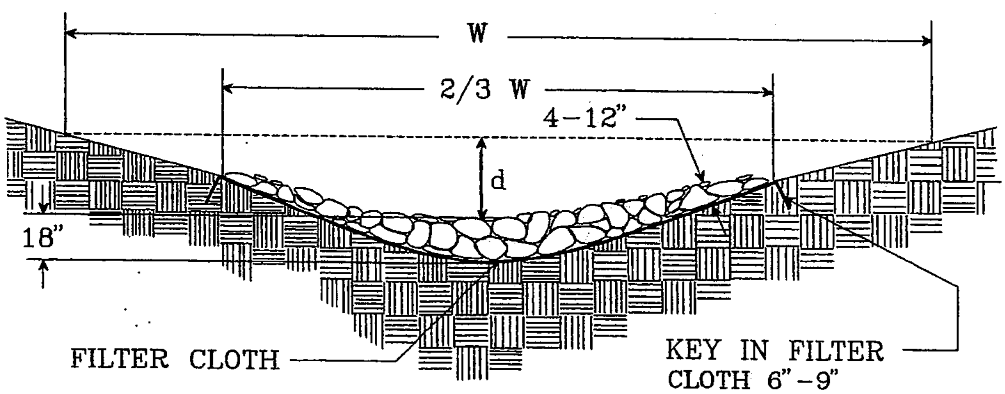
Plate 3.17-1

STONE-LINED WATERWAYS



V-SHAPED WATERWAY WITH STONE CENTER DRAIN

NOTE: A GRANULAR FILTER MAY BE SUBSTITUTED FOR FILTER CLOTH.



PARABOLIC WATERWAY WITH STONE CENTER DRAIN

NOTE: A GRANULAR FILTER MAY BE SUBSTITUTED FOR FILTER CLOTH.

Source: USDA-SCS

Plate 3.17-2

TABLE 3.17-A

PERMISSIBLE VELOCITIES FOR GRASS-LINED CHANNELS

CHANNEL SLOPE	LINING	PERMISSIBLE VELOCITY[a]
0 - 5%	Bermudagrass	6 ft./second
	Reed canarygrass Tall fescue Kentucky bluegrass	5 ft./second
	Grass-legume mixture	4 ft./second
	Red fescue Redtop Sericea lespedeza Annual lespedeza Small grains (temporary)	2.5 ft./second
5 - 10%	Bermudagrass	5 ft./second
	Reed canarygrass Tall fescue Kentucky bluegrass	4 ft./second
	Grass-legume mixture	3 ft./second
Greater than 10%	Bermudagrass	4 ft./second
	Reed canarygrass Tall fescue Kentucky bluegrass	3 ft./second

[a] For highly erodible soils, permissible velocities should be decreased by 25%. An erodibility factor (K) greater than 0.35 would indicate a highly erodible soil. Erodibility factors (K-factors) for many Virginia soils are listed in Chapter 6.

Source: Soil and Water Conservation Engineering, Schwab, et.al.

Riprap-lined channels can be designed to withstand most flow velocities by choosing a stable stone size. The procedures for selecting a stable stone size for channels and installation is contained in Std. & Spec. 3.19, RIPRAP. All riprap must be installed with a filter fabric or gravel (granular) underlining. Transition from a riprap lining to grass and earth linings must be carefully designed to meet the allowable velocities of each type of lining.

Concrete-lined channels are not usually limited in the velocity they can carry; however, it should be kept in mind that the flow velocity at the outlet of the paved section must not exceed the permissible velocity of the receiving channel. See OUTLET PROTECTION, Std. & Spec. 3.18. Concrete channels shall be at least 4 inches thick and meet all applicable VDOT criteria found in its Road and Bridge Standards and Road and Bridge Specifications.

Depth

The design water surface elevation of a channel receiving water from diversions or other tributary channels shall be equal to or less than the design water surface elevation of the diversion or other tributary channel at the point of intersection.

The top width of parabolic and vee-shaped, grass-lined channels shall not exceed 30 feet, and the bottom width of trapezoidal, grass-lined channels shall not exceed 15 feet unless multiple or divided waterways, riprap center, or other means are provided to control meandering of low flows.

Outlet

The outlets of all channels shall be protected from erosion (see OUTLET PROTECTION, Std. & Spec. 3.18).

Calculations

1. Peak runoff shall be calculated in accordance with the guidelines contained in Chapter 5.

2. Channel dimensions for roadside ditches and median channels shall be determined in accordance with applicable design procedures outlined in the latest edition of the VDOT Drainage Manual. Helpful design charts are also included in that publication to aid in the design of concrete-lined channels for many cross-sectional shapes.

3. Channel dimensions for parabolic, grass-lined channels may be determined from the tables in Appendix 3.19-a.

4. A general "trial and error" procedure for designing channels using Manning's Equation and the Continuity Equation is contained in Chapter 5 of this handbook.

5. There are various computer programs available to assist a designer in performing these calculations.

Construction Specifications

General

1. All trees, brush, stumps, roots, obstructions and other unsuitable material shall be removed and disposed of properly.

2. The channel shall be excavated or shaped to the proper grade and cross-section.

3. Any fills shall be well compacted to prevent unequal settlement.

4. Any excess soil shall be removed and disposed of properly.

Grass-lined Channels

The method used to establish grass in the ditch or channel will depend upon the severity of the conditions encountered. The methods available for grass establishment are set forth in PERMANENT SEEDINGS, Std. & Spec. 3.32 and SODDING, Std. & Spec. 3.33.

Riprap-lined Channels

Riprap shall be installed in accordance with RIPRAP, Std. & Spec. 3.19.

Concrete-lined Channels

Concrete-lined channels must be constructed in accordance with all applicable VDOT specifications. The following items highlight those specifications:

1. The subgrade should be moist at the time the concrete is poured.

2. Traverse joints for crack control should be provided at approximately 20-foot intervals and when more than 45 minutes elapses between the times of consecutive concrete placements. All sections should be at least 6 feet long. Crack control joints may be formed by using a 1/8-inch thick removable template, by scoring or sawing to a depth of at least 3/4 inch or by an approved "leave in"-type insert.

3. Expansion joints shall be installed every 100 feet.

Maintenance

Grass-lined Channels

During the initial establishment, grass-lined channels should be repaired immediately and grass re-established if necessary. After grass has become established, the channel should be checked periodically to determine if the grass is withstanding flow velocities without damage. If the channel is to be mowed, it should be done in a manner that will not damage the grass.

Riprap-lined Channels

Riprap-lined channels should be checked periodically to ensure that scour is not occurring beneath fabric underlining of the riprap layer. The channel should also be checked to determine that the stones are not dislodged by large flows.

Concrete-lined Channels

Concrete-lined channels should be checked periodically to ensure that there is no undermining of the channel. Particular attention should be paid to the outlet of the channel. If scour is occurring at the outlet, appropriate outlet protection shall be installed. See OUTLET PROTECTION, Std. & Spec. 3.18.

Sediment Deposition

If the channel is below a high sediment-producing area, sediment should be trapped before it enters the channel. Field experience has demonstrated that many newly constructed conveyance channels become damaged and require costly repairs as a result of improper upslope controls. If sediment is deposited in a grass-lined channel, it should be removed promptly to prevent damage to the grass. Sediment deposited in riprap and concrete-lined channels should be removed when it reduces the capacity of the channel.

APPENDIX 3.17-a

DESIGN OF PARABOLIC GRASS-LINED CHANNELS

The channel must be designed for capacity and erosion resistance. Capacity will be a minimum when the grass is long and unmowed. This condition corresponds to V_2 in Table 3.17-B. Erosion will be most likely to occur when the grass is short. This condition will correspond to V_1 in Table 3.17-B. A design based upon Table 3.17-B will result in a channel which will have adequate capacity when the vegetation in the channel is long and thick, which will remain stable when the vegetation is short or recently mowed, and which will have adequate freeboard for the design flow.

Use the following procedure to design a grass-lined parabolic channel based upon Tables 3.17-A and 3.17-B:

1. Determine the required channel capacity, Q. (Peak rate of runoff for the selected design storm).

2. Select an appropriate grass lining and note the maximum permissible velocity (V_1) from Table 3.17-A.

3. Choose the appropriate sheet of Table 3.17-B for the channel slope. Using the maximum permissible velocity (V_1) and the required flow capacity (Q), read the top width (T) and the depth (D) for the correct parabolic section.

Example Problem

Design a parabolic waterway to be lined with Kentucky 31-Tall Fescue which will carry 50 cfs on a 3% slope.

Solution:

1. Q = 50 cfs (given)

2. V_1 = 5 ft./sec. for Kentucky 31-Tall Fescue (from Table 3.17-A)

3. From sheet 9 of Table 3.17-B (for 3% slope): Read the top width (T) and depth (D) for Q = 50 cfs and V_1 = 5.0 fps

   T = 16.3 feet

   D = 1.45 feet

TABLE 3.17-B
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.25 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15												
20												
25	11.3	3.27	1.00									
30	13.2	3.09	1.09									
35	15.2	3.01	1.13									
40	17.3	2.99	1.15	12.1	3.61	1.36						
45	19.3	2.94	1.18	13.4	3.49	1.42						
50	21.4	2.93	1.18	14.7	3.41	1.48						
55	23.5	2.92	1.19	16.1	3.38	1.50						
60	25.5	2.89	1.21	17.5	3.35	1.52						
65	27.6	2.89	1.21	18.8	3.30	1.56						
70	29.7	2.89	1.21	20.2	3.28	1.57	14.4	3.98	1.81			
75	31.7	2.87	1.23	21.6	3.27	1.58	15.3	3.91	1.86			
80	33.8	2.87	1.23	23.0	3.26	1.58	16.3	3.90	1.87			
90	38.0	2.87	1.23	25.8	3.25	1.60	18.1	3.80	1.94			
100	42.1	2.85	1.24	28.6	3.23	1.61	20.0	3.76	1.98			
110	46.3	2.85	1.24	31.4	3.22	1.62	21.9	3.73	2.01			
120	50.4	2.84	1.25	34.1	3.20	1.64	23.9	3.73	2.00	17.0	4.47	2.34
130	54.6	2.85	1.24	36.9	3.19	1.64	25.8	3.70	2.02	18.3	4.42	2.39
140	58.7	2.84	1.25	39.7	3.19	1.65	27.7	3.68	2.04	19.6	4.37	2.43
150	62.9	2.85	1.25	42.5	3.19	1.65	29.6	3.67	2.06	20.9	4.33	2.47
160	67.0	2.84	1.25	45.3	3.18	1.65	31.6	3.68	2.05	22.2	4.30	2.50
170	71.1	2.84	1.26	48.1	3.18	1.65	33.5	3.66	2.07	23.5	4.27	2.53
180	75.3	2.84	1.25	50.9	3.18	1.66	35.4	3.65	2.08	24.8	4.24	2.55
190	79.4	2.84	1.26	53.7	3.18	1.66	37.4	3.66	2.07	26.1	4.22	2.57
200	83.5	2.84	1.26	56.5	3.18	1.66	39.3	3.65	2.08	27.5	4.23	2.56
220	91.8	2.84	1.26	62.1	3.18	1.66	43.2	3.65	2.08	30.1	4.19	2.60
240	100.0	2.83	1.26	67.6	3.17	1.67	47.0	3.63	2.10	32.7	4.15	2.64
260	108.3	2.84	1.26	73.2	3.17	1.67	50.9	3.63	2.10	35.4	4.15	2.64
280	116.6	2.84	1.26	78.8	3.17	1.67	54.8	3.63	2.10	38.1	4.14	2.64
300	124.8	2.84	1.26	84.4	3.17	1.67	58.6	3.62	2.11	40.8	4.14	2.65

Q cfs	V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15															
20															
25															
30															
35															
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65															
70															
75															
80															
90															
100															
110															
120															
130															
140															
150															
160															
170	18.5	4.95	2.76												
180	19.5	4.90	2.80												
190	20.5	4.87	2.84												
200	21.5	4.83	2.87												
220	23.5	4.77	2.92												
240	25.5	4.72	2.97												
260	27.5	4.68	3.01	21.4	5.50	3.29									
280	29.5	4.64	3.05	22.9	5.44	3.35									
300	31.5	4.61	3.08	24.5	5.42	3.37									

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.50 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	10.2	2.28	0.95																								
20	13.3	2.18	1.02																								
25	16.5	2.15	1.05	10.5	2.60	1.35																					
30	19.7	2.12	1.06	12.4	2.51	1.42	9.5	2.91	1.60																		
35	22.8	2.09	1.09	14.3	2.45	1.48	10.9	2.81	1.69																		
40	26.0	2.08	1.09	16.3	2.44	1.49	12.3	2.74	1.76																		
45	29.2	2.08	1.10	18.2	2.41	1.52	13.7	2.69	1.81																		
50	32.4	2.08	1.10	20.2	2.40	1.53	15.1	2.64	1.86	11.1	3.22	2.07															
55	35.6	2.08	1.11	22.1	2.38	1.55	16.6	2.64	1.86	12.0	3.11	2.18															
60	38.8	2.08	1.11	24.1	2.38	1.55	18.0	2.61	1.90	13.0	3.07	2.23															
65	42.0	2.08	1.11	26.0	2.36	1.57	19.5	2.61	1.89	14.0	3.03	2.27															
70	45.2	2.08	1.11	28.0	2.36	1.57	20.9	2.59	1.92	15.0	3.01	2.31															
75	48.4	2.08	1.11	29.9	2.35	1.59	22.4	2.59	1.92	16.0	2.98	2.34	12.7	3.48	2.52												
80	51.6	2.08	1.11	31.9	2.36	1.58	23.8	2.58	1.94	17.0	2.96	2.36	13.4	3.41	2.60												
90	57.9	2.07	1.12	35.8	2.35	1.59	26.7	2.56	1.96	19.1	2.95	2.37	15.0	3.37	2.64												
100	64.3	2.07	1.11	39.7	2.34	1.60	29.6	2.55	1.97	21.1	2.92	2.42	16.5	3.31	2.72	13.3	3.77	2.96									
110	70.7	2.08	1.11	43.6	2.34	1.61	32.6	2.56	1.96	23.2	2.92	2.42	18.1	3.29	2.75	14.5	3.70	3.05									
120	77.0	2.07	1.12	47.5	2.33	1.61	35.5	2.56	1.97	25.2	2.89	2.45	19.6	3.24	2.81	15.7	3.64	3.12									
130	83.4	2.08	1.12	51.5	2.34	1.61	38.4	2.55	1.98	27.3	2.90	2.45	21.2	3.23	2.82	16.9	3.60	3.18									
140	89.7	2.08	1.12	55.4	2.34	1.61	41.3	2.55	1.98	29.3	2.88	2.47	22.8	3.22	2.84	18.1	3.56	3.23									
150	96.0	2.08	1.12	59.3	2.34	1.61	44.2	2.55	1.99	31.4	2.88	2.47	24.3	3.19	2.88	19.4	3.56	3.23	15.5	4.09	3.52						
160	102.3	2.08	1.12	63.2	2.34	1.61	47.1	2.54	1.99	33.5	2.89	2.47	25.9	3.19	2.88	20.6	3.53	3.27	16.4	4.02	3.60						
170	108.6	2.08	1.12	67.1	2.34	1.62	50.0	2.54	1.99	35.5	2.87	2.48	27.5	3.19	2.89	21.9	3.54	3.27	17.4	4.01	3.62						
180	114.9	2.08	1.12	70.9	2.33	1.62	52.9	2.54	1.99	37.6	2.88	2.48	29.1	3.19	2.89	23.1	3.51	3.30	18.3	3.96	3.69						
190	121.2	2.08	1.12	74.8	2.33	1.62	55.8	2.54	2.00	39.6	2.87	2.49	30.6	3.16	2.92	24.3	3.49	3.34	19.3	3.96	3.70						
200	127.4	2.08	1.13	78.7	2.33	1.62	58.7	2.54	2.00	41.7	2.87	2.49	32.2	3.16	2.93	25.6	3.50	3.33	20.2	3.91	3.77	16.8	4.48	3.96			
220	140.0	2.08	1.13	86.5	2.33	1.62	64.5	2.54	2.00	45.8	2.87	2.50	35.4	3.16	2.93	28.1	3.49	3.35	22.1	3.87	3.83	18.3	4.39	4.08			
240	152.6	2.08	1.13	94.3	2.33	1.63	70.3	2.54	2.01	49.9	2.86	2.51	38.6	3.16	2.93	30.6	3.48	3.36	24.1	3.87	3.84	19.9	4.36	4.12			
260	165.2	2.08	1.13	102.1	2.33	1.63	76.1	2.54	2.01	54.0	2.86	2.51	41.7	3.15	2.95	33.1	3.47	3.38	26.0	3.84	3.88	21.5	4.34	4.15			
280	177.7	2.08	1.13	109.8	2.33	1.63	81.9	2.54	2.01	58.2	2.87	2.50	44.9	3.15	2.95	35.6	3.46	3.39	28.0	3.84	3.88	23.0	4.28	4.24	19.0	4.88	4.50
300	190.3	2.08	1.13	117.6	2.33	1.63	87.7	2.54	2.01	62.3	2.86	2.51	48.0	3.14	2.97	38.1	3.45	3.40	29.9	3.82	3.92	24.6	4.27	4.26	20.2	4.80	4.61

Source: USDA-SCS

Sheet 2 of 14

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.75 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	13.7	1.76	0.92	8.0	2.22	1.24																					
20	18.2	1.75	0.93	10.4	2.10	1.35																					
25	22.6	1.73	0.95	12.8	2.03	1.42	9.5	2.33	1.66																		
30	27.1	1.73	0.95	15.3	2.02	1.44	11.2	2.25	1.76	8.9	2.56	1.94															
35	31.5	1.72	0.96	17.8	2.01	1.45	13.0	2.23	1.79	10.2	2.47	2.05															
40	36.0	1.72	0.96	20.2	1.98	1.48	14.8	2.21	1.81	11.6	2.44	2.09															
45	40.4	1.71	0.96	22.7	1.98	1.49	16.5	2.17	1.86	12.9	2.39	2.16															
50	44.9	1.72	0.96	25.2	1.98	1.49	18.3	2.16	1.87	14.3	2.38	2.18	10.6	2.82	2.47												
55	49.3	1.72	0.96	27.6	1.96	1.51	20.1	2.16	1.88	15.7	2.37	2.19	11.6	2.80	2.51												
60	53.7	1.72	0.97	30.1	1.96	1.51	21.9	2.16	1.89	17.1	2.36	2.20	12.5	2.73	2.61												
65	58.1	1.72	0.97	32.5	1.95	1.52	23.6	2.14	1.92	18.4	2.33	2.25	13.5	2.71	2.63	11.2	3.04	2.83									
70	62.5	1.72	0.97	35.0	1.96	1.52	25.4	2.14	1.92	19.8	2.33	2.25	14.4	2.66	2.71	12.0	3.01	2.87									
75	66.9	1.72	0.97	37.4	1.95	1.53	27.2	2.14	1.92	21.2	2.33	2.26	15.4	2.65	2.73	12.8	2.99	2.91									
80	71.2	1.71	0.97	39.9	1.95	1.53	29.0	2.14	1.92	22.5	2.31	2.29	16.4	2.65	2.74	13.5	2.92	3.01									
90	80.0	1.71	0.97	44.8	1.95	1.53	32.5	2.12	1.94	25.3	2.31	2.29	18.4	2.63	2.76	15.1	2.89	3.07	12.4	3.26	3.30						
100	88.8	1.72	0.98	49.7	1.95	1.54	36.1	2.13	1.94	28.1	2.31	2.29	20.4	2.62	2.78	16.7	2.86	3.11	13.7	3.22	3.36						
110	97.6	1.72	0.98	54.7	1.95	1.53	39.7	2.13	1.94	30.8	2.30	2.31	22.4	2.61	2.79	18.3	2.84	3.15	14.9	3.15	3.48						
120	106.3	1.72	0.98	59.6	1.95	1.54	43.2	2.12	1.95	33.6	2.30	2.31	24.4	2.61	2.81	19.9	2.82	3.18	16.2	3.13	3.52	13.4	3.49	3.81			
130	115.0	1.72	0.98	64.5	1.95	1.54	46.8	2.12	1.95	36.4	2.30	2.31	26.3	2.58	2.85	21.5	2.81	3.20	17.5	3.11	3.55	14.5	3.49	3.82			
140	123.7	1.72	0.98	69.4	1.95	1.54	50.3	2.12	1.96	39.1	2.29	2.33	28.3	2.58	2.85	23.1	2.80	3.22	18.7	3.07	3.63	15.5	3.44	3.91			
150	132.4	1.72	0.98	74.2	1.95	1.55	53.9	2.12	1.95	41.9	2.30	2.32	30.3	2.58	2.86	24.7	2.79	3.24	20.0	3.06	3.65	16.5	3.39	3.98			
160	141.1	1.72	0.98	79.1	1.95	1.55	57.4	2.12	1.96	44.6	2.29	2.33	32.3	2.58	2.86	26.3	2.78	3.26	21.3	3.05	3.67	17.6	3.39	3.98	14.4	3.77	4.37
170	149.7	1.72	0.98	84.0	1.95	1.55	60.9	2.12	1.97	47.4	2.30	2.33	34.3	2.58	2.86	28.0	2.80	3.24	22.6	3.04	3.68	18.6	3.36	4.05	15.3	3.77	4.38
180	158.3	1.72	0.98	88.8	1.95	1.55	64.5	2.12	1.96	50.1	2.29	2.34	36.3	2.58	2.86	29.6	2.79	3.25	23.9	3.04	3.69	19.6	3.33	4.11	16.1	3.73	4.46
190	166.9	1.72	0.98	93.7	1.95	1.55	68.0	2.12	1.97	52.8	2.29	2.34	38.3	2.58	2.86	31.2	2.78	3.26	25.2	3.03	3.70	20.7	3.33	4.10	17.0	3.73	4.45
200	175.5	1.72	0.99	98.5	1.95	1.55	71.5	2.12	1.97	55.6	2.29	2.34	40.2	2.57	2.89	32.8	2.78	3.27	26.5	3.03	3.71	21.7	3.31	4.15	17.8	3.70	4.52
220	192.8	1.72	0.99	108.3	1.95	1.55	78.6	2.12	1.97	61.1	2.29	2.34	44.2	2.57	2.89	36.0	2.77	3.29	29.1	3.02	3.73	23.8	3.29	4.18	19.5	3.67	4.58
240	210.1	1.72	0.99	118.0	1.95	1.56	85.6	2.12	1.98	66.6	2.29	2.35	48.2	2.57	2.89	39.2	2.76	3.31	31.7	3.01	3.75	25.9	3.28	4.22	21.2	3.64	4.63
260	227.3	1.72	0.99	127.7	1.95	1.56	92.7	2.12	1.98	72.1	2.29	2.35	52.2	2.57	2.89	42.5	2.77	3.30	34.3	3.01	3.76	28.0	3.26	4.24	22.9	3.62	4.67
280	244.5	1.72	0.99	137.4	1.95	1.56	99.7	2.12	1.98	77.6	2.29	2.35	56.2	2.57	2.89	45.7	2.76	3.31	36.9	3.00	3.77	30.1	3.25	4.26	24.7	3.63	4.65
300	261.7	1.72	0.99	147.1	1.95	1.56	106.8	2.12	1.98	83.0	2.29	2.36	60.1	2.57	2.90	48.9	2.76	3.32	39.5	3.00	3.78	32.2	3.25	4.28	26.4	3.62	4.68

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.0 Percent

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	15.7	1.55	0.91	9.9	1.80	1.24																					
20	20.9	1.54	0.92	13.0	1.74	1.31	8.8	2.04	1.65																		
25	26.0	1.53	0.93	16.2	1.73	1.32	10.9	1.99	1.70	8.9	2.21	1.87															
30	31.1	1.52	0.94	19.3	1.70	1.35	12.9	1.94	1.78	10.5	2.14	1.98															
35	36.2	1.52	0.94	22.5	1.70	1.36	15.0	1.93	1.80	12.1	2.08	2.06	9.2	2.37	2.37												
40	41.3	1.52	0.95	25.7	1.70	1.36	17.1	1.92	1.81	13.7	2.04	2.12	10.4	2.32	2.45												
45	46.4	1.52	0.95	28.8	1.69	1.37	19.2	1.91	1.82	15.4	2.04	2.12	11.7	2.32	2.46												
50	51.5	1.52	0.95	32.0	1.70	1.37	21.2	1.89	1.85	17.0	2.02	2.16	12.9	2.28	2.52	9.9	2.61	2.86									
55	56.5	1.51	0.95	35.1	1.69	1.38	23.3	1.89	1.86	18.7	2.02	2.16	14.1	2.25	2.57	10.8	2.57	2.93									
60	61.6	1.52	0.95	38.3	1.69	1.37	25.4	1.89	1.86	20.3	2.00	2.19	15.3	2.23	2.61	11.7	2.54	3.00									
65	66.6	1.52	0.96	41.4	1.69	1.38	27.5	1.89	1.86	22.0	2.01	2.19	16.6	2.24	2.60	12.7	2.55	2.98	10.6	2.88	3.16						
70	71.6	1.51	0.96	44.6	1.70	1.38	29.5	1.88	1.88	23.6	1.99	2.21	17.8	2.22	2.63	13.6	2.52	3.03	11.3	2.82	3.26						
75	76.6	1.51	0.96	47.7	1.69	1.38	31.6	1.88	1.88	25.3	2.00	2.21	19.0	2.21	2.66	14.5	2.50	3.08	12.0	2.77	3.35						
80	81.6	1.52	0.96	50.8	1.69	1.38	33.7	1.88	1.88	26.9	1.99	2.22	20.3	2.22	2.64	15.4	2.48	3.11	12.7	2.73	3.43						
90	91.7	1.52	0.96	57.1	1.69	1.39	37.8	1.88	1.89	30.2	1.98	2.24	22.8	2.21	2.65	17.3	2.47	3.13	14.2	2.69	3.49	11.8	2.99	3.78			
100	101.7	1.52	0.96	63.4	1.69	1.39	42.0	1.88	1.89	33.5	1.98	2.24	25.2	2.19	2.69	19.2	2.47	3.14	15.7	2.67	3.55	13.0	2.94	3.88			
110	111.7	1.52	0.97	69.6	1.69	1.39	46.1	1.87	1.90	36.8	1.98	2.25	27.7	2.19	2.70	21.0	2.44	3.20	17.3	2.68	3.53	14.3	2.94	3.88	12.4	3.23	4.07
120	121.7	1.52	0.97	75.8	1.69	1.39	50.2	1.87	1.90	40.1	1.98	2.26	30.2	2.19	2.70	22.9	2.44	3.20	18.8	2.66	3.57	15.5	2.91	3.96	13.4	3.17	4.19
130	131.6	1.51	0.97	82.1	1.69	1.39	54.4	1.87	1.90	43.4	1.97	2.26	32.7	2.19	2.70	24.8	2.44	3.20	20.3	2.64	3.61	16.7	2.88	4.03	14.4	3.12	4.30
140	141.5	1.51	0.97	88.3	1.69	1.39	58.5	1.87	1.90	46.7	1.97	2.26	35.2	2.19	2.70	26.6	2.42	3.24	21.8	2.63	3.64	17.9	2.85	4.08	15.5	3.12	4.31
150	151.4	1.52	0.97	94.5	1.69	1.40	62.6	1.87	1.91	50.0	1.98	2.26	37.6	2.18	2.72	28.5	2.42	3.23	23.3	2.62	3.66	19.2	2.86	4.07	16.5	3.08	4.39
160	161.3	1.52	0.97	100.7	1.69	1.40	66.7	1.87	1.91	53.3	1.98	2.26	40.1	2.18	2.72	30.4	2.43	3.23	24.8	2.61	3.68	20.4	2.84	4.11	17.6	3.08	4.39
170	171.1	1.52	0.97	106.8	1.69	1.40	70.8	1.87	1.91	56.5	1.97	2.28	42.6	2.19	2.72	32.2	2.41	3.26	26.3	2.60	3.70	21.7	2.85	4.10	18.6	3.05	4.46
180	180.9	1.52	0.98	113.0	1.69	1.40	74.9	1.87	1.91	59.8	1.97	2.27	45.0	2.18	2.73	34.1	2.42	3.25	27.9	2.61	3.68	22.9	2.83	4.14	19.6	3.02	4.52
190	190.6	1.52	0.98	119.1	1.69	1.40	79.0	1.87	1.91	63.1	1.98	2.27	47.5	2.18	2.73	35.9	2.41	3.27	29.4	2.61	3.69	24.1	2.81	4.17	20.7	3.03	4.51
200	200.4	1.52	0.98	125.3	1.69	1.40	83.0	1.87	1.92	66.3	1.97	2.28	49.9	2.18	2.74	37.8	2.41	3.27	30.9	2.60	3.71	25.4	2.82	4.15	21.7	3.00	4.57
220	220.1	1.52	0.98	137.6	1.69	1.41	91.2	1.87	1.92	72.9	1.97	2.28	54.9	2.18	2.74	41.5	2.41	3.28	33.9	2.59	3.73	27.9	2.82	4.17	23.8	2.99	4.61
240	239.8	1.52	0.98	150.0	1.69	1.41	99.4	1.87	1.93	79.5	1.98	2.28	59.8	2.18	2.75	45.3	2.41	3.28	37.0	2.60	3.72	30.4	2.81	4.18	25.9	2.97	4.64
260	259.4	1.52	0.98	162.3	1.69	1.41	107.6	1.87	1.93	86.0	1.97	2.28	64.8	2.18	2.74	49.0	2.41	3.29	40.0	2.59	3.75	32.9	2.81	4.20	28.0	2.96	4.67
280	279.0	1.52	0.98	174.6	1.70	1.41	115.8	1.87	1.93	92.5	1.97	2.29	69.7	2.18	2.75	52.7	2.40	3.30	43.0	2.58	3.76	35.3	2.79	4.24	30.2	2.97	4.65
300	298.5	1.52	0.98	186.9	1.70	1.41	123.9	1.87	1.93	99.1	1.98	2.29	74.6	2.18	2.75	56.4	2.40	3.30	46.1	2.59	3.75	37.8	2.79	4.24	32.3	2.97	4.67

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.25 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0		
	T	D	V_2	T	D	V_2	T	D	V_2
15	18.1	1.40	0.88	11.5	1.59	1.21	7.7	1.85	1.55
20	24.0	1.38	0.89	15.2	1.56	1.25	10.1	1.79	1.64
25	30.0	1.38	0.89	19.0	1.56	1.25	12.5	1.75	1.69
30	35.9	1.38	0.90	22.7	1.55	1.27	14.9	1.73	1.73
35	41.8	1.38	0.90	26.4	1.54	1.28	17.3	1.71	1.75
40	47.7	1.38	0.90	30.1	1.54	1.28	19.7	1.70	1.77
45	53.6	1.38	0.90	33.9	1.54	1.28	22.1	1.69	1.78
50	59.4	1.38	0.91	37.6	1.54	1.28	24.5	1.69	1.79
55	65.3	1.38	0.91	41.3	1.54	1.28	26.9	1.69	1.80
60	71.1	1.38	0.91	44.9	1.53	1.29	29.3	1.68	1.81
65	76.9	1.38	0.91	48.6	1.54	1.29	31.7	1.68	1.81
70	82.7	1.38	0.91	52.3	1.54	1.29	34.1	1.68	1.81
75	88.4	1.38	0.91	55.9	1.53	1.30	36.5	1.68	1.82
80	94.2	1.38	0.91	59.6	1.54	1.30	38.9	1.68	1.82
90	105.8	1.38	0.91	66.9	1.53	1.30	43.7	1.68	1.82
100	117.3	1.38	0.92	74.3	1.54	1.30	48.5	1.68	1.83
110	128.9	1.38	0.92	81.6	1.54	1.31	53.3	1.68	1.83
120	140.4	1.38	0.92	88.9	1.54	1.31	58.1	1.68	1.83
130	151.8	1.38	0.92	96.1	1.53	1.31	62.9	1.68	1.83
140	163.2	1.38	0.92	103.4	1.54	1.31	67.6	1.68	1.84
150	174.6	1.38	0.92	110.6	1.53	1.31	72.4	1.68	1.83
160	186.0	1.38	0.92	117.8	1.53	1.32	77.1	1.68	1.84
170	197.3	1.39	0.92	125.0	1.54	1.32	81.9	1.68	1.84
180	208.5	1.38	0.93	132.2	1.54	1.32	86.6	1.68	1.84
190	219.8	1.39	0.93	139.3	1.54	1.32	91.3	1.68	1.84
200	231.0	1.39	0.93	146.5	1.54	1.32	96.0	1.68	1.84
220	253.7	1.39	0.93	160.9	1.54	1.32	105.5	1.68	1.84
240	276.3	1.39	0.93	175.3	1.54	1.33	115.0	1.69	1.84
260	298.9	1.39	0.93	189.7	1.54	1.33	124.4	1.68	1.85
280	321.3	1.39	0.93	204.0	1.54	1.33	133.9	1.69	1.85
300	343.7	1.39	0.93	218.2	1.54	1.33	143.3	1.69	1.85

Q cfs	V_1 = 3.5			V_1 = 4.0			V_1 = 4.5		
	T	D	V_2	T	D	V_2	T	D	V_2
15									
20	7.7	2.03	1.89						
25	9.5	1.97	1.97	7.8	2.19	2.16			
30	11.2	1.90	2.09	9.2	2.11	2.28			
35	13.0	1.88	2.12	10.5	2.02	2.44	8.3	2.36	2.64
40	14.8	1.87	2.15	12.0	2.02	2.44	9.4	2.32	2.72
45	16.6	1.86	2.17	13.4	1.99	2.50	10.5	2.28	2.78
50	18.4	1.85	2.18	14.9	1.99	2.50	11.5	2.22	2.90
55	20.2	1.84	2.19	16.3	1.97	2.54	12.6	2.20	2.94
60	22.0	1.84	2.20	17.7	1.96	2.57	13.7	2.19	2.97
65	23.7	1.82	2.24	19.2	1.97	2.56	14.8	2.18	2.99
70	25.5	1.82	2.24	20.6	1.95	2.58	15.9	2.17	3.01
75	27.3	1.82	2.24	22.1	1.96	2.57	17.0	2.16	3.03
80	29.1	1.82	2.24	23.5	1.95	2.59	18.1	2.16	3.05
90	32.7	1.82	2.25	26.4	1.95	2.60	20.3	2.14	3.07
100	36.3	1.82	2.25	29.3	1.95	2.61	22.5	2.14	3.10
110	39.8	1.81	2.27	32.2	1.95	2.61	24.7	2.13	3.11
120	43.4	1.81	2.27	35.0	1.94	2.64	26.9	2.12	3.13
130	47.0	1.82	2.27	37.9	1.94	2.64	29.1	2.12	3.14
140	50.5	1.81	2.28	40.8	1.94	2.64	31.3	2.12	3.14
150	54.1	1.81	2.28	43.7	1.94	2.64	33.5	2.12	3.15
160	57.6	1.81	2.29	46.5	1.93	2.65	35.7	2.12	3.16
170	61.2	1.81	2.28	49.4	1.94	2.65	37.9	2.12	3.16
180	64.7	1.81	2.29	52.2	1.93	2.66	40.1	2.12	3.16
190	68.2	1.81	2.29	55.1	1.94	2.65	42.3	2.12	3.16
200	71.8	1.82	2.29	57.9	1.93	2.66	44.5	2.12	3.17
220	78.9	1.82	2.29	63.7	1.94	2.66	48.9	2.12	3.17
240	85.9	1.81	2.30	69.4	1.94	2.66	53.3	2.11	3.18
260	93.0	1.81	2.30	75.1	1.93	2.67	57.6	2.11	3.19
280	100.1	1.82	2.30	80.8	1.93	2.67	62.0	2.11	3.19
300	107.1	1.81	2.30	86.5	1.94	2.67	66.4	2.11	3.19

Q cfs	V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2
15									
20									
25									
30									
35									
40									
45									
50	9.4	2.49	3.16						
55	10.3	2.47	3.20						
60	11.2	2.45	3.23						
65	12.0	2.40	3.34	9.8	2.76	3.55			
70	12.9	2.39	3.36	10.5	2.74	3.61			
75	13.8	2.39	3.38	11.1	2.67	3.76			
80	14.7	2.38	3.39	11.8	2.65	3.80	10.3	2.92	3.94
90	16.4	2.34	3.48	13.2	2.62	3.87	11.4	2.83	4.14
100	18.2	2.34	3.49	14.6	2.59	3.92	12.6	2.80	4.21
110	20.0	2.34	3.50	16.0	2.58	3.97	13.8	2.77	4.27
120	21.7	2.31	3.56	17.4	2.56	4.00	15.0	2.75	4.32
130	23.5	2.31	3.56	18.8	2.55	4.04	16.2	2.74	4.36
140	25.3	2.31	3.56	20.2	2.54	4.06	17.4	2.72	4.39
150	27.0	2.30	3.60	21.6	2.53	4.08	18.6	2.71	4.42
160	28.8	2.30	3.60	22.9	2.50	4.16	19.8	2.70	4.45
170	30.6	2.30	3.59	24.3	2.50	4.17	21.0	2.69	4.47
180	32.3	2.29	3.62	25.7	2.49	4.18	22.2	2.69	4.49
190	34.1	2.30	3.62	27.1	2.49	4.19	23.4	2.68	4.51
200	35.8	2.29	3.64	28.5	2.49	4.20	24.6	2.68	4.52
220	39.4	2.29	3.63	31.3	2.48	4.22	27.0	2.67	4.55
240	42.9	2.29	3.65	34.1	2.48	4.23	29.4	2.66	4.57
260	46.5	2.29	3.64	36.9	2.48	4.24	31.8	2.65	4.59
280	50.0	2.29	3.65	39.7	2.47	4.25	34.2	2.65	4.61
300	53.5	2.28	3.66	42.5	2.47	4.26	36.6	2.65	4.62

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.50 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	20.1	1.29	0.86	13.2	1.43	1.17	8.9	1.65	1.51																		
20	26.8	1.29	0.86	17.5	1.42	1.19	11.7	1.60	1.58	8.1	1.86	1.95	6.7	2.09	2.10												
25	33.4	1.28	0.86	21.8	1.41	1.21	14.5	1.57	1.63	9.9	1.78	2.10	8.1	1.95	2.34												
30	40.0	1.28	0.87	26.2	1.42	1.20	17.4	1.57	1.63	11.8	1.75	2.15	9.6	1.90	2.43	8.0	2.13	2.60									
35	46.5	1.28	0.87	30.5	1.41	1.21	20.2	1.56	1.65	13.7	1.74	2.18	11.1	1.86	2.50	9.2	2.06	2.72									
40	53.1	1.28	0.87	34.8	1.41	1.21	23.0	1.55	1.67	15.6	1.73	2.20	12.6	1.84	2.56	10.4	2.02	2.82	8.2	2.38	3.03						
45	59.6	1.28	0.88	39.0	1.40	1.22	25.9	1.55	1.66	17.5	1.72	2.22	14.2	1.85	2.55	11.7	2.02	2.82	9.1	2.31	3.16						
50	66.1	1.28	0.88	43.3	1.41	1.22	28.7	1.55	1.67	19.4	1.71	2.24	15.7	1.83	2.58	12.9	1.99	2.89	10.0	2.26	3.27						
55	72.6	1.28	0.88	47.6	1.41	1.22	31.5	1.55	1.68	21.3	1.71	2.25	17.2	1.82	2.61	14.2	1.99	2.89	10.9	2.22	3.36	9.3	2.47	3.54			
60	79.0	1.28	0.88	51.8	1.41	1.22	34.3	1.54	1.69	23.2	1.70	2.25	18.8	1.82	2.60	15.4	1.97	2.94	11.9	2.22	3.36	10.1	2.45	3.59			
65	85.5	1.28	0.88	56.0	1.40	1.23	37.1	1.54	1.69	25.1	1.70	2.26	20.3	1.82	2.62	16.6	1.95	2.98	12.8	2.19	3.43	10.8	2.39	3.73			
70	91.9	1.28	0.88	60.3	1.41	1.22	39.9	1.54	1.69	27.0	1.70	2.26	21.8	1.81	2.64	17.9	1.96	2.96	13.8	2.20	3.42	11.6	2.38	3.76	9.8	2.62	4.03
75	98.2	1.28	0.89	64.5	1.41	1.23	42.7	1.54	1.69	28.9	1.70	2.27	23.3	1.80	2.66	19.1	1.95	3.00	14.7	2.18	3.48	12.4	2.37	3.79	10.5	2.62	4.04
80	104.6	1.28	0.89	68.7	1.41	1.23	45.5	1.54	1.70	30.8	1.70	2.27	24.9	1.81	2.64	20.4	1.95	2.98	15.7	2.18	3.46	13.2	2.36	3.81	11.1	2.58	4.15
90	117.5	1.28	0.89	77.1	1.41	1.23	51.1	1.54	1.70	34.6	1.70	2.28	27.9	1.80	2.67	22.9	1.95	3.00	17.6	2.17	3.50	14.7	2.31	3.93	12.4	2.54	4.24
100	130.3	1.28	0.89	85.6	1.41	1.23	56.7	1.54	1.70	38.3	1.69	2.30	31.0	1.80	2.66	25.4	1.94	3.02	19.5	2.16	3.53	16.3	2.30	3.96	13.7	2.51	4.32
110	143.0	1.28	0.89	94.0	1.41	1.24	62.3	1.54	1.71	42.1	1.69	2.30	34.0	1.79	2.68	27.9	1.94	3.03	21.4	2.15	3.56	17.9	2.30	3.98	15.0	2.49	4.38
120	155.8	1.28	0.89	102.4	1.41	1.24	67.9	1.54	1.71	45.9	1.69	2.30	37.1	1.80	2.68	30.4	1.94	3.03	23.3	2.14	3.57	19.5	2.29	3.99	16.3	2.47	4.43
130	168.4	1.28	0.90	110.7	1.41	1.24	73.4	1.54	1.71	49.7	1.69	2.30	40.1	1.79	2.69	32.9	1.94	3.04	25.2	2.14	3.59	21.1	2.29	4.01	17.6	2.45	4.48
140	181.0	1.28	0.90	119.1	1.41	1.24	79.0	1.54	1.71	53.4	1.69	2.31	43.2	1.80	2.68	35.3	1.93	3.07	27.1	2.14	3.60	22.7	2.29	4.02	18.9	2.44	4.51
150	193.6	1.28	0.90	127.4	1.41	1.24	84.5	1.54	1.72	57.2	1.69	2.31	46.2	1.79	2.70	37.8	1.93	3.07	29.0	2.13	3.61	24.2	2.27	4.07	20.2	2.43	4.54
160	206.2	1.28	0.90	135.7	1.41	1.24	90.0	1.54	1.72	60.9	1.69	2.32	49.3	1.80	2.69	40.3	1.93	3.07	30.9	2.13	3.62	25.8	2.27	4.08	21.6	2.45	4.51
170	218.6	1.28	0.90	144.0	1.41	1.24	95.6	1.54	1.72	64.7	1.69	2.31	52.3	1.80	2.69	42.8	1.93	3.07	32.8	2.13	3.62	27.4	2.27	4.08	22.9	2.44	4.53
180	231.1	1.28	0.90	152.2	1.41	1.25	101.0	1.54	1.72	68.4	1.69	2.32	55.3	1.80	2.70	45.3	1.93	3.07	34.7	2.13	3.63	29.0	2.27	4.08	24.2	2.43	4.56
190	243.5	1.28	0.90	160.4	1.41	1.25	106.5	1.54	1.72	72.1	1.69	2.32	58.3	1.80	2.71	47.7	1.92	3.08	36.5	2.12	3.66	30.6	2.27	4.08	25.5	2.42	4.58
200	255.8	1.28	0.91	168.6	1.41	1.25	112.0	1.54	1.72	75.9	1.69	2.32	61.3	1.79	2.71	50.2	1.93	3.08	38.4	2.12	3.66	32.1	2.26	4.12	26.8	2.42	4.60
220	280.9	1.28	0.91	185.2	1.41	1.25	123.0	1.54	1.73	83.4	1.69	2.32	67.4	1.80	2.71	55.2	1.93	3.08	42.2	2.12	3.67	35.3	2.26	4.12	29.5	2.42	4.58
240	305.8	1.28	0.91	201.7	1.41	1.25	134.1	1.54	1.73	90.9	1.69	2.32	73.5	1.80	2.71	60.1	1.92	3.09	46.0	2.12	3.67	38.5	2.26	4.12	32.1	2.41	4.62
260	330.7	1.28	0.91	218.2	1.41	1.26	145.1	1.54	1.73	98.3	1.69	2.33	79.5	1.80	2.72	65.1	1.93	3.09	49.8	2.12	3.68	41.7	2.26	4.12	34.7	2.41	4.64
280	355.5	1.28	0.91	234.7	1.41	1.26	156.0	1.54	1.73	105.8	1.69	2.33	85.5	1.79	2.72	70.0	1.93	3.10	53.6	2.12	3.68	44.8	2.25	4.14	37.4	2.41	4.63
300	380.2	1.28	0.91	251.1	1.41	1.26	167.0	1.54	1.73	113.2	1.69	2.33	91.6	1.80	2.72	74.9	1.92	3.11	57.4	2.12	3.68	48.0	2.25	4.14	40.0	2.41	4.65

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B"

Grade 1.75 Percent

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	21.8	1.21	0.84	14.2	1.33	1.17	10.0	1.50	1.48	6.9	1.74	1.84															
20	29.0	1.20	0.85	18.9	1.33	1.18	13.2	1.46	1.53	9.0	1.66	1.98	7.6	1.83	2.12												
25	36.2	1.20	0.85	23.5	1.32	1.20	16.4	1.45	1.56	11.2	1.64	2.01	9.3	1.75	2.27	7.6	1.93	2.51									
30	43.4	1.21	0.85	28.2	1.32	1.20	19.6	1.44	1.58	13.3	1.60	2.08	11.1	1.72	2.32	9.0	1.88	2.62									
35	50.5	1.20	0.85	32.8	1.31	1.21	22.8	1.43	1.59	15.5	1.60	2.09	12.8	1.68	2.40	10.4	1.84	2.70	8.2	2.11	2.98						
40	57.6	1.20	0.85	37.4	1.31	1.21	26.0	1.43	1.60	17.6	1.58	2.13	14.6	1.68	2.42	11.8	1.81	2.77	9.3	2.08	3.06						
45	64.6	1.20	0.86	42.0	1.31	1.21	29.2	1.43	1.61	19.8	1.58	2.13	16.4	1.68	2.43	13.2	1.79	2.82	10.3	2.01	3.21	8.6	2.26	3.41			
50	71.6	1.20	0.86	46.6	1.31	1.21	32.4	1.43	1.61	21.9	1.57	2.16	18.2	1.67	2.44	14.7	1.80	2.80	11.4	2.00	3.25	9.5	2.24	3.48			
55	78.6	1.20	0.86	51.2	1.31	1.22	35.6	1.43	1.61	24.1	1.58	2.15	19.9	1.66	2.48	16.1	1.79	2.83	12.5	1.99	3.28	10.3	2.17	3.64	8.6	2.51	3.77
60	85.6	1.20	0.87	55.8	1.31	1.22	38.8	1.43	1.61	26.2	1.57	2.17	21.7	1.66	2.48	17.5	1.78	2.86	13.6	1.98	3.31	11.2	2.16	3.67	9.2	2.41	4.00
65	92.6	1.20	0.87	60.3	1.31	1.22	41.9	1.42	1.62	28.4	1.57	2.16	23.5	1.66	2.48	18.9	1.77	2.88	14.7	1.97	3.33	12.1	2.15	3.70	9.9	2.38	4.08
70	99.5	1.20	0.87	64.9	1.32	1.22	45.1	1.42	1.62	30.5	1.57	2.18	25.2	1.65	2.50	20.3	1.76	2.90	15.8	1.96	3.35	13.0	2.14	3.73	10.6	2.35	4.15
75	106.4	1.20	0.87	69.4	1.31	1.22	48.2	1.42	1.63	32.7	1.57	2.17	27.0	1.65	2.50	21.8	1.78	2.88	16.9	1.96	3.36	13.9	2.13	3.75	11.4	2.37	4.11
80	113.3	1.20	0.87	73.9	1.31	1.22	51.4	1.43	1.62	34.8	1.57	2.18	28.8	1.66	2.50	23.2	1.77	2.90	17.9	1.94	3.43	14.8	2.13	3.77	12.1	2.35	4.17
90	127.2	1.20	0.87	83.0	1.31	1.23	57.7	1.42	1.63	39.1	1.57	2.18	32.3	1.65	2.52	26.0	1.76	2.93	20.1	1.93	3.45	16.6	2.12	3.81	13.5	2.31	4.28
100	141.0	1.20	0.87	92.1	1.32	1.23	64.0	1.42	1.64	43.4	1.57	2.18	35.8	1.64	2.53	28.9	1.76	2.92	22.3	1.93	3.46	18.4	2.11	3.83	14.9	2.28	4.37
110	154.9	1.21	0.87	101.2	1.32	1.23	70.4	1.43	1.63	47.7	1.57	2.19	39.4	1.65	2.52	31.7	1.76	2.94	24.5	1.92	3.47	20.1	2.08	3.91	16.4	2.29	4.36
120	168.6	1.20	0.88	110.2	1.32	1.23	76.6	1.42	1.64	51.9	1.57	2.20	42.9	1.64	2.53	34.6	1.76	2.93	26.7	1.92	3.48	21.9	2.08	3.93	17.8	2.26	4.43
130	182.3	1.21	0.88	119.2	1.32	1.23	82.9	1.42	1.64	56.2	1.57	2.20	46.4	1.64	2.54	37.4	1.76	2.95	28.9	1.92	3.49	23.7	2.07	3.93	19.2	2.25	4.48
140	196.0	1.21	0.88	128.1	1.32	1.23	89.2	1.43	1.64	60.4	1.57	2.21	49.9	1.64	2.55	40.2	1.75	2.96	31.1	1.92	3.49	25.5	2.07	3.94	20.7	2.25	4.47
150	209.6	1.21	0.88	137.1	1.32	1.23	95.4	1.42	1.64	64.7	1.57	2.20	53.4	1.64	2.55	43.1	1.76	2.95	33.3	1.92	3.49	27.3	2.07	3.95	22.1	2.24	4.51
160	223.1	1.21	0.88	146.0	1.32	1.24	101.6	1.42	1.65	68.9	1.57	2.21	56.9	1.64	2.55	45.9	1.76	2.96	35.4	1.91	3.52	29.1	2.07	3.95	23.6	2.25	4.49
170	236.6	1.21	0.88	154.9	1.32	1.24	107.9	1.43	1.64	73.1	1.57	2.21	60.4	1.64	2.55	48.7	1.76	2.96	37.6	1.91	3.52	30.9	2.07	3.95	25.0	2.24	4.53
180	250.0	1.21	0.89	163.7	1.32	1.24	114.0	1.43	1.65	77.4	1.57	2.21	63.9	1.64	2.55	51.5	1.75	2.97	39.8	1.92	3.52	32.6	2.06	3.99	26.4	2.23	4.56
190	263.4	1.21	0.89	172.6	1.32	1.24	120.2	1.43	1.65	81.6	1.57	2.21	67.4	1.66	2.55	54.3	1.75	2.97	42.0	1.92	3.52	34.4	2.06	3.99	27.9	2.23	4.54
200	276.7	1.21	0.89	181.4	1.32	1.24	126.4	1.43	1.65	85.7	1.57	2.22	70.8	1.64	2.56	57.1	1.75	2.98	44.1	1.91	3.54	36.2	2.06	3.99	29.3	2.23	4.57
220	303.8	1.21	0.89	199.2	1.32	1.24	138.8	1.43	1.65	94.2	1.57	2.22	77.8	1.64	2.57	62.8	1.76	2.97	48.5	1.91	3.53	39.8	2.07	3.99	32.2	2.22	4.58
240	330.8	1.21	0.89	217.0	1.32	1.24	151.2	1.43	1.66	102.7	1.57	2.22	84.8	1.64	2.57	68.4	1.75	2.98	52.9	1.92	3.53	43.3	2.06	4.02	35.1	2.22	4.58
260	357.7	1.21	0.89	234.7	1.32	1.25	163.6	1.43	1.66	111.1	1.57	2.22	91.8	1.64	2.57	74.1	1.76	2.98	57.2	1.91	3.54	46.9	2.06	4.01	38.0	2.22	4.59
280	384.5	1.21	0.89	252.3	1.32	1.25	176.0	1.43	1.66	119.5	1.57	2.23	98.7	1.64	2.58	79.7	1.76	2.98	61.6	1.92	3.54	50.5	2.06	4.01	40.9	2.22	4.59
300	411.2	1.21	0.90	269.9	1.32	1.25	188.3	1.43	1.66	127.9	1.57	2.23	105.7	1.64	2.57	85.3	1.76	2.99	65.9	1.91	3.55	54.0	2.06	4.03	43.7	2.21	4.62

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 2.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	24.7	1.14	0.79	15.0	1.25	1.18	11.0	1.40	1.43	7.8	1.56	1.81															
20	32.8	1.14	0.79	20.0	1.25	1.18	14.5	1.37	1.49	10.3	1.53	1.88	7.5	1.71	2.29	6.3	1.91	2.44									
25	41.0	1.14	0.79	24.9	1.24	1.20	18.1	1.37	1.50	12.7	1.48	1.96	9.3	1.68	2.36	7.7	1.82	2.62									
30	49.0	1.14	0.80	29.8	1.24	1.20	21.6	1.35	1.52	15.2	1.48	1.98	11.0	1.63	2.47	9.1	1.77	2.76	7.6	1.97	2.95						
35	57.1	1.14	0.80	34.7	1.24	1.21	25.1	1.35	1.54	17.7	1.47	1.99	12.8	1.62	2.50	10.5	1.73	2.86	8.8	1.94	3.03						
40	65.1	1.14	0.80	39.6	1.24	1.21	28.7	1.35	1.53	20.2	1.47	2.00	14.6	1.62	2.51	12.0	1.73	2.86	9.9	1.88	3.18	8.2	2.13	3.38			
45	73.1	1.14	0.80	44.5	1.24	1.21	32.2	1.35	1.54	22.6	1.46	2.03	16.4	1.61	2.52	13.5	1.73	2.86	11.1	1.87	3.21	9.1	2.08	3.52			
50	81.0	1.14	0.81	49.3	1.24	1.22	35.7	1.35	1.55	25.1	1.46	2.03	18.1	1.59	2.57	14.9	1.71	2.92	12.3	1.86	3.24	10.0	2.03	3.64	8.6	2.29	3.76
55	88.9	1.14	0.81	54.2	1.24	1.21	39.2	1.34	1.55	27.6	1.46	2.03	19.9	1.60	2.57	16.4	1.71	2.91	13.5	1.85	3.26	11.0	2.03	3.65	9.3	2.21	3.96
60	96.8	1.14	0.81	59.0	1.24	1.22	42.7	1.34	1.55	30.0	1.45	2.05	21.7	1.60	2.57	17.8	1.69	2.95	14.7	1.85	3.28	11.9	2.00	3.74	10.1	2.19	4.01
65	104.6	1.14	0.81	63.8	1.24	1.22	46.2	1.35	1.55	32.5	1.46	2.04	23.4	1.58	2.60	19.3	1.70	2.94	15.8	1.82	3.36	12.9	2.00	3.73	10.9	2.18	4.06
70	112.4	1.14	0.81	68.6	1.24	1.22	49.7	1.35	1.56	34.9	1.45	2.05	25.2	1.59	2.60	20.7	1.69	2.98	17.0	1.82	3.36	13.8	1.98	3.81	11.7	2.16	4.10
75	120.2	1.14	0.81	73.4	1.24	1.22	53.1	1.34	1.56	37.3	1.45	2.06	27.0	1.59	2.60	22.2	1.69	2.96	18.2	1.82	3.37	14.8	1.98	3.79	12.5	2.15	4.14
80	127.9	1.14	0.82	78.1	1.24	1.23	56.6	1.35	1.56	39.8	1.45	2.06	28.7	1.58	2.62	23.6	1.69	2.99	19.4	1.82	3.37	15.8	1.99	3.78	13.3	2.14	4.17
90	143.6	1.14	0.82	87.8	1.24	1.23	63.5	1.34	1.57	44.7	1.45	2.06	32.3	1.59	2.61	26.5	1.68	3.00	21.8	1.82	3.38	17.7	1.97	3.83	14.9	2.12	4.22
100	159.2	1.14	0.82	97.4	1.24	1.23	70.5	1.34	1.57	49.6	1.45	2.07	35.8	1.58	2.63	29.4	1.68	3.01	24.1	1.80	3.43	19.6	1.96	3.87	16.5	2.11	4.26
110	174.8	1.14	0.82	106.9	1.24	1.23	77.4	1.34	1.57	54.5	1.45	2.07	39.3	1.58	2.64	32.3	1.68	3.02	26.5	1.80	3.43	21.5	1.95	3.90	18.1	2.10	4.30
120	190.3	1.14	0.82	116.5	1.24	1.23	84.3	1.34	1.58	59.4	1.45	2.07	42.8	1.58	2.65	35.2	1.68	3.02	28.9	1.80	3.43	23.4	1.94	3.92	19.7	2.09	4.33
130	205.7	1.14	0.82	126.0	1.24	1.23	91.2	1.34	1.58	64.2	1.45	2.08	46.4	1.58	2.64	38.1	1.68	3.03	31.3	1.80	3.43	25.4	1.95	3.90	21.3	2.09	4.35
140	221.0	1.14	0.82	135.4	1.24	1.24	98.0	1.34	1.58	69.1	1.45	2.08	49.9	1.58	2.64	41.0	1.68	3.03	33.6	1.80	3.46	27.3	1.95	3.92	22.9	2.08	4.37
150	236.3	1.14	0.83	144.9	1.25	1.24	104.9	1.34	1.58	73.9	1.45	2.08	53.4	1.58	2.65	43.9	1.68	3.03	36.0	1.80	3.45	29.2	1.95	3.93	24.5	2.08	4.38
160	251.5	1.14	0.83	154.3	1.25	1.24	111.7	1.34	1.59	78.7	1.45	2.09	56.9	1.58	2.65	46.7	1.67	3.05	38.3	1.79	3.47	31.1	1.94	3.94	26.1	2.08	4.40
170	266.6	1.14	0.83	163.7	1.25	1.24	118.5	1.34	1.59	83.6	1.45	2.08	60.3	1.58	2.66	49.6	1.68	3.05	40.7	1.80	3.46	33.0	1.94	3.95	27.7	2.07	4.41
180	281.7	1.14	0.83	173.0	1.25	1.24	125.2	1.34	1.59	88.4	1.45	2.09	63.8	1.58	2.66	52.5	1.68	3.04	43.0	1.79	3.48	34.9	1.94	3.96	29.3	2.07	4.41
190	296.7	1.14	0.83	182.3	1.25	1.24	132.0	1.34	1.59	93.2	1.45	2.09	67.3	1.58	2.66	55.3	1.68	3.06	45.4	1.80	3.47	36.8	1.94	3.97	30.8	2.06	4.46
200	311.7	1.14	0.83	191.6	1.25	1.24	138.7	1.34	1.60	97.9	1.45	2.10	70.7	1.58	2.67	58.2	1.68	3.05	47.7	1.79	3.49	38.7	1.94	3.97	32.4	2.06	4.47
220	342.1	1.14	0.83	210.4	1.25	1.25	152.4	1.35	1.60	107.6	1.45	2.10	77.7	1.58	2.67	63.9	1.68	3.06	52.5	1.80	3.47	42.5	1.93	3.99	35.6	2.06	4.48
240	372.4	1.14	0.84	229.2	1.25	1.25	165.9	1.34	1.60	117.2	1.45	2.10	84.7	1.58	2.67	69.7	1.68	3.06	57.2	1.80	3.48	46.4	1.94	3.97	38.8	2.06	4.49
260	402.5	1.14	0.84	247.9	1.25	1.25	179.5	1.34	1.60	126.8	1.45	2.10	91.7	1.58	2.67	75.4	1.68	3.07	61.9	1.80	3.49	50.2	1.94	3.99	42.0	2.06	4.49
280	432.6	1.14	0.84	266.5	1.25	1.25	193.0	1.34	1.61	136.4	1.45	2.10	98.6	1.58	2.68	81.1	1.68	3.07	66.6	1.80	3.49	54.0	1.94	3.99	45.2	2.06	4.49
300	462.5	1.14	0.84	285.1	1.25	1.25	206.5	1.35	1.61	146.0	1.46	2.10	105.5	1.58	2.69	86.8	1.68	3.07	71.2	1.79	3.51	57.8	1.94	4.00	48.4	2.06	4.50

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 3.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2
15	28.1	0.98	0.80	19.2	1.05	1.10	13.4	1.15	1.44	10.3	1.24	1.74	7.6	1.37	2.12
20	37.4	0.98	0.80	25.6	1.05	1.10	17.8	1.14	1.46	13.7	1.23	1.76	10.0	1.33	2.22
25	46.7	0.99	0.80	31.9	1.05	1.11	22.2	1.14	1.47	17.0	1.21	1.80	12.5	1.33	2.23
30	55.9	0.99	0.81	38.2	1.05	1.11	26.6	1.14	1.47	20.3	1.20	1.82	14.9	1.31	2.27
35	65.0	0.99	0.81	44.4	1.04	1.12	31.0	1.14	1.47	23.7	1.21	1.81	17.3	1.30	2.30
40	74.1	0.99	0.81	50.6	1.04	1.12	35.3	1.14	1.48	27.0	1.20	1.83	19.7	1.29	2.33
45	83.2	0.99	0.81	56.8	1.04	1.13	39.7	1.14	1.48	30.3	1.20	1.84	22.1	1.29	2.34
50	92.2	0.99	0.81	63.0	1.04	1.13	44.0	1.14	1.48	33.6	1.20	1.84	24.6	1.30	2.32
55	101.1	0.99	0.82	69.1	1.04	1.13	48.3	1.14	1.49	36.9	1.20	1.84	27.0	1.30	2.34
60	110.1	0.99	0.82	75.3	1.05	1.13	52.6	1.14	1.49	40.2	1.20	1.85	29.4	1.29	2.34
65	118.9	0.99	0.82	81.4	1.05	1.13	56.9	1.14	1.49	43.4	1.20	1.86	31.8	1.29	2.35
70	127.8	0.99	0.82	87.4	1.04	1.14	61.1	1.14	1.50	46.7	1.20	1.86	34.2	1.29	2.35
75	136.6	0.99	0.82	93.5	1.05	1.14	65.4	1.14	1.50	49.9	1.20	1.87	36.6	1.29	2.35
80	145.3	0.99	0.83	99.5	1.05	1.14	69.6	1.14	1.50	53.1	1.20	1.87	38.9	1.29	2.37
90	163.1	0.99	0.83	111.7	1.05	1.14	78.2	1.14	1.50	59.7	1.20	1.87	43.7	1.29	2.38
100	180.8	0.99	0.83	123.8	1.05	1.15	86.7	1.14	1.51	66.2	1.20	1.88	48.5	1.29	2.38
110	198.3	0.99	0.83	135.9	1.05	1.15	95.2	1.14	1.51	72.7	1.20	1.88	53.3	1.29	2.38
120	215.8	0.99	0.83	148.0	1.05	1.15	103.7	1.14	1.51	79.2	1.20	1.88	58.1	1.29	2.38
130	233.3	0.99	0.83	160.0	1.05	1.15	112.1	1.14	1.51	85.7	1.20	1.88	62.8	1.29	2.39
140	250.6	0.99	0.84	171.9	1.05	1.15	120.5	1.14	1.52	92.1	1.20	1.89	67.6	1.29	2.38
150	267.8	0.99	0.84	183.8	1.05	1.16	128.9	1.14	1.52	98.5	1.20	1.89	72.3	1.29	2.39
160	285.0	0.99	0.84	195.7	1.05	1.16	137.2	1.14	1.52	104.9	1.20	1.89	77.0	1.29	2.39
170	302.0	0.99	0.84	207.5	1.05	1.16	145.5	1.14	1.52	111.3	1.20	1.89	81.7	1.29	2.40
180	319.0	0.99	0.84	219.2	1.05	1.16	153.8	1.14	1.53	117.7	1.20	1.89	86.4	1.29	2.40
190	335.9	0.99	0.85	231.0	1.05	1.16	162.1	1.14	1.53	124.0	1.20	1.90	91.1	1.30	2.40
200	352.7	0.99	0.85	242.6	1.05	1.16	170.3	1.14	1.53	130.3	1.20	1.90	95.7	1.29	2.40
220	387.1	0.99	0.85	266.3	1.05	1.17	187.0	1.14	1.53	143.1	1.20	1.90	105.1	1.29	2.41
240	421.2	0.99	0.85	289.9	1.05	1.17	203.6	1.14	1.53	155.9	1.20	1.90	114.5	1.29	2.41
260	455.2	0.99	0.85	313.4	1.05	1.17	220.2	1.14	1.54	168.6	1.20	1.91	123.9	1.30	2.41
280	489.0	0.99	0.85	336.9	1.05	1.17	236.7	1.14	1.54	181.3	1.20	1.91	133.3	1.30	2.41
300	522.6	0.99	0.86	360.2	1.05	1.17	253.2	1.15	1.54	193.9	1.20	1.91	142.6	1.30	2.42

Q cfs	V_1 = 4.5 T	D	V_2	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15	5.8	1.56	2.44									
20	7.6	1.50	2.59	6.8	1.58	2.74						
25	9.4	1.46	2.69	8.4	1.54	2.85	6.9	1.68	3.18			
30	11.2	1.44	2.75	9.9	1.48	3.02	8.2	1.64	3.28	6.7	1.88	3.50
35	13.0	1.43	2.80	11.5	1.47	3.07	9.5	1.62	3.36	7.7	1.82	3.68
40	14.8	1.42	2.83	13.1	1.46	3.10	10.8	1.60	3.42	8.7	1.78	3.82
45	16.6	1.41	2.85	14.7	1.45	3.12	12.1	1.59	3.46	9.7	1.75	3.92
50	18.4	1.40	2.87	16.3	1.45	3.14	13.4	1.58	3.50	10.7	1.72	4.01
55	20.2	1.40	2.88	17.9	1.45	3.15	14.7	1.57	3.53	11.7	1.70	4.09
60	22.0	1.40	2.89	19.5	1.45	3.16	16.0	1.57	3.55	12.7	1.69	4.15
65	23.8	1.40	2.90	21.1	1.45	3.16	17.3	1.57	3.56	13.8	1.70	4.11
70	25.6	1.40	2.90	22.7	1.45	3.17	18.5	1.55	3.63	14.8	1.69	4.16
75	27.4	1.40	2.91	24.2	1.44	3.21	19.8	1.55	3.64	15.8	1.68	4.20
80	29.2	1.40	2.91	25.8	1.44	3.21	21.1	1.55	3.64	16.9	1.69	4.16
90	32.7	1.39	2.94	29.0	1.44	3.21	23.7	1.54	3.66	18.9	1.67	4.23
100	36.3	1.39	2.95	32.2	1.44	3.21	26.3	1.54	3.67	21.0	1.67	4.23
110	39.9	1.39	2.95	35.4	1.44	3.21	28.9	1.54	3.67	23.1	1.68	4.22
120	43.5	1.39	2.95	38.5	1.43	3.23	31.5	1.54	3.68	25.1	1.67	4.27
130	47.0	1.39	2.96	41.7	1.44	3.23	34.1	1.54	3.68	27.2	1.67	4.26
140	50.6	1.39	2.96	44.8	1.43	3.24	36.7	1.54	3.68	29.3	1.67	4.25
150	54.1	1.39	2.97	48.0	1.44	3.24	39.3	1.55	3.68	31.3	1.67	4.28
160	57.7	1.39	2.96	51.1	1.44	3.25	41.8	1.54	3.70	33.4	1.67	4.27
170	61.2	1.39	2.97	54.3	1.44	3.24	44.4	1.54	3.70	35.4	1.67	4.29
180	64.7	1.39	2.98	57.4	1.44	3.25	47.0	1.55	3.69	37.5	1.67	4.28
190	68.2	1.39	2.98	60.5	1.44	3.25	49.5	1.54	3.71	39.5	1.67	4.30
200	71.7	1.39	2.99	63.6	1.44	3.26	52.1	1.55	3.70	41.6	1.67	4.28
220	78.8	1.39	2.99	69.9	1.44	3.26	57.2	1.54	3.71	45.7	1.67	4.29
240	85.9	1.39	2.99	76.2	1.44	3.26	62.3	1.54	3.72	49.8	1.67	4.30
260	92.9	1.39	2.99	82.4	1.44	3.27	67.5	1.55	3.72	53.9	1.67	4.31
280	99.9	1.39	3.00	88.6	1.44	3.27	72.6	1.55	3.72	58.0	1.67	4.31
300	106.9	1.39	3.00	94.9	1.44	3.27	77.7	1.55	3.73	62.0	1.67	4.33

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 4.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2
15	33.1	0.87	0.77	23.6	0.93	1.01	16.3	1.00	1.36	12.1	1.08	1.69	9.2	1.15	2.08
20	44.0	0.87	0.77	31.4	0.93	1.01	21.7	1.00	1.37	16.1	1.08	1.70	12.3	1.16	2.08
25	54.9	0.87	0.77	39.1	0.93	1.02	27.1	1.00	1.37	20.1	1.08	1.71	15.3	1.15	2.11
30	65.7	0.87	0.78	46.8	0.93	1.02	32.4	0.99	1.38	24.0	1.07	1.73	18.3	1.14	2.13
35	76.4	0.87	0.78	54.5	0.93	1.02	37.7	0.99	1.39	27.9	1.07	1.74	21.3	1.14	2.14
40	87.1	0.87	0.78	62.1	0.93	1.03	43.0	0.99	1.39	31.9	1.07	1.74	24.3	1.14	2.15
45	97.7	0.87	0.78	69.7	0.93	1.03	48.3	0.99	1.39	35.8	1.07	1.74	27.2	1.13	2.17
50	108.3	0.87	0.78	77.3	0.93	1.03	53.5	0.99	1.40	39.7	1.07	1.75	30.2	1.13	2.17
55	118.8	0.87	0.78	84.7	0.93	1.04	58.7	0.99	1.40	43.6	1.07	1.75	33.2	1.13	2.17
60	129.2	0.87	0.79	92.2	0.93	1.04	63.9	0.99	1.40	47.4	1.07	1.76	36.1	1.13	2.18
65	139.6	0.87	0.79	99.6	0.93	1.04	69.1	0.99	1.41	51.3	1.07	1.76	39.0	1.13	2.19
70	149.9	0.88	0.79	107.0	0.93	1.04	74.2	0.99	1.41	55.1	1.07	1.77	42.0	1.13	2.19
75	160.2	0.88	0.79	114.3	0.93	1.05	79.3	0.99	1.42	58.9	1.07	1.77	44.9	1.13	2.19
80	170.4	0.88	0.79	121.6	0.93	1.05	84.4	0.99	1.42	62.7	1.07	1.77	47.8	1.13	2.20
90	191.1	0.88	0.80	136.5	0.93	1.05	94.8	0.99	1.42	70.4	1.07	1.78	53.7	1.13	2.20
100	211.8	0.88	0.80	151.2	0.93	1.05	105.1	0.99	1.42	78.1	1.07	1.78	59.6	1.13	2.20
110	232.3	0.88	0.80	165.9	0.93	1.06	115.3	0.99	1.43	85.8	1.07	1.78	65.4	1.13	2.21
120	252.7	0.88	0.80	180.5	0.93	1.06	125.5	0.99	1.43	93.4	1.07	1.78	71.2	1.13	2.22
130	273.0	0.88	0.80	195.1	0.93	1.06	135.6	0.99	1.43	101.0	1.07	1.79	77.0	1.13	2.22
140	293.2	0.88	0.80	209.5	0.93	1.06	145.7	0.99	1.44	108.5	1.07	1.79	82.8	1.13	2.22
150	313.3	0.88	0.81	223.9	0.93	1.07	155.8	0.99	1.44	116.0	1.07	1.80	88.6	1.13	2.22
160	333.2	0.88	0.81	238.2	0.93	1.07	165.8	1.00	1.44	123.5	1.07	1.80	94.3	1.13	2.23
170	353.1	0.88	0.81	252.4	0.93	1.07	175.8	1.00	1.44	131.0	1.07	1.80	100.0	1.13	2.23
180	372.8	0.88	0.81	266.5	0.93	1.07	185.7	1.00	1.45	138.4	1.07	1.80	105.7	1.13	2.24
190	392.4	0.88	0.81	280.6	0.93	1.08	195.6	1.00	1.45	145.8	1.07	1.81	111.4	1.13	2.24
200	411.9	0.88	0.82	294.6	0.93	1.08	205.4	1.00	1.45	153.2	1.07	1.81	117.1	1.14	2.24
220	451.9	0.88	0.82	323.2	0.93	1.08	225.4	1.00	1.46	168.2	1.07	1.81	128.6	1.14	2.24
240	491.5	0.88	0.82	351.6	0.93	1.09	245.3	1.00	1.46	183.2	1.07	1.81	140.0	1.14	2.25
260	531.0	0.88	0.82	379.9	0.93	1.09	265.2	1.00	1.46	198.0	1.07	1.82	151.5	1.14	2.25
280	570.3	0.88	0.82	408.0	0.93	1.09	284.9	1.00	1.47	212.9	1.08	1.82	162.8	1.14	2.25
300	609.3	0.88	0.83	436.0	0.93	1.09	304.6	1.00	1.47	227.6	1.08	1.83	174.2	1.14	2.25

Q cfs	V_1 = 4.5 T	D	V_2	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15	7.4	1.27	2.34	5.7	1.43	2.69						
20	9.7	1.23	2.48	7.4	1.35	2.94	6.4	1.47	3.12			
25	12.1	1.22	2.50	9.2	1.33	3.01	7.9	1.43	3.26	6.5	1.56	3.62
30	14.4	1.20	2.57	11.0	1.32	3.05	9.3	1.38	3.46	7.7	1.52	3.78
35	16.8	1.20	2.57	12.7	1.30	3.14	10.9	1.39	3.42	8.9	1.49	3.90
40	19.2	1.21	2.56	14.5	1.30	3.15	12.4	1.38	3.47	10.2	1.50	3.87
45	21.5	1.20	2.59	16.3	1.30	3.16	13.9	1.37	3.51	11.4	1.48	3.95
50	23.9	1.20	2.58	18.1	1.30	3.16	15.4	1.36	3.54	12.6	1.46	4.01
55	26.2	1.20	2.60	19.8	1.29	3.21	16.9	1.36	3.56	13.8	1.45	4.06
60	28.5	1.19	2.62	21.6	1.29	3.20	18.4	1.36	3.57	15.1	1.46	4.02
65	30.9	1.20	2.61	23.4	1.29	3.19	19.9	1.35	3.58	16.3	1.46	4.06
70	33.2	1.20	2.62	25.1	1.28	3.23	21.4	1.35	3.59	17.5	1.45	4.09
75	35.5	1.20	2.62	26.9	1.29	3.22	22.9	1.35	3.60	18.7	1.45	4.12
80	37.8	1.20	2.63	28.6	1.28	3.24	24.4	1.35	3.60	20.0	1.46	4.08
90	42.4	1.19	2.65	32.1	1.28	3.26	27.4	1.35	3.62	22.4	1.45	4.13
100	47.1	1.20	2.64	35.7	1.29	3.24	30.4	1.35	3.63	24.9	1.45	4.12
110	51.7	1.19	2.65	39.2	1.29	3.25	33.4	1.35	3.63	27.3	1.44	4.16
120	56.3	1.19	2.66	42.7	1.28	3.26	36.3	1.34	3.66	29.8	1.45	4.14
130	60.9	1.19	2.66	46.2	1.29	3.26	39.3	1.34	3.66	32.2	1.44	4.16
140	65.5	1.20	2.66	49.6	1.28	3.28	42.3	1.35	3.66	34.6	1.44	4.18
150	70.1	1.20	2.66	53.1	1.28	3.28	45.3	1.35	3.66	37.1	1.45	4.17
160	74.6	1.20	2.67	56.6	1.28	3.28	48.2	1.35	3.67	39.5	1.44	4.18
170	79.2	1.20	2.67	60.0	1.28	3.29	51.2	1.35	3.67	41.9	1.44	4.19
180	83.7	1.20	2.68	63.5	1.28	3.29	54.1	1.35	3.68	44.3	1.44	4.20
190	88.2	1.20	2.68	66.9	1.28	3.30	57.0	1.34	3.69	46.7	1.44	4.21
200	92.7	1.20	2.68	70.3	1.28	3.30	60.0	1.35	3.68	49.1	1.44	4.21
220	101.9	1.20	2.68	77.2	1.28	3.31	65.9	1.35	3.69	54.0	1.44	4.21
240	110.9	1.20	2.69	84.1	1.28	3.32	71.8	1.35	3.70	58.8	1.44	4.22
260	120.0	1.20	2.69	91.0	1.28	3.32	77.7	1.35	3.70	63.7	1.44	4.21
280	129.0	1.20	2.70	97.9	1.28	3.32	83.5	1.35	3.71	68.5	1.44	4.22
300	138.1	1.20	2.69	104.8	1.29	3.32	89.4	1.35	3.71	73.3	1.44	4.23

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 5.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	34.8	0.80	0.79	25.2	0.86	1.02	17.7	0.92	1.36
20	46.3	0.80	0.79	33.5	0.86	1.02	23.5	0.92	1.37
25	57.7	0.80	0.80	41.7	0.86	1.03	29.3	0.92	1.38
30	69.0	0.80	0.80	49.9	0.86	1.04	35.0	0.91	1.39
35	80.3	0.80	0.80	58.1	0.86	1.04	40.8	0.91	1.39
40	91.5	0.81	0.80	66.2	0.86	1.04	46.5	0.91	1.40
45	102.6	0.81	0.81	74.2	0.86	1.05	52.2	0.91	1.40
50	113.7	0.81	0.81	82.3	0.86	1.05	57.9	0.92	1.40
55	124.7	0.81	0.81	90.2	0.86	1.05	63.5	0.91	1.41
60	135.7	0.81	0.81	98.2	0.86	1.05	69.1	0.91	1.41
65	146.5	0.81	0.81	106.1	0.86	1.05	74.7	0.92	1.41
70	157.3	0.81	0.82	113.9	0.86	1.06	80.2	0.91	1.42
75	168.1	0.81	0.82	121.7	0.86	1.06	85.8	0.92	1.42
80	178.8	0.81	0.82	129.4	0.86	1.06	91.3	0.92	1.42
90	200.5	0.81	0.82	145.2	0.86	1.07	102.4	0.92	1.43
100	222.2	0.81	0.82	160.9	0.86	1.07	113.5	0.92	1.43
110	243.7	0.81	0.82	176.5	0.86	1.07	124.6	0.92	1.43
120	265.0	0.81	0.83	192.0	0.86	1.07	135.6	0.92	1.43
130	286.3	0.81	0.83	207.5	0.86	1.08	146.6	0.92	1.43
140	307.4	0.81	0.83	222.8	0.86	1.08	157.5	0.92	1.44
150	328.4	0.81	0.83	238.1	0.87	1.08	168.3	0.92	1.44
160	349.3	0.81	0.83	253.2	0.86	1.08	179.1	0.92	1.44
170	370.0	0.81	0.84	268.3	0.87	1.09	189.9	0.92	1.45
180	390.7	0.82	0.84	283.3	0.87	1.09	200.6	0.92	1.45
190	411.2	0.82	0.84	298.2	0.87	1.09	211.2	0.92	1.45
200	431.6	0.82	0.84	313.0	0.87	1.09	221.8	0.92	1.46
220	473.3	0.82	0.84	343.4	0.87	1.10	243.4	0.92	1.46
240	514.8	0.82	0.84	373.6	0.87	1.10	264.9	0.92	1.46
260	556.1	0.82	0.85	403.6	0.87	1.10	286.3	0.92	1.46
280	597.1	0.82	0.85	433.5	0.87	1.10	307.6	0.92	1.47
300	638.0	0.82	0.85	463.1	0.87	1.11	328.7	0.92	1.47

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15	14.3	0.96	1.61	10.6	1.04	2.00	8.4	1.12	2.34
20	19.0	0.96	1.62	14.1	1.04	2.02	11.1	1.10	2.41
25	23.7	0.96	1.63	17.5	1.03	2.06	13.8	1.09	2.46
30	28.3	0.95	1.65	21.0	1.03	2.06	16.6	1.10	2.44
35	33.0	0.95	1.65	24.4	1.02	2.08	19.3	1.09	2.46
40	37.6	0.95	1.66	27.8	1.02	2.09	22.0	1.09	2.47
45	42.2	0.95	1.66	31.3	1.03	2.08	24.7	1.09	2.48
50	46.8	0.95	1.66	34.7	1.03	2.08	27.3	1.08	2.51
55	51.4	0.96	1.66	38.0	1.02	2.11	30.0	1.08	2.51
60	56.0	0.96	1.66	41.4	1.02	2.11	32.7	1.08	2.51
65	60.5	0.96	1.67	44.8	1.02	2.10	35.3	1.08	2.53
70	65.0	0.96	1.67	48.1	1.02	2.11	38.0	1.08	2.53
75	69.5	0.96	1.67	51.4	1.02	2.12	40.6	1.08	2.54
80	74.0	0.96	1.67	54.8	1.02	2.12	43.3	1.09	2.53
90	83.0	0.96	1.68	61.5	1.02	2.12	48.6	1.08	2.54
100	92.1	0.96	1.68	68.2	1.02	2.13	53.9	1.08	2.54
110	101.0	0.96	1.69	74.8	1.02	2.14	59.2	1.09	2.55
120	110.0	0.96	1.69	81.4	1.02	2.15	64.4	1.08	2.56
130	118.9	0.96	1.69	88.1	1.02	2.14	69.7	1.09	2.56
140	127.8	0.96	1.69	94.6	1.02	2.15	74.9	1.08	2.57
150	136.[illegible]	0.96	1.70	101.2	1.02	2.15	80.1	1.08	2.57
160	145.4	0.96	1.70	107.7	1.02	2.16	85.3	1.09	2.57
170	154.1	0.96	1.70	114.2	1.02	2.16	90.4	1.08	2.58
180	162.9	0.96	1.70	120.7	1.02	2.17	95.6	1.09	2.58
190	171.5	0.96	1.71	127.1	1.02	2.17	100.7	1.08	2.59
200	180.2	0.96	1.71	133.5	1.02	2.18	105.8	1.09	2.59
220	197.8	0.97	1.71	146.6	1.02	2.18	116.2	1.09	2.60
240	215.3	0.97	1.72	159.6	1.02	2.18	126.5	1.09	2.60
260	232.7	0.97	1.72	172.6	1.03	2.19	136.8	1.09	2.61
280	250.1	0.97	1.72	185.5	1.03	2.19	147.1	1.09	2.61
300	267.4	0.97	1.73	198.4	1.03	2.19	157.3	1.09	2.61

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15	6.7	1.23	2.67	5.4	1.36	3.00			
20	8.8	1.19	2.81	7.0	1.28	3.29	6.1	1.40	3.44
25	10.9	1.17	2.90	8.7	1.26	3.37	7.5	1.35	3.64
30	13.0	1.15	2.96	10.4	1.25	3.41	8.9	1.32	3.78
35	15.2	1.16	2.94	12.1	1.24	3.45	10.3	1.30	3.87
40	17.3	1.15	2.97	13.8	1.24	3.47	11.8	1.30	3.85
45	19.4	1.15	2.99	15.4	1.22	3.55	13.2	1.29	3.91
50	21.5	1.15	3.01	17.1	1.22	3.55	14.7	1.30	3.88
55	23.7	1.15	2.98	18.8	1.22	3.55	16.1	1.29	3.93
60	25.8	1.15	3.00	20.5	1.22	3.55	17.5	1.28	3.97
65	27.9	1.15	3.00	22.1	1.22	3.59	18.9	1.28	4.00
70	30.0	1.15	3.01	23.8	1.22	3.58	20.4	1.29	3.96
75	32.0	1.15	3.04	25.4	1.21	3.62	21.8	1.28	3.98
80	34.1	1.15	3.04	27.1	1.22	3.61	23.2	1.28	4.00
90	38.3	1.15	3.05	30.4	1.21	3.63	26.1	1.28	4.00
100	42.5	1.15	3.05	33.8	1.22	3.61	28.9	1.28	4.03
110	46.7	1.15	3.05	37.1	1.22	3.63	31.8	1.28	4.02
120	50.8	1.15	3.07	40.4	1.21	3.64	34.6	1.28	4.04
130	55.0	1.15	3.06	43.7	1.21	3.65	37.5	1.28	4.03
140	59.1	1.15	3.07	47.0	1.21	3.65	40.3	1.28	4.04
150	63.2	1.15	3.08	50.2	1.21	3.67	43.1	1.28	4.05
160	67.3	1.15	3.09	53.5	1.21	3.67	45.9	1.28	4.06
170	71.4	1.15	3.09	56.8	1.21	3.67	48.7	1.28	4.07
180	75.5	1.15	3.09	60.0	1.21	3.69	51.5	1.28	4.07
190	79.6	1.15	3.09	63.3	1.21	3.68	54.3	1.28	4.07
200	83.6	1.15	3.10	66.5	1.21	3.69	57.1	1.28	4.08
220	91.9	1.15	3.10	73.1	1.22	3.69	62.7	1.28	4.09
240	100.1	1.15	3.10	79.6	1.21	3.70	68.3	1.28	4.09
260	108.2	1.15	3.11	86.1	1.21	3.71	73.9	1.28	4.10
280	116.4	1.15	3.11	92.6	1.21	3.71	79.5	1.28	4.10
300	124.5	1.15	3.12	99.1	1.22	3.71	85.1	1.28	4.10

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 6.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2
15	40.5	0.72	0.76	26.9	0.81	1.02	19.6	0.85	1.34	14.8	0.90	1.66	11.7	0.96	1.97
20	53.9	0.72	0.76	35.7	0.81	1.03	26.1	0.85	1.34	19.6	0.89	1.69	15.6	0.96	1.97
25	67.1	0.72	0.76	44.5	0.81	1.03	32.5	0.85	1.35	24.5	0.90	1.69	19.4	0.95	2.00
30	80.3	0.72	0.76	53.2	0.80	1.04	38.9	0.85	1.35	29.3	0.89	1.70	23.3	0.96	1.99
35	93.4	0.72	0.76	61.9	0.81	1.04	45.3	0.85	1.35	34.1	0.89	1.70	27.1	0.96	2.00
40	106.4	0.73	0.77	70.6	0.81	1.04	51.6	0.85	1.36	38.9	0.89	1.71	30.9	0.95	2.01
45	119.3	0.73	0.77	79.2	0.81	1.04	57.9	0.85	1.36	43.7	0.90	1.71	34.6	0.95	2.03
50	132.1	0.73	0.77	87.7	0.81	1.05	64.1	0.84	1.37	48.4	0.89	1.71	38.4	0.95	2.03
55	144.9	0.73	0.77	96.2	0.81	1.05	70.4	0.85	1.37	53.1	0.89	1.72	42.2	0.95	2.03
60	157.5	0.73	0.77	104.6	0.81	1.05	76.5	0.84	1.38	57.8	0.89	1.72	45.9	0.95	2.04
65	170.1	0.73	0.78	113.0	0.81	1.06	82.7	0.85	1.38	62.5	0.90	1.72	49.6	0.95	2.04
70	182.6	0.73	0.78	121.3	0.81	1.06	88.8	0.85	1.38	67.2	0.90	1.72	53.3	0.95	2.05
75	195.1	0.73	0.78	129.6	0.81	1.06	94.9	0.85	1.39	71.8	0.90	1.73	57.0	0.95	2.05
80	207.4	0.73	0.78	137.8	0.81	1.06	100.9	0.85	1.39	76.4	0.90	1.73	60.6	0.95	2.06
90	232.6	0.73	0.78	154.5	1.81	1.07	113.2	0.85	1.40	85.8	0.90	1.73	68.1	0.95	2.06
100	257.7	0.73	0.78	171.2	0.81	1.07	125.5	0.85	1.40	95.1	0.90	1.74	75.5	0.95	2.06
110	282.6	0.74	0.78	187.8	0.81	1.07	137.7	0.85	1.40	104.4	0.90	1.74	82.8	0.95	2.07
120	307.3	0.74	0.79	204.2	0.81	1.08	149.8	0.85	1.40	113.6	0.90	1.74	90.2	0.95	2.07
130	331.9	0.74	0.79	220.6	0.81	1.08	161.9	0.85	1.41	122.8	0.90	1.75	97.5	0.95	2.08
140	356.3	0.74	0.79	236.8	0.81	1.08	173.9	0.85	1.41	131.9	0.90	1.75	104.7	0.95	2.09
150	380.5	0.74	0.79	253.0	0.81	1.09	185.8	0.85	1.41	141.0	0.90	1.75	112.0	0.96	2.09
160	404.6	0.74	0.79	269.0	0.81	1.09	197.7	0.85	1.42	150.1	0.90	1.76	119.2	0.96	2.09
170	428.6	0.74	0.79	285.0	0.81	1.09	209.5	0.85	1.42	159.1	0.90	1.76	126.4	0.96	2.09
180	452.4	0.74	0.79	300.8	0.61	1.09	221.3	0.85	1.42	168.1	0.90	1.76	133.5	0.96	2.10
190	476.1	0.74	0.80	316.6	0.81	1.10	233.0	0.85	1.42	177.0	0.90	1.77	140.6	0.96	2.10
200	499.6	0.74	0.80	332.3	0.81	1.10	244.6	0.85	1.43	185.9	0.90	1.77	147.7	0.96	2.11
220	547.7	0.74	0.80	364.5	0.81	1.10	268.4	0.85	1.43	204.1	0.91	1.77	162.1	0.96	2.11
240	595.6	0.74	0.80	396.5	0.81	1.11	292.1	0.85	1.43	222.1	0.91	1.78	176.5	0.96	2.11
260	643.2	0.74	0.80	428.3	0.81	1.11	315.7	0.85	1.43	240.1	0.91	1.78	190.7	0.96	2.12
280	690.5	0.75	0.81	459.9	0.81	1.11	339.1	0.85	1.44	258.0	0.91	1.78	205.0	0.96	2.12
300	737.5	0.75	0.81	491.4	0.81	1.11	362.4	0.85	1.44	275.8	0.91	1.78	219.1	0.96	2.13

Q cfs	V_1 = 4.5 T	D	V_2	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15	9.4	1.02	2.31	7.6	1.09	2.67	6.1	1.18	3.05	5.0	1.32	3.33
20	12.5	1.01	2.33	10.1	1.08	2.71	8.0	1.14	3.23	6.5	1.24	3.63
25	15.5	1.00	2.39	12.5	1.06	2.80	10.0	1.14	3.24	8.1	1.23	3.69
30	18.6	1.00	2.39	15.0	1.06	2.80	11.9	1.12	3.32	9.6	1.20	3.84
35	21.6	0.99	2.42	17.4	1.05	2.84	13.9	1.13	3.31	11.2	1.20	3.84
40	24.7	1.00	2.41	19.9	1.05	2.83	15.8	1.12	3.36	12.7	1.19	3.93
45	27.7	1.00	2.42	22.3	1.05	2.86	17.7	1.11	3.40	14.3	1.19	3.92
50	30.7	0.99	2.43	24.7	1.05	2.87	19.7	1.12	3.38	15.8	1.18	3.98
55	33.7	0.99	2.44	27.1	1.04	2.89	21.6	1.11	3.40	17.4	1.18	3.96
60	36.7	1.00	2.44	29.6	1.05	2.87	23.5	1.11	3.42	18.9	1.18	4.01
65	39.7	1.00	2.44	32.0	1.05	2.88	25.4	1.11	3.43	20.5	1.18	3.98
70	42.7	1.00	2.44	34.4	1.05	2.88	27.4	1.11	3.41	22.0	1.18	4.01
75	45.6	1.00	2.46	36.7	1.04	2.91	29.3	1.11	3.42	23.6	1.18	3.99
80	48.6	1.00	2.45	39.1	1.05	2.91	31.2	1.11	3.42	25.1	1.18	4.02
90	54.6	1.00	2.45	43.9	1.05	2.92	35.0	1.11	3.44	28.2	1.18	4.02
100	60.5	1.00	2.46	48.7	1.05	2.92	38.8	1.11	3.46	31.3	1.18	4.03
110	66.4	1.00	2.47	53.5	1.05	2.92	42.6	1.11	3.47	34.4	1.18	4.03
120	72.3	1.00	2.47	58.3	1.05	2.92	46.4	1.11	3.47	37.4	1.18	4.06
130	78.2	1.00	2.48	63.0	1.05	2.93	50.2	1.11	3.48	40.5	1.18	4.05
140	84.0	1.00	2.48	67.7	1.05	2.94	54.0	1.11	3.48	43.5	1.18	4.07
150	89.9	1.00	2.48	72.5	1.05	2.93	57.8	1.11	3.48	46.6	1.18	4.06
160	95.7	1.00	2.49	77.2	1.05	2.94	61.5	1.11	3.49	49.6	1.18	4.08
170	101.5	1.00	2.49	81.8	1.05	2.95	65.3	1.11	3.49	52.7	1.18	4.07
180	107.2	1.00	2.50	86.5	1.05	2.95	69.0	1.11	3.49	55.7	1.18	4.08
190	113.0	1.00	2.50	91.1	1.05	2.96	72.7	1.11	3.50	58.7	1.18	4.08
200	118.7	1.00	2.50	95.8	1.05	2.96	76.4	1.11	3.51	61.7	1.18	4.09
220	130.3	1.00	2.51	105.2	1.05	2.96	83.9	1.11	3.51	67.8	1.18	4.09
240	141.9	1.00	2.51	114.5	1.05	2.97	91.4	1.11	3.52	73.8	1.18	4.11
260	153.4	1.00	2.52	123.9	1.05	2.97	98.9	1.11	3.52	79.9	1.18	4.10
280	164.9	1.00	2.52	133.2	1.05	2.97	106.3	1.11	3.53	85.9	1.18	4.11
300	176.3	1.00	2.52	142.4	1.05	2.98	113.7	1.11	3.53	91.9	1.18	4.12

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 8.0 Percent

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	43.1	0.64	0.80	31.6	0.71	0.98	22.2	0.76	1.31	18.0	0.79	1.56	13.7	0.84	1.92	11.0	0.89	2.26	9.2	0.95	2.54	7.4	0.99	3.00	6.2	1.09	3.26
20	57.3	0.64	0.80	42.0	0.71	0.99	29.5	0.76	1.32	24.0	0.79	1.56	18.2	0.84	1.94	14.7	0.89	2.25	12.2	0.93	2.59	9.8	0.98	3.08	8.1	1.04	3.49
25	71.4	0.65	0.80	52.3	0.71	0.99	36.7	0.76	1.33	29.9	0.79	1.57	22.7	0.84	1.95	18.3	0.89	2.28	15.2	0.93	2.62	12.2	0.97	3.12	10.1	1.04	3.53
30	85.4	0.65	0.80	62.6	0.71	0.99	43.9	0.76	1.33	35.8	0.79	1.57	27.2	0.84	1.95	21.9	0.89	2.29	18.1	0.92	2.67	14.6	0.97	3.15	12.1	1.03	3.55
35	99.3	0.65	0.80	72.8	0.72	0.99	51.1	0.76	1.34	41.6	0.79	1.58	31.7	0.84	1.95	25.5	0.89	2.30	21.1	0.92	2.67	17.0	0.96	3.16	14.0	1.02	3.64
40	113.1	0.65	0.81	82.9	0.72	1.00	58.2	0.76	1.34	47.4	0.79	1.59	36.1	0.84	1.96	29.0	0.88	2.32	24.1	0.92	2.67	19.4	0.96	3.17	16.0	1.02	3.63
45	126.8	0.65	0.81	93.0	0.72	1.00	65.3	0.76	1.34	53.2	0.79	1.59	40.5	0.84	1.97	32.6	0.88	2.32	27.0	0.92	2.69	21.8	0.97	3.17	18.0	1.02	3.62
50	140.4	0.65	0.81	102.9	0.72	1.01	72.3	0.76	1.35	59.0	0.79	1.59	44.9	0.84	1.97	36.1	0.88	2.33	30.0	0.92	2.68	24.2	0.97	3.17	19.9	1.02	3.67
55	153.9	0.65	0.81	112.8	0.72	1.01	79.3	0.76	1.35	64.7	0.79	1.60	49.3	0.84	1.97	39.6	0.88	2.34	32.9	0.92	2.70	26.5	0.96	3.20	21.9	1.02	3.65
60	167.3	0.65	0.81	122.7	0.72	1.01	86.2	0.76	1.36	70.4	0.79	1.60	53.7	0.84	1.97	43.1	0.88	2.34	35.8	0.92	2.70	28.9	0.97	3.19	23.8	1.02	3.69
65	180.6	0.65	0.82	132.4	0.72	1.01	93.1	0.76	1.36	76.0	0.79	1.61	58.0	0.84	1.98	46.6	0.88	2.35	38.7	0.92	2.71	31.3	0.97	3.18	25.7	1.01	3.71
70	193.9	0.65	0.82	142.2	0.72	1.01	100.0	0.76	1.37	81.7	0.79	1.61	62.3	0.84	1.98	50.1	0.88	2.35	41.6	0.92	2.71	33.6	0.97	3.20	27.7	1.02	3.69
75	207.0	0.65	0.82	151.8	0.72	1.02	106.8	0.76	1.37	87.2	0.79	1.62	66.6	0.84	1.99	53.5	0.88	2.36	44.5	0.92	2.72	35.9	0.96	3.22	29.6	1.02	3.71
80	220.1	0.66	0.82	161.4	0.72	1.02	113.6	0.76	1.37	92.8	0.79	1.62	70.9	0.84	1.99	56.9	0.88	2.37	47.3	0.92	2.73	38.2	0.96	3.23	31.5	1.01	3.72
90	246.8	0.66	0.82	180.9	0.72	1.02	127.4	0.76	1.38	104.1	0.79	1.62	79.5	0.84	2.00	63.9	0.88	2.37	53.1	0.92	2.74	42.9	0.96	3.23	35.4	1.02	3.72
100	273.3	0.66	0.82	200.3	0.72	1.03	141.1	0.76	1.38	115.4	0.79	1.62	88.1	0.84	2.00	70.8	0.88	2.38	58.9	0.92	2.74	47.6	0.97	3.24	39.2	1.01	3.75
110	299.6	0.66	0.83	219.6	0.72	1.03	154.8	0.76	1.38	126.5	0.79	1.63	96.7	0.84	2.01	77.7	0.88	2.38	64.7	0.92	2.74	52.3	0.97	3.23	43.1	1.02	3.74
120	325.7	0.66	0.83	238.8	0.72	1.03	168.4	0.76	1.39	137.7	0.79	1.63	105.3	0.84	2.01	84.6	0.88	2.39	70.4	0.92	2.75	56.9	0.97	3.25	46.9	1.01	3.75
130	351.7	0.66	0.83	257.9	0.72	1.04	181.9	0.76	1.39	148.7	0.79	1.64	113.8	0.84	2.01	91.4	0.88	2.40	76.1	0.92	2.75	61.6	0.97	3.24	50.7	1.01	3.76
140	377.5	0.66	0.83	276.8	0.72	1.04	195.3	0.76	1.39	159.7	0.79	1.64	122.2	0.84	2.02	98.2	0.88	2.40	81.8	0.92	2.76	66.2	0.97	3.25	54.5	1.01	3.77
150	403.1	0.66	0.83	295.6	0.72	1.04	208.6	0.76	1.40	170.7	0.80	1.64	130.6	0.84	2.02	105.0	0.88	2.40	87.4	0.92	2.77	70.8	0.97	3.25	58.3	1.01	3.78
160	428.5	0.66	0.83	314.2	0.72	1.04	221.9	0.76	1.40	181.5	0.79	1.65	139.0	0.85	2.02	111.7	0.88	2.41	93.1	0.92	2.77	75.3	0.97	3.27	62.1	1.01	3.78
170	453.8	0.66	0.84	332.8	0.72	1.05	235.1	0.76	1.40	192.4	0.80	1.65	147.3	0.85	2.03	118.4	0.88	2.42	98.7	0.92	2.77	79.9	0.97	3.27	65.9	1.02	3.78
180	478.9	0.66	0.84	351.2	0.72	1.05	248.2	0.76	1.41	203.1	0.80	1.65	155.6	0.85	2.03	125.1	0.88	2.42	104.3	0.93	2.78	84.4	0.97	3.28	69.6	1.02	3.79
190	503.9	0.66	0.84	369.5	0.72	1.05	261.2	0.77	1.41	213.8	0.80	1.66	163.9	0.85	2.03	131.8	0.89	2.42	109.8	0.92	2.79	89.0	0.97	3.27	73.4	1.02	3.79
200	528.5	0.67	0.84	387.7	0.73	1.05	274.1	0.77	1.42	224.4	0.80	1.66	172.1	0.85	2.04	138.4	0.89	2.43	115.3	0.92	2.79	93.5	0.97	3.28	77.1	1.02	3.80
220	579.5	0.67	0.84	425.1	0.73	1.06	300.7	0.77	1.42	246.2	0.80	1.66	188.8	0.85	2.04	151.8	0.88	2.44	126.6	0.93	2.80	102.6	0.97	3.29	84.7	1.02	3.80
240	630.1	0.67	0.84	462.2	0.73	1.06	327.0	0.77	1.42	267.9	0.80	1.67	205.5	0.85	2.05	165.2	0.89	2.44	137.8	0.93	2.80	111.8	0.97	3.29	92.2	1.02	3.81
260	680.4	0.67	0.85	499.1	0.73	1.06	353.3	0.77	1.42	289.4	0.80	1.67	222.1	0.85	2.05	178.6	0.89	2.45	149.0	0.93	2.80	120.8	0.97	3.30	99.7	1.02	3.82
280	730.4	0.67	0.85	535.6	0.73	1.07	379.3	0.77	1.43	310.8	0.80	1.68	238.6	0.85	2.05	191.9	0.89	2.45	160.1	0.93	2.81	129.9	0.97	3.30	107.2	1.02	3.82
300	780.0	0.67	0.85	572.1	0.73	1.07	405.2	0.77	1.43	332.1	0.80	1.68	255.0	0.85	2.06	205.1	0.89	2.46	171.2	0.93	2.81	138.9	0.97	3.31	114.7	1.02	3.82

Source: USDA-SCS

TABLE 3.17-B (Continued)
DESIGN TABLES FOR PARABOLIC GRASS-LINED CHANNELS

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 10.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	51.4	0.56	0.77	38.3	0.63	0.92	27.2	0.69	1.18	19.6	0.73	1.56	15.7	0.76	1.86	12.6	0.81	2.18	10.6	0.85	2.45	8.7	0.90	2.83	7.2	0.94	3.28
20	68.2	0.55	0.78	50.9	0.63	0.92	36.2	0.69	1.18	26.1	0.73	1.56	20.9	0.76	1.87	16.8	0.81	2.18	14.0	0.84	2.53	11.5	0.88	2.91	9.5	0.92	3.39
25	85.0	0.56	0.78	63.4	0.63	0.92	45.1	0.69	1.19	32.5	0.73	1.57	26.1	0.76	1.87	20.9	0.80	2.20	17.5	0.84	2.52	14.3	0.87	2.96	11.9	0.92	3.37
30	101.6	0.56	0.78	75.8	0.63	0.92	53.9	0.69	1.20	38.8	0.72	1.58	31.2	0.76	1.88	25.0	0.80	2.22	20.9	0.83	2.55	17.1	0.87	2.98	14.2	0.91	3.42
35	118.1	0.56	0.78	88.1	0.63	0.93	62.7	0.69	1.20	45.2	0.73	1.58	36.3	0.76	1.88	29.1	0.80	2.22	24.3	0.83	2.57	19.9	0.87	3.00	16.5	0.91	3.46
40	134.4	0.56	0.79	100.3	0.64	0.93	71.3	0.69	1.21	51.5	0.73	1.59	41.3	0.76	1.90	33.2	0.80	2.22	27.7	0.83	2.58	22.7	0.87	3.00	18.9	0.91	3.43
45	150.7	0.56	0.79	112.5	0.64	0.93	80.0	0.69	1.21	57.7	0.72	1.60	46.4	0.76	1.90	37.2	0.80	2.24	31.1	0.83	2.58	25.5	0.87	3.01	21.2	0.91	3.45
50	166.8	0.56	0.79	124.5	0.64	0.93	88.5	0.69	1.21	63.9	0.72	1.60	51.3	0.76	1.91	41.3	0.80	2.23	34.5	0.83	2.58	28.3	0.87	3.01	23.5	0.91	3.46
55	182.8	0.56	0.79	136.4	0.64	0.93	97.1	0.69	1.21	70.1	0.73	1.60	56.3	0.76	1.92	45.3	0.80	2.24	37.8	0.83	2.60	31.1	0.87	3.00	25.8	0.91	3.47
60	198.6	0.56	0.79	148.2	0.64	0.94	105.5	0.69	1.22	76.2	0.72	1.61	61.2	0.76	1.92	49.3	0.80	2.25	41.1	0.83	2.61	33.8	0.87	3.02	28.1	0.91	3.47
65	214.3	0.57	0.79	160.0	0.64	0.94	113.9	0.69	1.22	32.3	0.73	1.62	66.2	0.76	1.92	53.2	0.80	2.26	44.4	0.83	2.62	36.5	0.87	3.04	30.3	0.91	3.51
70	229.9	0.57	0.79	171.6	0.64	0.94	122.2	0.69	1.23	88.4	0.73	1.62	71.0	0.76	1.93	57.2	0.80	2.26	47.7	0.83	2.63	39.3	0.87	3.03	32.6	0.91	3.50
75	245.4	0.57	0.80	183.2	0.64	0.94	130.5	0.69	1.23	94.4	0.73	1.62	75.9	0.76	1.94	61.1	0.80	2.27	51.0	0.83	2.63	42.0	0.87	3.04	34.9	0.91	3.50
80	260.7	0.57	0.80	194.6	0.64	0.95	138.6	0.69	1.24	100.3	0.73	1.63	80.7	0.76	1.94	65.0	0.80	2.27	54.3	0.83	2.63	44.7	0.87	3.04	37.1	0.91	3.52
90	292.1	0.57	0.80	218.1	0.64	0.95	155.4	0.69	1.24	112.5	0.73	1.64	90.5	0.76	1.95	73.0	0.81	2.27	60.9	0.83	2.64	50.1	0.87	3.06	41.7	0.91	3.52
100	323.3	0.57	0.80	241.5	0.64	0.95	172.1	0.69	1.24	124.6	0.73	1.64	100.3	0.76	1.95	80.9	0.81	2.28	67.5	0.83	2.65	55.6	0.87	3.06	46.2	0.91	3.53
110	354.3	0.57	0.80	264.6	0.64	0.96	188.6	0.69	1.25	136.7	0.73	1.64	110.0	0.76	1.96	88.7	0.81	2.29	74.1	0.83	2.65	61.0	0.87	3.07	50.7	0.91	3.54
120	385.0	0.57	0.80	287.6	0.64	0.96	205.0	0.69	1.25	148.7	0.73	1.65	119.6	0.76	1.97	96.5	0.81	2.29	80.6	0.83	2.66	66.4	0.87	3.08	55.2	0.91	3.55
130	415.5	0.57	0.81	310.3	0.65	0.96	221.3	0.69	1.26	160.6	0.73	1.65	129.3	0.76	1.97	104.3	0.81	2.30	87.1	0.83	2.67	71.8	0.87	3.08	59.7	0.91	3.55
140	445.7	0.57	0.81	333.0	0.65	0.96	237.5	0.69	1.26	172.5	0.73	1.65	138.8	0.76	1.97	112.1	0.81	2.30	93.5	0.83	2.68	77.1	0.87	3.09	64.2	0.91	3.55
150	475.7	0.58	0.81	355.4	0.65	0.97	253.6	0.69	1.26	184.2	0.73	1.66	148.4	0.76	1.97	119.8	0.81	2.30	100.0	0.83	2.68	82.5	0.88	3.09	68.6	0.91	3.57
160	505.5	0.58	0.81	377.7	0.65	0.97	269.5	0.69	1.27	195.9	0.73	1.66	157.8	0.76	1.98	127.4	0.81	2.31	106.4	0.83	2.69	87.8	0.88	3.10	73.0	0.91	3.58
170	535.0	0.58	0.81	399.7	0.65	0.97	285.3	0.69	1.27	207.6	0.73	1.66	167.2	0.76	1.98	135.0	0.81	2.32	112.8	0.83	2.69	93.0	0.87	3.11	77.5	0.91	3.57
180	564.3	0.58	0.81	421.7	0.65	0.97	301.0	0.70	1.28	219.1	0.73	1.67	176.6	0.76	1.99	142.6	0.81	2.32	119.1	0.83	2.70	98.3	0.88	3.11	81.8	0.91	3.59
190	593.4	0.58	0.82	443.4	0.65	0.98	316.6	0.70	1.28	230.6	0.73	1.67	185.9	0.76	1.99	150.1	0.81	2.33	125.4	0.83	2.71	103.5	0.88	3.12	86.2	0.91	3.59
200	622.2	0.58	0.82	465.0	0.65	0.98	332.1	0.70	1.28	242.1	0.73	1.68	195.2	0.76	1.99	157.6	0.81	2.33	131.7	0.83	2.71	108.7	0.88	3.13	90.6	0.92	3.59
220	681.9	0.58	0.82	509.6	0.65	0.98	364.1	0.70	1.29	265.5	0.73	1.68	214.1	0.76	2.00	173.0	0.81	2.33	144.6	0.83	2.71	119.3	0.88	3.13	99.4	0.91	3.60
240	741.1	0.58	0.82	553.8	0.65	0.99	395.9	0.70	1.29	288.8	0.73	1.68	233.0	0.76	2.00	188.2	0.81	2.34	157.4	0.84	2.72	129.9	0.88	3.13	108.3	0.92	3.60
260	799.9	0.58	0.82	597.7	0.65	0.99	427.4	0.70	1.29	312.0	0.73	1.69	251.7	0.77	2.01	203.4	0.81	2.34	170.1	0.84	2.72	140.4	0.88	3.14	117.0	0.92	3.61
280	858.2	0.58	0.83	641.3	0.65	0.99	458.7	0.70	1.30	335.0	0.73	1.69	270.4	0.77	2.01	218.5	0.81	2.35	182.7	0.84	2.73	150.9	0.88	3.15	125.8	0.92	3.62
300	916.0	0.59	0.83	684.6	0.65	0.99	489.8	0.70	1.30	357.9	0.73	1.69	289.0	0.77	2.01	233.5	0.81	2.35	195.4	0.84	2.73	161.3	0.88	3.15	134.5	0.92	3.62

Source: USDA-SCS

STD & SPEC 3.18

OUTLET PROTECTION

OP

Definition

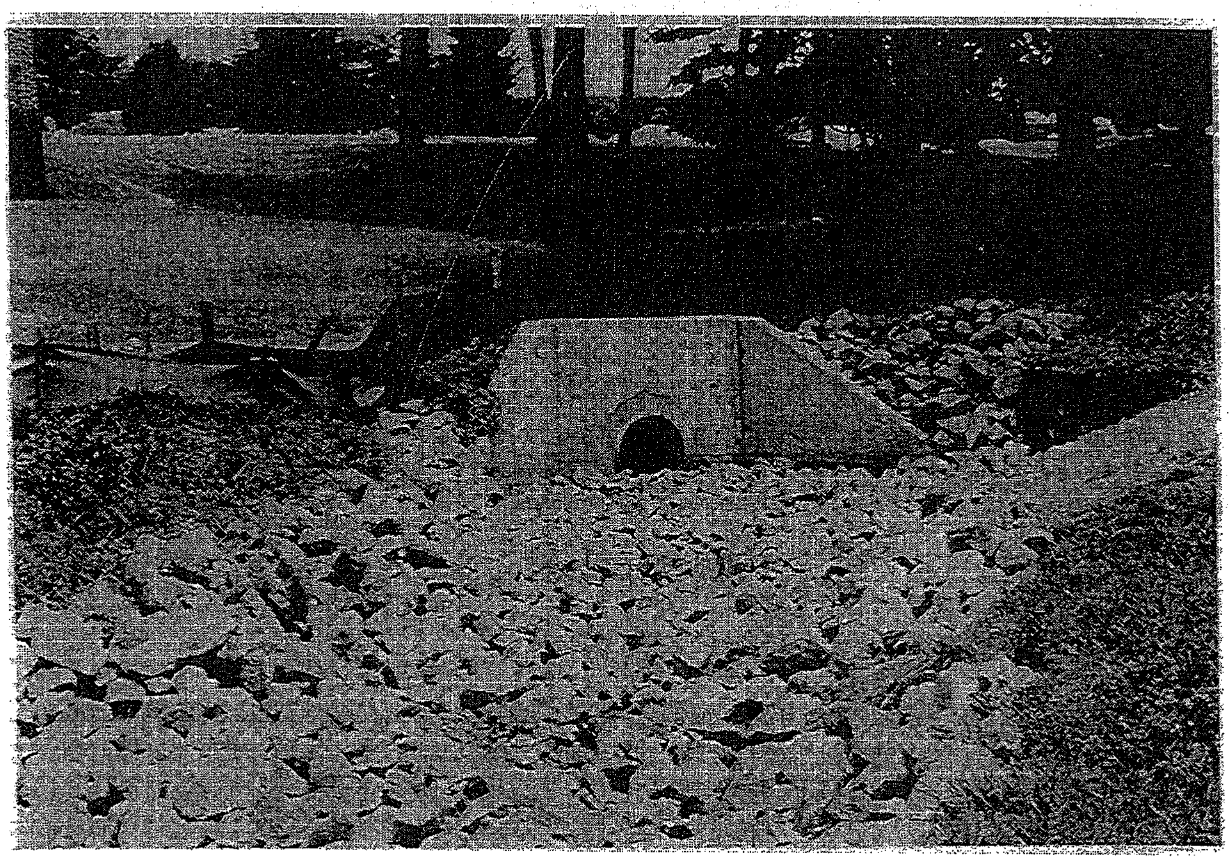
Structurally lined aprons or other acceptable energy dissipating devices placed at the outlets of pipes or paved channel sections.

Purpose

To prevent scour at stormwater outlets, to protect the outlet structure, and to minimize the potential for downstream erosion by reducing the velocity and energy of concentrated stormwater flows.

Conditions Where Practice Applies

Applicable to the outlets of all pipes and engineered channel sections.



Planning Considerations

The outlets of pipes and structurally lined channels are points of critical erosion potential. Stormwater which is transported through man-made conveyance systems at design capacity generally reaches a velocity which exceeds the capacity of the receiving channel or area to resist erosion. To prevent scour at stormwater outlets, a flow transition structure is needed which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area.

The most commonly used device for outlet protection is a structurally lined apron. These aprons are generally lined with riprap, grouted riprap or concrete. They are constructed at a zero grade for a distance which is related to the outlet flow rate and the tailwater level. Criteria for designing such an apron are contained in this practice. Sample problems of outlet protection design are contained in Appendix 3.18-a.

Where flow is excessive for the economical use of an apron, excavated stilling basins may be used. Acceptable designs for stilling basins may be found in the following sources:

1. Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Circular No. 14, U. S. Department of Transportation, Federal Highway Administration (83).

2. Hydraulic Design of Stilling Basins and Energy Dissipators, Engineering Monograph No. 25, U.S. Department of the Interior - Bureau of Reclamation, (74).

   Note: Both of the above are available from the U.S. Government Printing Office.

Design Criteria

The design of structurally lined aprons at the outlets of pipes and paved channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous rock linings of channels or streams (See STORMWATER CONVEYANCE CHANNEL, Std. & Spec. 3.17). Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% should not be protected using just outlet protection as a result of the reconcentration and large velocity of flow encountered as the flow leaves the structural apron. Outlet protection shall be designed according to the following criteria:

Pipe Outlets

(See Plate 3.18-1)

1. Tailwater depth: The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth (see Chapter 5, Engineering Calculations). If the tailwater depth is less than half the diameter of the outlet pipe, it shall be classified as a

Minimum Tailwater Condition. If the tailwater depth is greater than half the pipe diameter, it shall be classified as a Maximum Tailwater Condition. Pipes which outlet onto flat areas with no defined channel may be assumed to have a Minimum Tailwater Condition. Notably, in most cases where post-development stormwater runoff has been concentrated or increased, MS #19 will be satisfied only by outfall into a defined channel.

2. Apron length: The apron length shall be determined from the curves according to the tailwater condition:

    Minimum Tailwater - Use Plate 3.18-3.
    Maximum Tailwater - Use Plate 3.18-4.

3. Apron width: When the pipe discharges directly into a well-defined channel, the apron shall extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less).

   If the pipe discharges onto a flat area with no defined channel, the width of the apron shall be determined as follows:

   a. The upstream end of the apron, adjacent to the pipe, shall have a width three times the diameter of the outlet pipe.

   b. For a Minimum Tailwater Condition, the downstream end of the apron shall have a width equal to the pipe diameter plus the length of the apron.

   c. For a Maximum Tailwater Condition, the downstream end shall have a width equal to the pipe diameter plus 0.4 times the length of the apron.

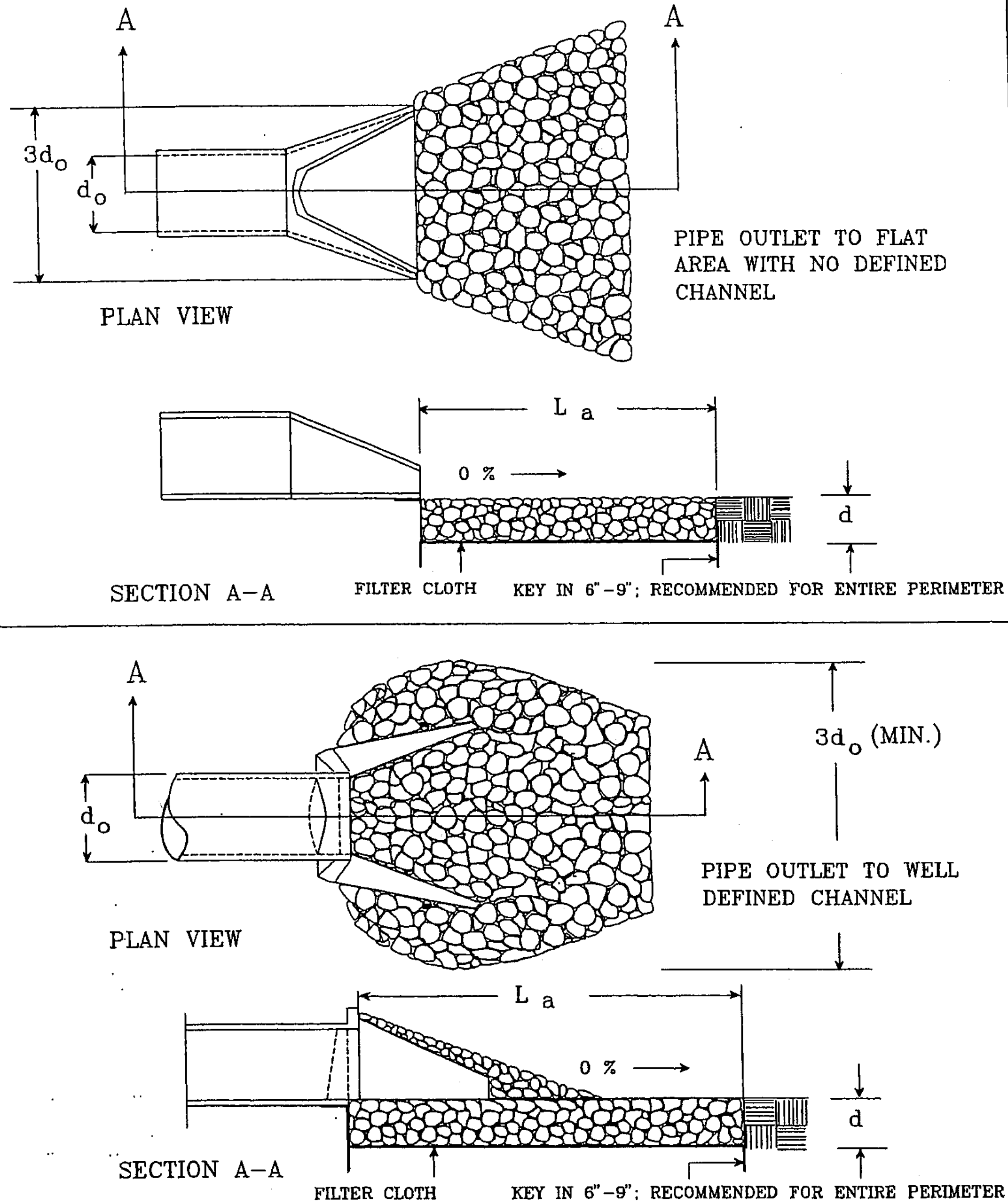
4. Bottom grade: The apron shall be constructed with no slope along its length (0.0% grade). The invert elevation of the downstream end of the apron shall be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

5. Side slopes: If the pipe discharges into a well-defined channel, the side slopes of the channel shall not be steeper than 2:1 (horizontal: vertical).

6. Alignment: The apron shall be located so there are not bends in the horizontal alignment.

7. Materials: The apron may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median sized stone for riprap shall be determined from the curves in Appendix 3.18-a (Plates 3.18-3 and 3.18-4) according to the tailwater condition. The gradation, quality and placement of riprap shall conform to Std. & Spec. 3.19, RIPRAP.

PIPE OUTLET CONDITIONS



NOTES: 1. APRON LINING MAY BE RIPRAP, GROUTED RIPRAP, GABION BASKET, OR CONCRETE.
2. La IS THE LENGTH OF THE RIPRAP APRON AS CALCULATED USING PLATES 3.18–3 AND 3.18–4.
3. d = 1.5 TIMES THE MAXIMUM STONE DIAMETER, BUT NOT LESS THAN 6 INCHES.

Source: Va. DSWC

Plate 3.18-1

8. Filter cloth: In all cases, filter cloth shall be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the physical properties for filter cloth found in Std. & Spec. 3.19, RIPRAP. See Plate 3.18-1 for orientation details.

Paved Channel Outlets

(See Plate 3.18-2)

1. The flow velocity at the outlet of paved channels flowing at design capacity must not exceed the permissible velocity of the receiving channel (see Tables 3.18-A and 3.18-B)

2. The end of the paved channel shall merge smoothly with the receiving channel section. There shall be no overfall at the end of the paved section. Where the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section shall be provided The maximum side divergence of the transition shall be 1 in 3F where;

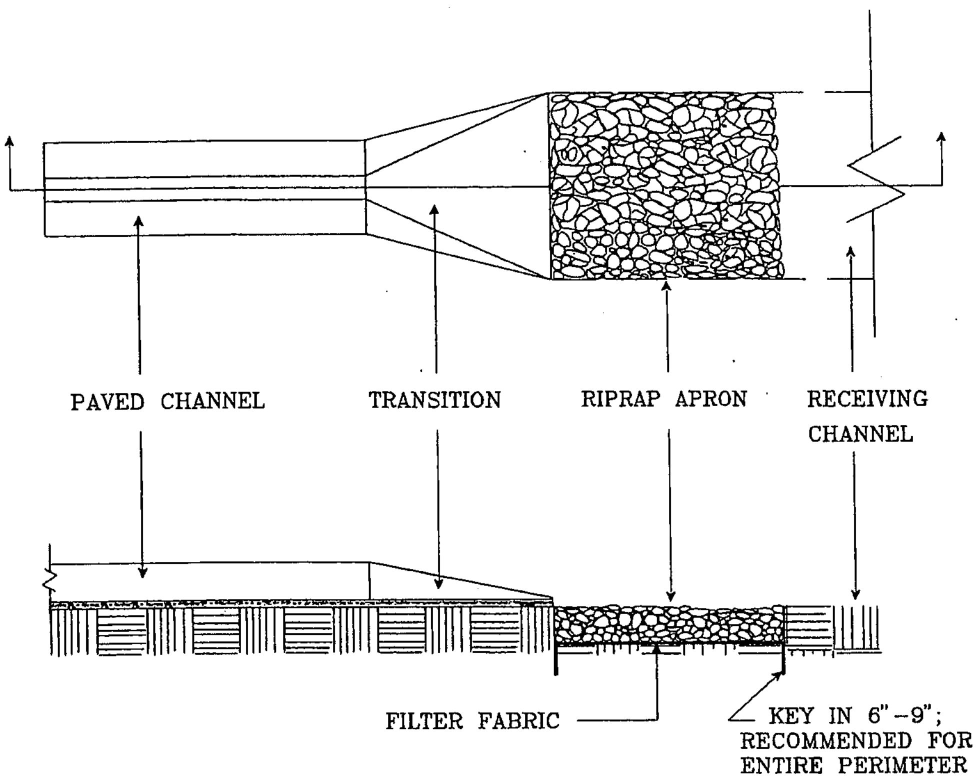
$$F = \frac{V}{\sqrt{gd}}$$

where,

F	=	Froude number
V	=	Velocity at beginning of transition (ft./sec.)
d	=	depth of flow at beginning of transition (ft.)
g	=	32.2 ft./sec.^{2}

3. Bends or curves in the horizontal alignment at the transition are not allowed unless the Froude number (F) is 1.0 or less, or the section is specifically designed for turbulent flow.

PAVED CHANNEL OUTLET



NOTES:

1. RIPRAP APRON REDUCES THE FLOW VELOCITY BELOW THE PERMISSIBLE VELOCITY OF THE NATURAL RECEIVING CHANNEL.
2. TRANSITION SIDE DIVERGENCE IS 1 IN 3F, WHERE

$$F = \text{FROUDE NUMBER} = \frac{V}{\sqrt{gd}}, \text{ WHERE}$$

V = VELOCITY AT THE BEGINING OF THE TRANSITION
d = DEPTH OF FLOW AT THE BEGINING OF THE TRANSITION

$g = 32.2$ ft./sec.^{2}

Source: Va. DSWC

Plate 3.18-2

TABLE 3.18-A

PERMISSIBLE VELOCITIES FOR GRASS-LINED CHANNELS

Channel Slope	Lining	Velocity* (ft./sec.)
0 - 0.5%	Bermudagrass	6
	Reed canarygrass Tall fescue Kentucky bluegrass	5
	Grass-legume mixture	4
	Red fescue Redtop Sericea lespedeza Annual lespedeza Small grains Temporary vegetation	2.5
5 - 10%	Bermudagrass	5
	Reed canarygrass Tall fescue Kentucky bluegrass	4
	Grass-legume mixture	3
Greater than 10%	Bermudagrass	4
	Reed canarygrass Tall fescue Kentucky bluegrass	3

* For highly erodible soils, decrease permissible velocities by 25%.

Source: Soil and Water Conservation Engineering, Schwab, et. al. and American Society of Civil Engineers

TABLE 3.18-B?

PERMISSIBLE VELOCITIES FOR EARTH LININGS

Soil Types	Permissible Velocities (ft./sec.)
Fine Sand (noncolloidal)	2.5
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (colloidal)	5.5
Alluvial Silts (noncolloidal)	5.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Plans	6.0

Source: Soil and Water Conservation Engineering, Schwab, et.al. and American Society of Civil Engineers

APPENDIX 3.18-a

Sample Problems: Outlet Protection Design

Example 1

Given: An 18-inch pipe discharges 24 cfs at design capacity onto a grassy slope (no defined channel).

Find: The required length, width and median stone size (d_{50}) for a riprap-lined apron.

Solution:

1. Since the pipe discharges onto a grassy slope with no defined channel, a Minimum Tailwater Condition may be assumed.

2. From Plate 3.18-3, an apron length (L_a) of 20 feet and a median stone size (d_{50}) of 0.8 ft. are determined.

3. The upstream apron width equals three times the pipe diameter; 3 x 1.5 ft = 4.5 ft.

4. The downstream apron width equals the apron length plus the pipe diameter; 20 ft. + 1.5 ft. = 21.5 ft.

Example 2

Given: The pipe in example No. 1 discharges into a channel with a triangular cross-section, 2 feet deep and 2:1 side slopes. The channel has a 2% slope and an "n" factor of .045.

Find: The required length, width and the median stone size (d_{50}) for a riprap lining.

Solution:

1. Determine the tailwater depth using Manning's Equation.

$$Q = \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} A$$

$$24 = \frac{1.49}{.045}\left(\frac{2d}{2\sqrt{2^2+1}}\right)^{\frac{2}{3}}(.02)^{\frac{1}{2}}\,(2d^2)$$

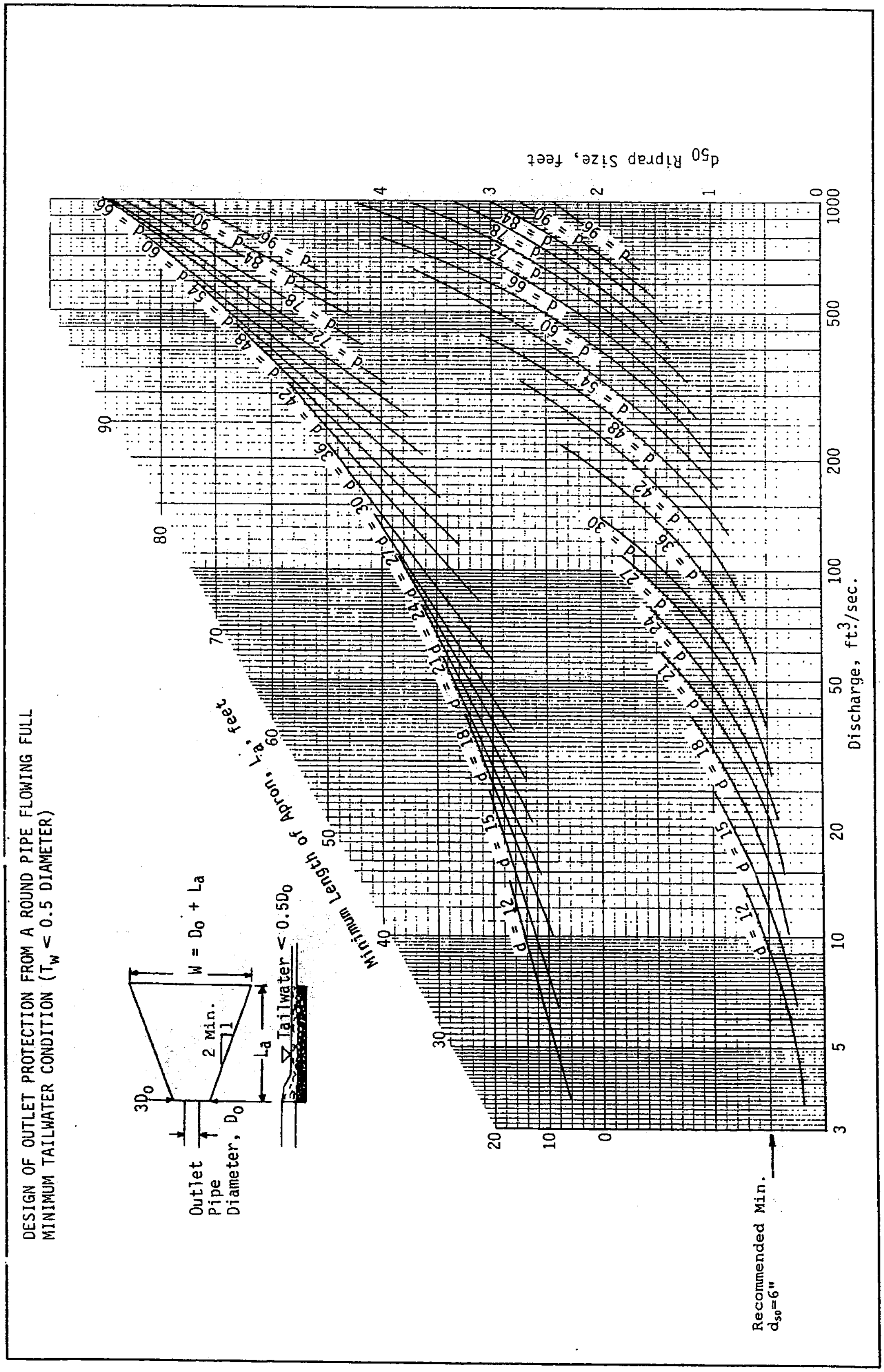
where,

d = depth of tailwater
d = 1.74 ft. *

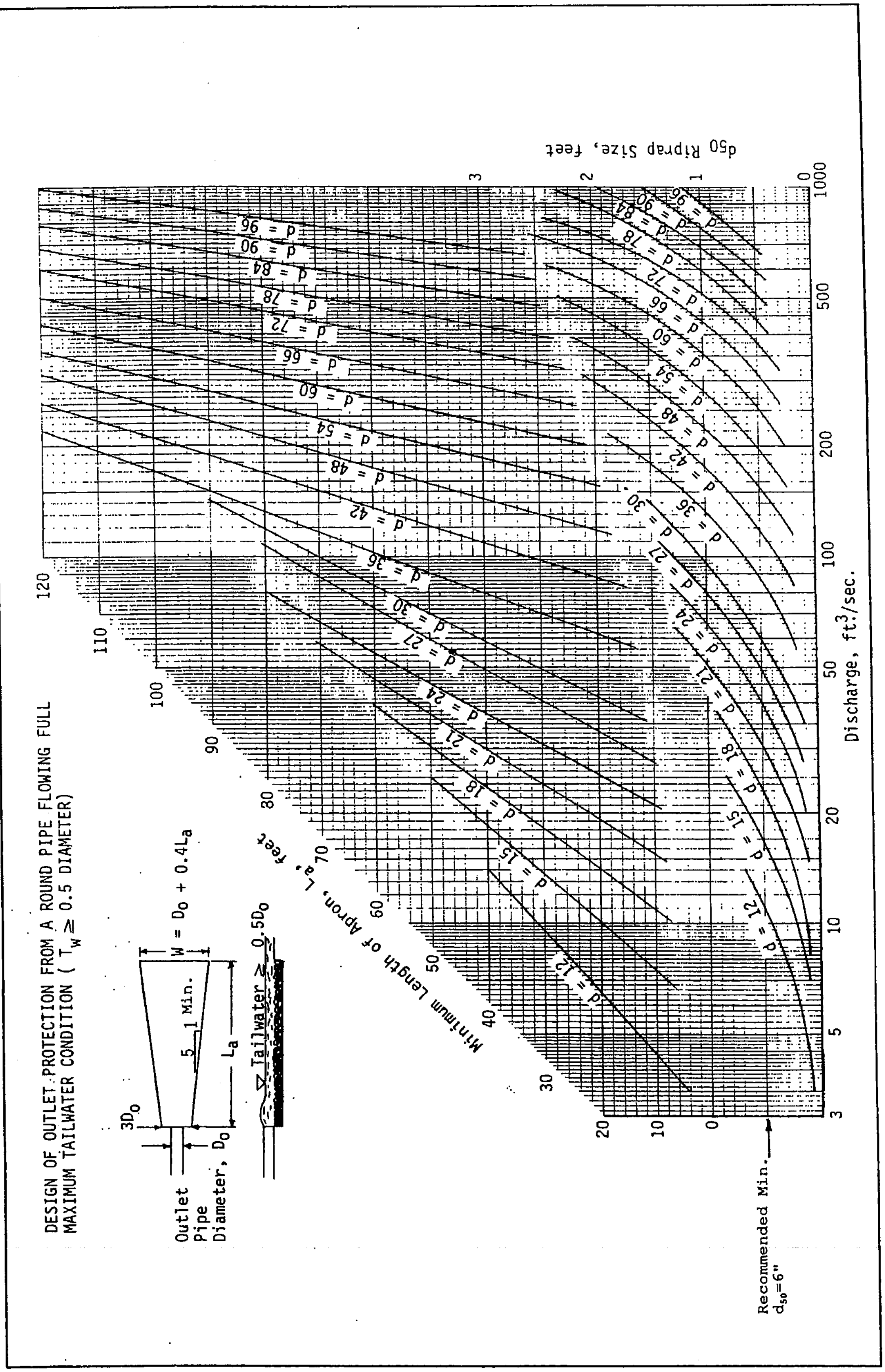
* since d is greater than half the pipe diameter, a Maximum Tailwater Condition exists.

2. From Plate 3.18-4, a median stone size (d_{50}) of 0.5 ft. and an apron length (L_a) of 41 ft. is determined.

3. The entire channel cross-section should be lined since the maximum tailwater depth is within one foot of the top of the channel.



Source: USDA-SCS Plate 3.18-3



Source: USDA-SCS

Plate 3.18-4

STD & SPEC 3.19

RIPRAP

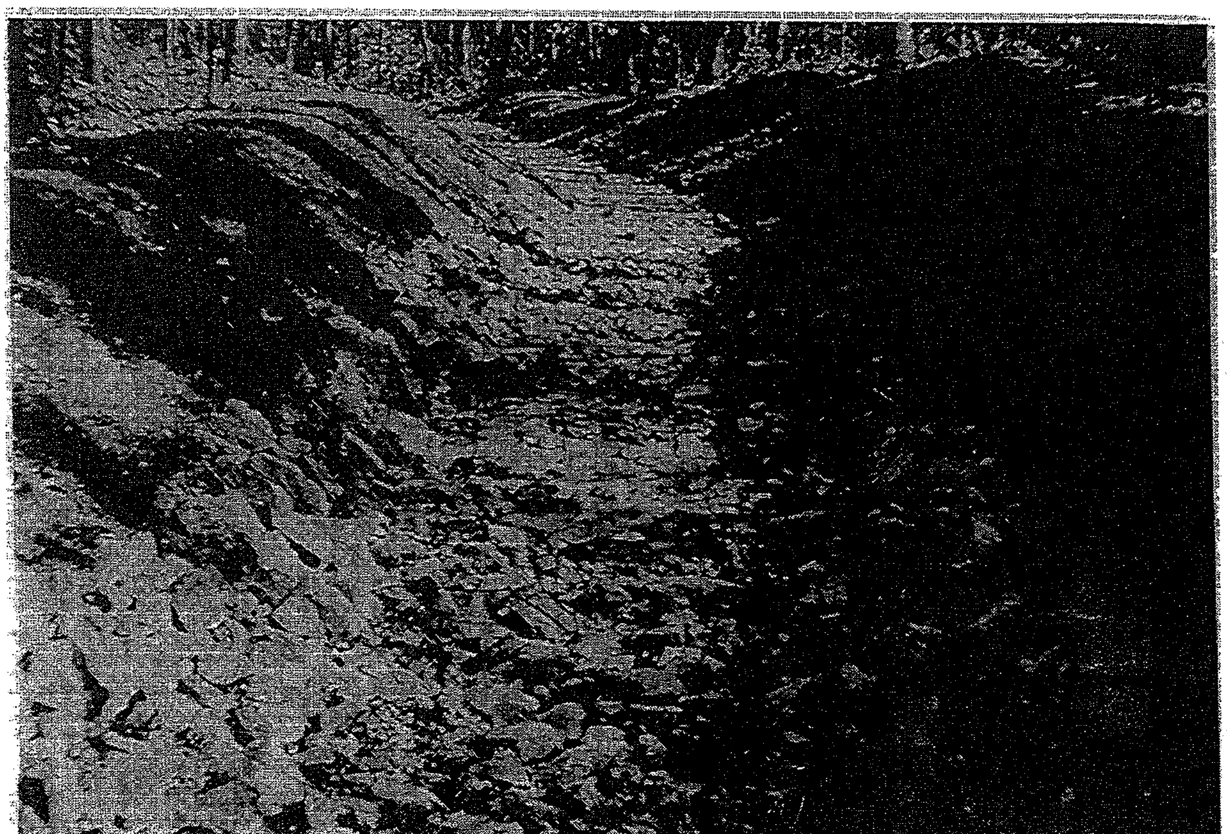
RR

Definition

A permanent, erosion-resistant ground cover of large, loose, angular stone with filter fabric or granular underlining.

Purposes

1. To protect the soil from the erosive forces of concentrated runoff.
2. To slow the velocity of concentrated runoff while enhancing the potential for infiltration.
3. To stabilize slopes with seepage problems and/or non-cohesive soils.



Conditions Where Practice Applies

Wherever soil and water interface and the soil conditions, water turbulence and velocity, expected vegetative cover, etc., are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at stormdrain outlets, on channel banks and/or bottoms, roadside ditches, drop structures, at the toe of slopes, as transition from concrete channels to vegetated channels, etc.

Planning Considerations

Graded vs. Uniform Riprap

Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones which vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size.

For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand or mechanical labor.

Riprap sizes can be designed by either the diameter or the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be angular instead of spherical. However, it is simpler to specify the diameter of an equivalent size of spherical stone. Table 3.19-A lists some typical stones by weight, spherical diameter and the corresponding rectangular dimensions. These stone sizes are based upon an assumed specific weight of 165 lbs./ft^3.

Since graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is done by specifying a diameter of stone in the mixture for which some percentage, by weight, will be smaller. For example, d_{85} refers to a mixture of stones in which 85% of the stone by weight would be smaller than the diameter specified. Most designs are based on d_{50}. In other words, the design is based on the average size of stone in the mixture. Table 3.19-B lists VDOT standard graded riprap sizes by diameter the weight of the stone.

To ensure that stone of substantial <u>weight</u> is used when implementing riprap structures, specified weight ranges for individual stones and composition requirements should be followed. Such guidelines will help to prevent inadequate stone from being used in construction of the measures and will promote more consistent stone classification statewide. Table 3.19-C notes these requirements.

TABLE 3.19-A

SIZE OF RIPRAP STONES

Weight (lbs.)	Mean Spherical Diameter (ft.)	Angular Shape: Length (ft.)	Width, Height (ft.)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1,000	2.2	3.7	1.25
1,500	2.6	4.7	1.5
2,000	2.75	5.4	1.8
4,000	3.6	6.0	2.0
6,000	4.0	6.9	2.3
8,000	4.5	7.6	2.5
20,000	6.1	10.0	3.3

Source: VDOT Drainage Manual

Sequence of Construction

Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

Design Criteria

Gradation

The riprap shall be composed of a well-graded mixture down to the one-inch size particle such that 50% of the mixture by weight shall be larger than the d_{50} size as determined from the design procedure. A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be 1½ times the d_{50} size.

TABLE 3.19-B

GRADED RIPRAP - DESIGN VALUES

Riprap Class	D_{15} Weight (lbs.)	Mean D_{15} Spherical Diameter (ft.)	Mean D_{50} Spherical Diameter (ft.)
Class AI	25	0.7	0.9
Class I	50	0.8	1.1
Class II	150	1.3	1.6
Class III	500	1.9	2.2
Type I	1,500	2.6	2.8
Type II	6,000	4.0	4.5

Source: VDOT Drainage Manual

The designer, after determining the riprap size that will be stable under the flow conditions, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. The possibility of damage by children shall be considered in selecting a riprap size, especially if there is nearby water or a gully in which to toss the stones.

Thickness

The minimum thickness of the riprap layer shall be 2 times the maximum stone diameter, but not less than 6 inches.

Quality of Stone

Stone for riprap shall consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all respects for the purpose intended. The specific gravity of the individual stones shall be at least 2.5.

Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot, and otherwise meets the requirement of this standard and specification.

TABLE 3.19-C

GRADED RIPRAP - WEIGHT ANALYSIS

Riprap Class/Type	Weight Range* (lbs.)	Requirements for Stone Mixture
Class AI	25-75	Max. 10% > 75 lbs.
Class I	50-150	60% > 100 lbs.
Class II	150-500	50% > 300 lbs.
Class III	500-1,500	50% > 900 lbs.
Type I	1,500-4,000	Av. wt. = 2,000 lbs.
Type II	6,000-20,000	Av. wt. = 8,000 lbs.

* In all classes/types of riprap, a maximum 10% of the stone in the mixture may weigh less than the lower end of the range.

Source: Adapted from VDOT Road and Bridge Specifications

Filter Fabric Underlining

A lining of engineering filter fabric (geotextile) shall be placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. Table 3.19-D notes the minimum physical properties of the filter fabric.

Filter fabric shall not be used on slopes greater than 1½:1 as slippage may occur and should be used in conjunction with a layer of course aggregate (granular filter blanket is described below) when the riprap to be placed is Class II or larger.

Granular Filter

Although the filter cloth underlining or bedding is the preferred method of installation, a granular (stone) bedding is a viable option when the following relationship exists:

$$\frac{d_{15}\ filter}{d_{85}\ base} < 5 < \frac{d_{15}\ filter}{d_{15}\ base} < 40$$

and,

$$\frac{d_{50}\ filter}{d_{50}\ base} < 40$$

In these relationships, filter refers to the overlying material and base refers to the underlying material. The relationships must hold between the filter material and the base material and between the riprap and the filter material. In some cases, more than one layer of filter material may be needed. Each layer of filter material should be approximately 6-inches thick.

TABLE 3.19-D

REQUIREMENTS FOR FILTER FABRIC USED WITH RIPRAP

Physical Property	Test Method	Requirements
Equivalent Opening Size	Corps of Engineers CWO 2215-77	Equal or greater than U.S. No. 50 sieve
Tensile Strength* @ 20% (maximum)	VTM-52	30 lbs./linear in. (minimum)
Puncture Strength	ASTM D751*	80 lbs. (minimum)

* Tension testing machine with ring clamp, steel ball replaced with 5/16 diameter solid steel cylinder with hemispherical tip centered within the ring clamp.

Seams shall be equal in strength to basic material.

Additional fabric material or non-corrosive steel wire may be incorporated into the fabric to increase overall strength.

Source: VDOT Road and Bridge Specifications

Riprap at Outlets

Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlet of drainage structure are contained in OUTLET PROTECTION (Std. & Spec. 3.18). A filter fabric underlining is required for riprap used as outlet protection.

Riprap for Channel Stabilization

Riprap for channel stabilization shall be designed to be stable for the condition of bank-full flow in the reach of channel being stabilized. The design procedure in Appendix 3.19-a, which is extracted from the Federal Highway Administration's Design of Stable Channels with Flexible Linings (82), shall be used. This method establishes the stability of the rock material relative to the forces exerted upon it.

Riprap shall extend up the banks of the channel to a height equal to the maximum depth of flow or to a point where vegetation can be established to adequately protect the channel.

The riprap size to be used in a channel bend shall extend upstream from the point of curvature and downstream from the bottom of the channel to a minimum depth equal to the thickness of the blanket and shall extend across the bottom of the channel the same distance (see Plate 3.19-1).

Freeboard and Height of Bank

For riprapped and other lined channels, the height of channel lining above the water surface should be based on the size of the channel, the flow velocity, the curvature, inflows, wind action, flow regulation, etc.

The height of the bank above the water surface varies in a similar manner, depending on the above factors plus the type of soil.

Plate 3.19-2 is based on information developed by the U.S. Bureau of Reclamation for average freeboard and bank height in relation to channel capacity. This chart should be used by the designer to obtain a minimum freeboard for placement of riprap and top of bank.

Riprap for Slope Stabilization

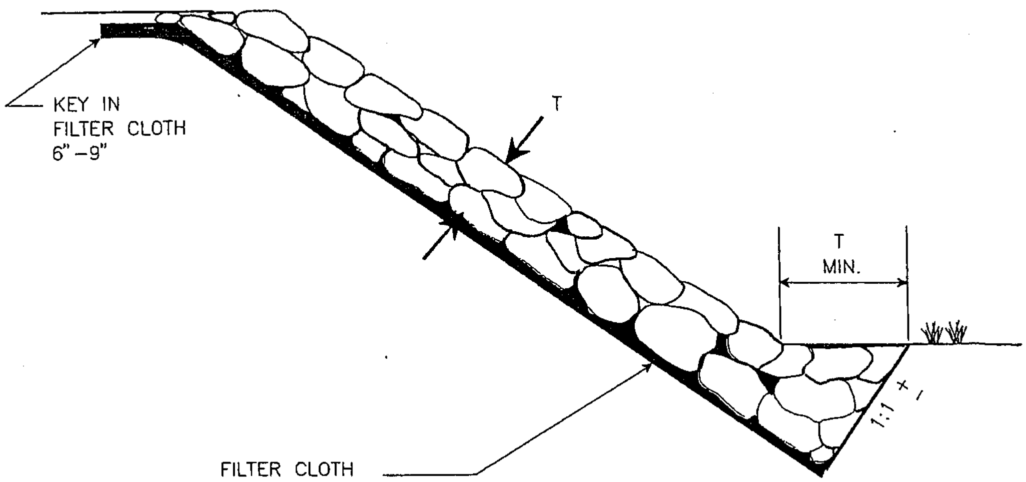
Riprap for slope stabilization shall be designed so that the natural angle of repose of the stone mixture is greater than the gradient of the slope being stabilized (see Plate 3.19-5).

Riprap for Lakes and Ponds Subject to Wave Action

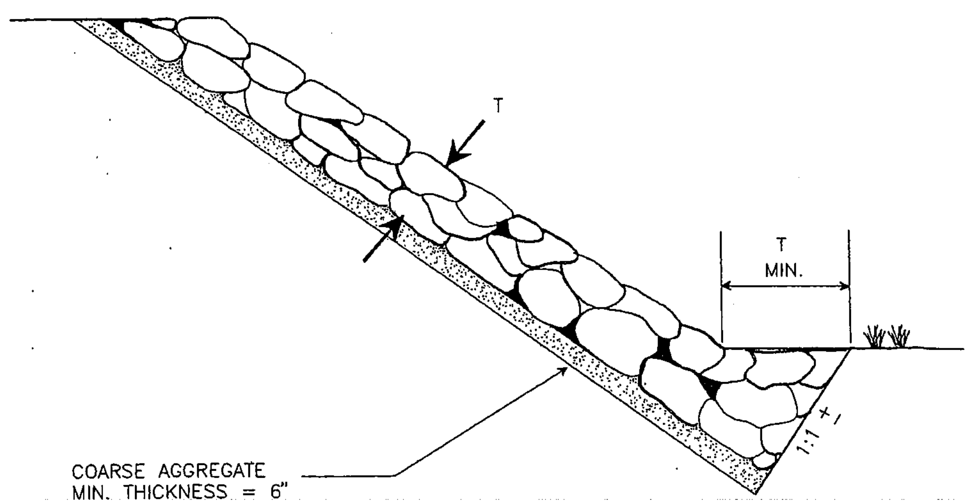
Riprap used for shoreline protection on lakes and ponds may be subject to wave action. The waves affecting the shoreline may be wind-driven or created by boat wakes. Consult

TOE REQUIREMENTS FOR BANK STABILIZATION

FILTER CLOTH UNDERLINER (PREFERRED)



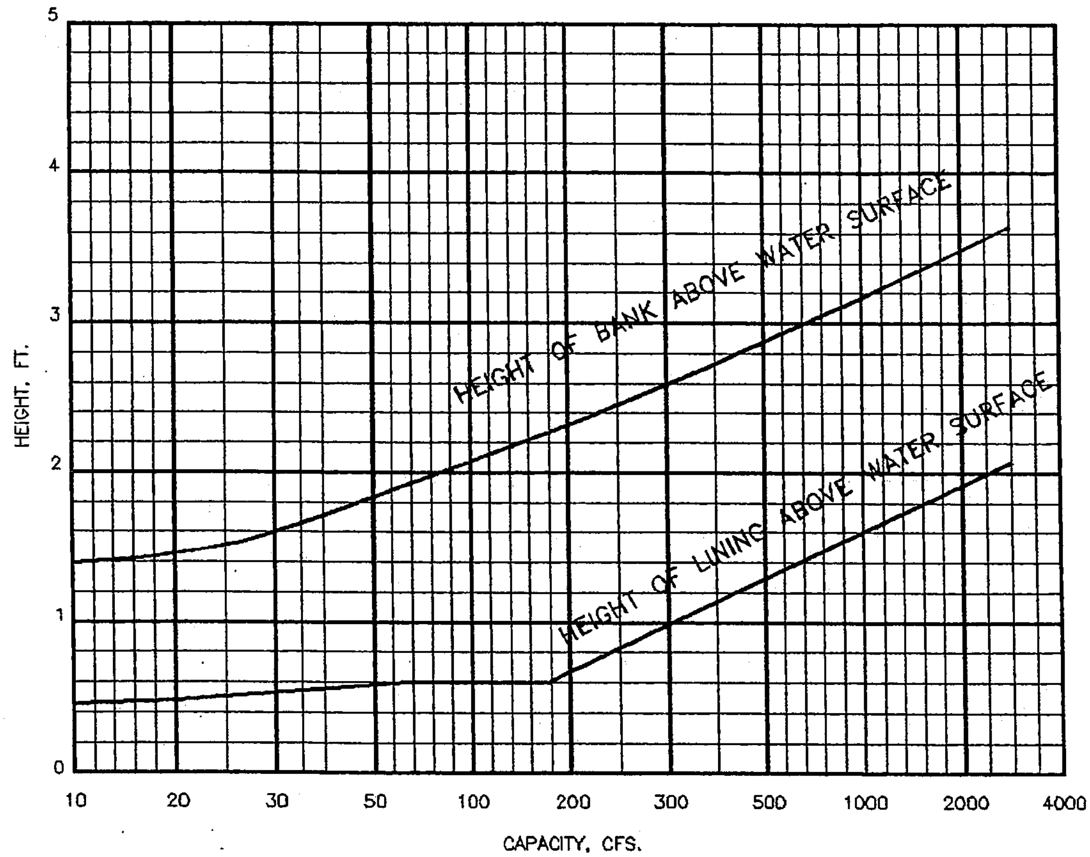
GRANULAR FILTER



Source: Adapted from VDOT Drainage Manual

Plate 3.19-1

RECOMMENDED FREEBOARD AND HEIGHT OF BANK OF LINED CHANNELS



Source: U. S. Bureau of Reclamation

Plate 3.19-2

the latest edition of the VDOT Drainage Manual ("Design of Slope Protection to Resist Wave Action") for specific design criteria in determining the required size of stones and the design wave height for such an installation. Use the equations in Appendix 3.19-b to calculate other pertinent design parameters. For more in-depth design criteria concerning these installations, see the U.S. Army Corps of Engineers' Shore Protection Manual (59).

Riprap for Abrupt Channel Contractions

Refer to latest edition of VDOT Drainage Manual.

Riprap for Installations Subject to Tidal and Wave Action

The design of riprap structures for tidal areas is beyond the scope of the VESCL and VESCR. The DSWC's Shoreline Programs Bureau provides advice regarding minimum design parameters for these installations. Notably, a riprap design for shoreline protection in tidal areas must meet all applicable state and federal requirements and should be carried out by a qualified professional.

Construction Specifications

Subgrade Preparation: The subgrade for the riprap or filter shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximately that of the surrounding undisturbed material. Brush, trees, stumps and other objectionable material shall be removed.

Filter Fabric or Granular Filter: Placement of the filter fabric should be done immediately after slope preparation. For granular filters, the stone should be spread in a uniform layer to the specified depth (normally 6 inches). Where more than one layer of filter material is used, the layer should be spread so that there is minimal mixing of the layers.

When installing geotextile filter cloths, the cloth should be placed directly on the prepared slope. The edges of the sheets should overlap by at least 12 inches. Anchor pins, 15 inches long, should be spaced every 3 feet along the overlap. The upper and lower ends of the cloth should be buried at least 12 inches. Care should be taken not to damage the cloth when placing the riprap. If damage occurs, that sheet should be removed and replaced. For large stone (Class II or greater), a 6-inch layer of granular filter will be necessary to prevent damage to the cloth.

Stone Placement: Placement of riprap should follow immediately after placement of the filter. The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled dumping of successive loads during final placing, or by a combination of these methods. The riprap should be placed to its full thickness in one operation. The riprap should not be placed in layers. The riprap should not be placed by dumping into chutes or similar methods which are likely to cause segregation of the various stone sizes. Care should be taken not to dislodge the underlying material when placing the stones.

The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Final thickness of the riprap blanket should be within plus or minus 1/4 of the specified thickness.

Maintenance

Once a riprap installation has been completed, it should require very little maintenance. It should, however, be inspected periodically to determine if high flows have caused scour beneath the riprap or filter fabric or dislodged any of the stone. Care must be taken to properly control sediment-laden construction runoff which may drain to the point of the new installation. If repairs are needed, they should be accomplished immediately.

APPENDIX 3.19-a

RIPRAP DESIGN IN CHANNEL

The design method described below is adapted from Hydraulic Engineering Circular No. 15 of the Federal Highway Administration. It is applicable to both straight and curved sections of channel where the flow is tangent to the bank of the channel.

Tangent Flow - Federal Highway Administration Method

This design method determines a stable rock size for straight and curved sections of channels. It is assumed that the shape, depth of flow, and slope of the channel are known. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3:1, the stone size must be modified accordingly. The final design size will be stable on both sides of the channel and the bottom.

1. Enter Plate 3.19-3 with the maximum depth of flow (feet) and channel slope (feet/foot). Where the two lines intersect, choose the d_{50} size of stone. (Select the d_{50} for the diagonal line above the point of intersection).

2. If channel side slopes are steeper than 3:1, continue with step 3; if not, the procedure is complete.

3. Enter Plate 3.19-4 with the side slope and the base width to maximum depth ratio (B/d). Where the two lines intersect, move horizontally left to read K_1.

4. Determine from Plate 3.19-5 the angle of repose for the d_{50} size of stone and the side slope of the channel. (Use 42° for d_{50} greater than 1.0. Do not use riprap on slopes steeper than the angle of repose for the size of stone).

5. Enter Plate 3.19-6 with the side slope of the channel and the angle of repose for the d_{50} size of stone. Where the two lines intersect, move vertically down to read k_2.

6. Compute $d_{50} \times K_1/K_2 = d'_{50}$ to determine the correct size stone for the bottom and side slopes of straight sections of channel.

For Curved Sections of Channel

1. Compute the radius of the curve (Ro), measured at the outside edge of the bottom.

2. Compute the ratio of the top width of the water surface (Bs) to the radius of the curve (Ro), Bs/Ro.

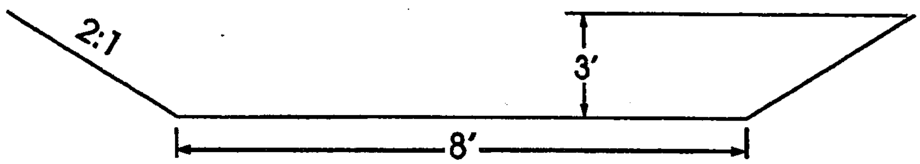
3. Enter Plate 3.19-7 with the radio Bs/Ro. Move vertically until the curve is intersected. Move horizontally left to read K_3.

4. Compute d'_{50} x K_3 = d_{50c} to determine the correct size stone for bottom and side slopes of the curved sections of channel.

Example Problem

Given:

A trapezoidal channel 3 feet deep, 8 foot bottom width, 2:1 side slopes, and a 2% slope.



Calculate:

A stable riprap size for the bottom and side slopes of the channel.

Solution:

1. From Plate 3.19-3, for a 3-foot-deep channel on a 2% grade, d_{50} = 0.75 feet or 9 inches.

2. Since the side slopes are steeper than 3:1, continue with step 3.

3. From Plate 3.19-4, B/d = 8/3 = 2.67, Z = 2, K_1 = 0.82.

4. From Plate 3.19-5, for d_{50} = 9 inches, = 41°.

5. From Plate 3.19-6, for Z = 2 and = 41°, K_2 = 0.73.

6. d_{50} x K_1/k_2 = d'_{50} = 0.75 x 0.82/0.73 = 0.84 feet.

$$0.84 \text{ feet} \times \frac{12 \text{ inches}}{1 \text{ foot}} = 10.08.$$ Use d'_{50} = 10 inches.

Given:

The preceding channel has a curved section with a radius of 50 feet.

Calculate:

A stable riprap size for the bottom and side slopes of the curved section of channel.

Solution:

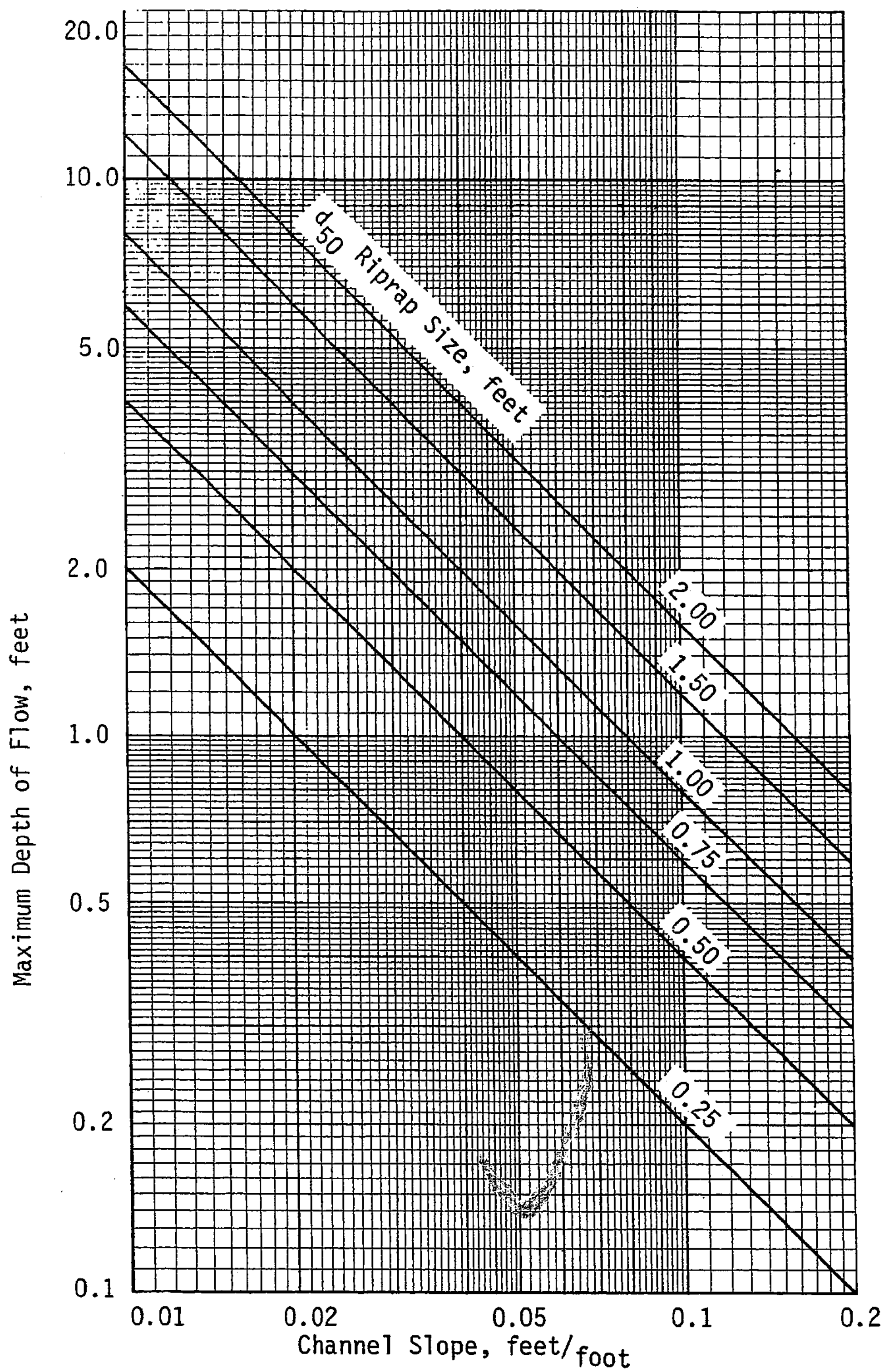
1. Ro = 50 feet

2. Bs/Ro = 20/50 = 0.40

3. From Plate 3.19-7, for Bs/Ro = 0.40, K_3 = 1.1

4. $d'_{50} \times K_3 = 0.84 \times 1.1 = 0.92$ feet

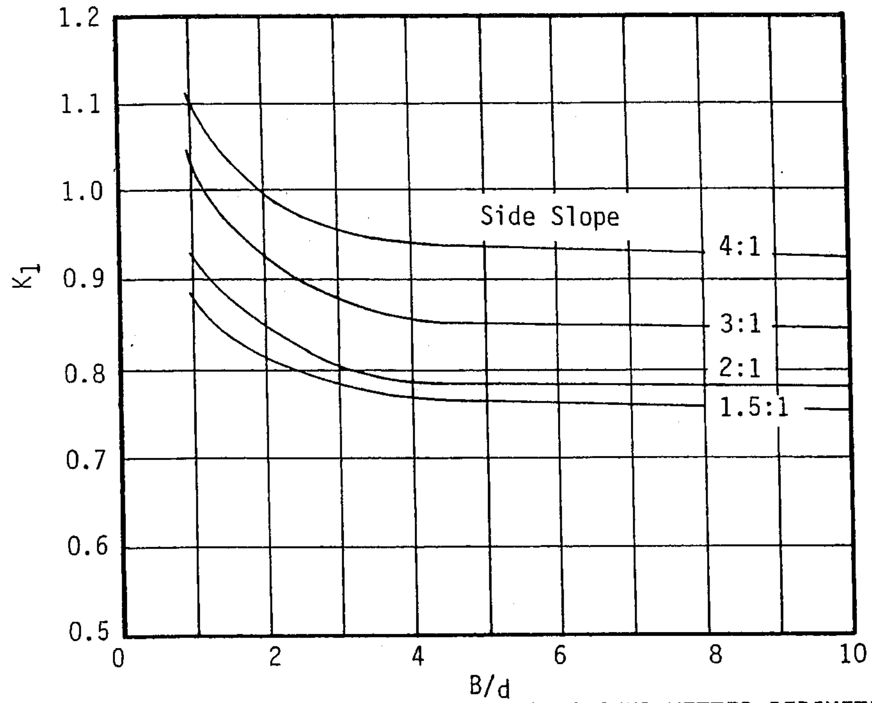
   $0.92 \text{ feet} \times \frac{12 \text{ inches}}{1 \text{ foot}} = 11.0.$



MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

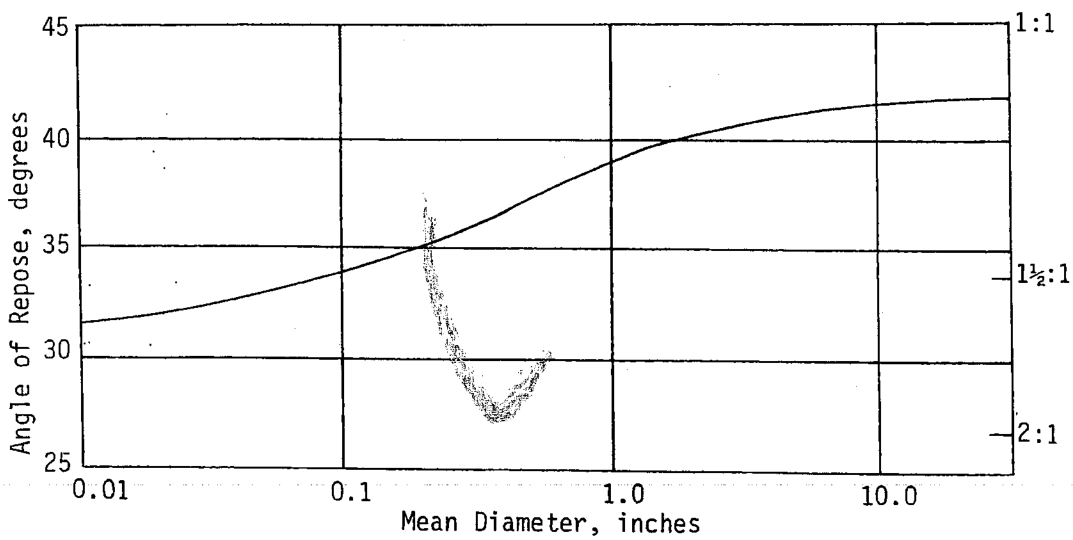
Source: VDOT Drainage Manual

Plate 3.19-3



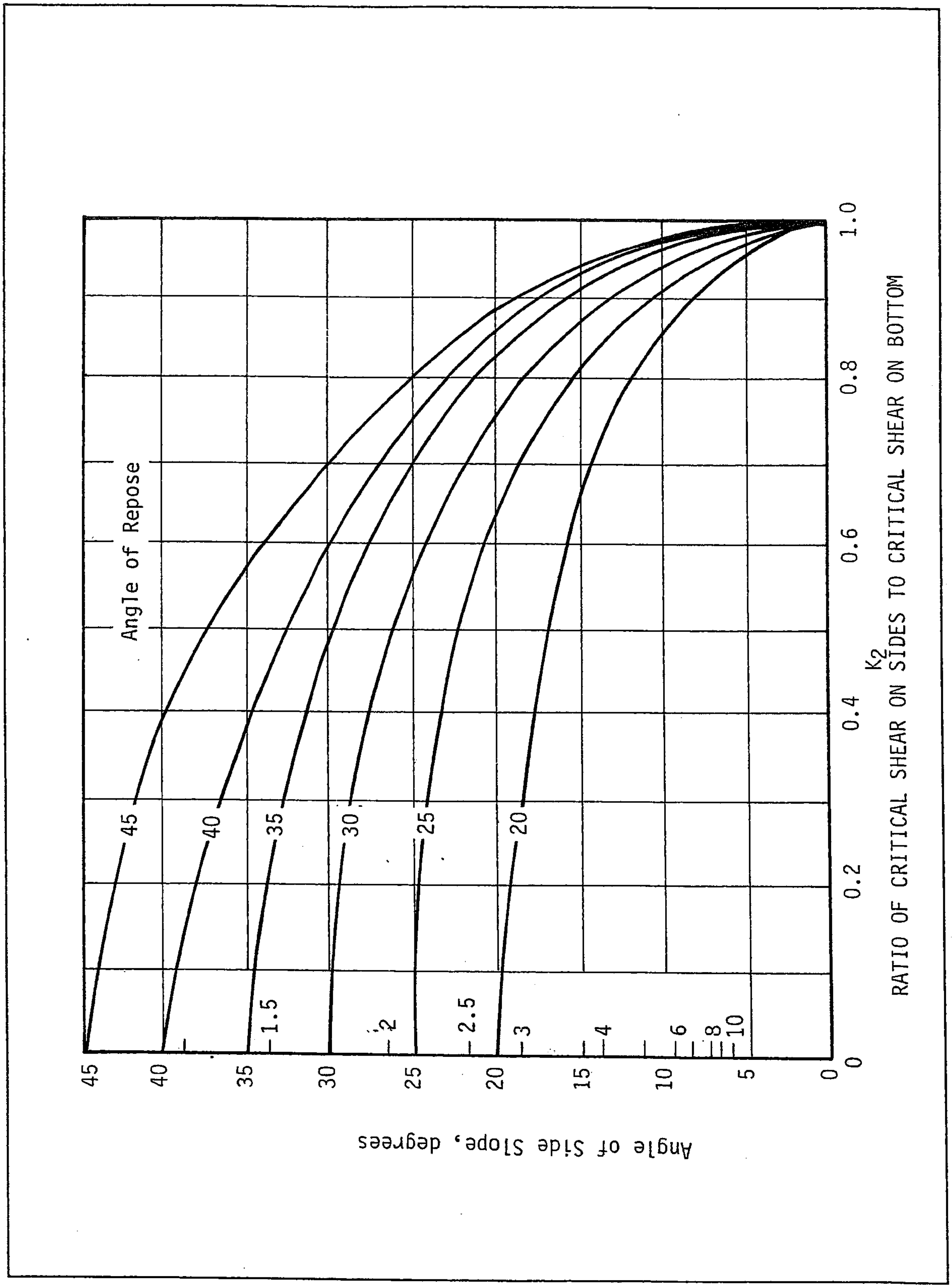
DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPEZOIDAL CHANNEL

Source: VDOT Drainage Manual Plate 3.19-4



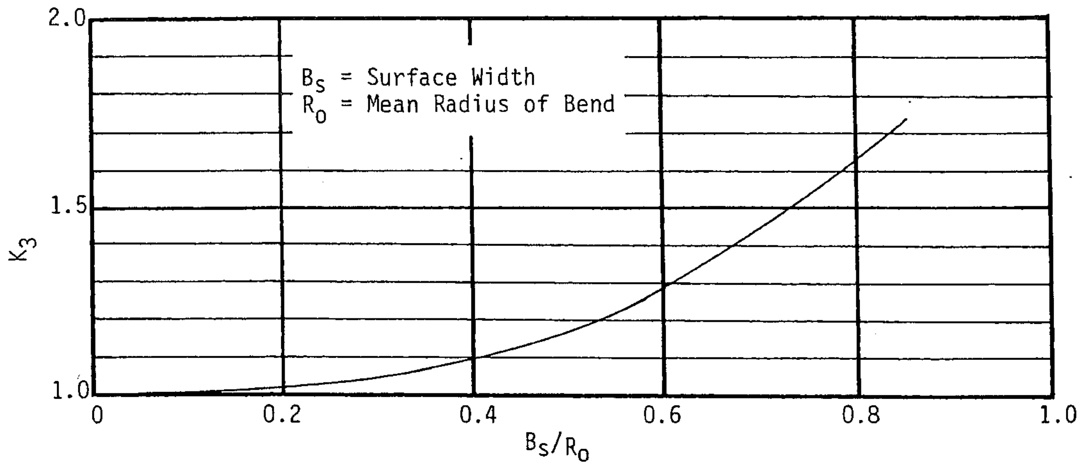
ANGLE OF REPOSE FOR RIPRAP STONES

Source: VDOT Drainage Manual Plate 3.19-5



Source: VDOT Drainage Manual

Plate 3.19-6



RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACHES

Source: VDOT Drainage Manual

Plate 3.19-7

APPENDIX 3.19-b

RIPRAP DESIGN EQUATIONS FOR LAKES AND PONDS SUBJECT TO WAVE ACTION

In many instances, riprap is installed along the shoreline of nontidal ponds and lakes in order to protect them from the continual scour of wind-driven waves. The following methods/equations will produce minimum design parameters for size of stone, depth of buried toe (or width of riprap apron) and height of structure above average water level.

I. **Size of Riprap Required** - See VDOT Drainage Manual ("Design of Slope Protection to Resist Wave Action").

II. **DWH** (Design Wave Height) - See VDOT Drainage Manual ("Design of Slope Protection to Resist Wave Action") or U.S. Army Corps of Engineers' Shore Protection Manual.

III. **Depth of Buried Toe** = DWH at design wind speed.

IV. **Width of Riprap Apron** (Alternative to Buried Toe) = DWH x 2

V. **Height of Structure** (Above the Average Water Level) = DWH x 1.5

STD & SPEC 3.20

ROCK CHECK DAMS

CD

Definition

Small temporary stone dams constructed across a swale or drainage ditch.

Purpose

To reduce the velocity of concentrated stormwater flows, thereby reducing erosion of the swale or ditch. This practice also traps sediment generated from adjacent areas or the ditch itself, mainly by ponding of the stormwater runoff. Field experience has shown it to perform more effectively than silt fence or straw bales in the effort to stabilize "wet-weather" ditches.

Conditions Where Practice Applies

This practice, utilizing a combination of stone sizes, is limited to use in small open channels which drain 10 acres or less. It should not be used in a live stream as the objective should be to protect the live watercourse. Some specific applications include:

1. Temporary ditches or swales which, because of their short length of service, cannot receive a non-erodible lining but still need protection to reduce erosion.

2. Permanent ditches or swales which, for some reason, cannot receive a permanent non-erodible lining for an extended period of time.

3. Either temporary or permanent ditches or swales which need protection during the establishment of grass linings.

4. An aid in the sediment trapping strategy for a construction site. This practice is not a substitute for major perimeter trapping measures such as a SEDIMENT TRAP (Std. & Spec. 3.13) or a SEDIMENT BASIN (Std. & Spec. 3.14).

Planning Considerations

Check dams are effective in reducing flow velocity and thereby the potential for channel erosion. It is usually better to establish a protective vegetative lining before flow is confined or to install a structural channel lining than to install check dams. However, under circumstances where this is not feasible, check dams are useful.

Check dams installed in grass-lined channels may kill the vegetative lining if submergence after rains is too long and/or silting is excessive.

If check dams are used in grass-lined channels which will be mowed, care should be taken to remove all the stone when the dam is removed. This should include any stone which has washed downstream.

As previously mentioned, they have been found to be an effective aid in trapping sediment particles by virtue of their ability to pond runoff.

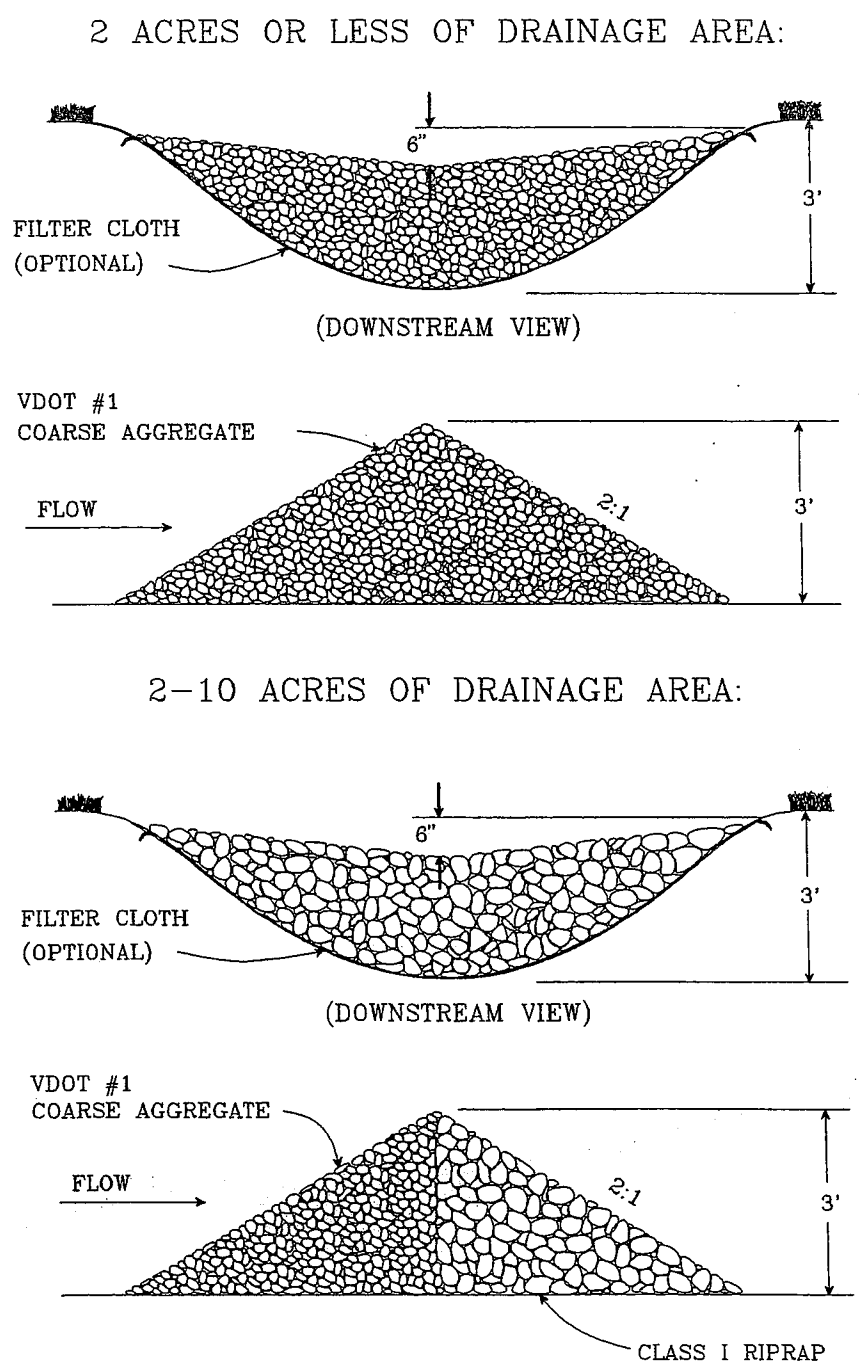
Specifications

No formal design is required for a check dam, however the following criteria should be adhered to when specifying check dams:

1. The drainage area of the ditch or swale being protected shall not exceed 2 acres when VDOT #1 Coarse Aggregate is used alone and shall not exceed 10 acres when a combination of Class I Riprap (added for stability) and VDOT #1 Coarse Aggregate is used. Refer to Plate 3.20-1 for orientation of stone and a cross-sectional view of the measure. An effort should be made to extend the stone to the top of channel banks.

2. However, the maximum height of the dam shall be 3.0 feet.

ROCK CHECK DAM



Source: Va. DSWC

Plate 3.20-1

3. The center of the check dam must be at least 6 inches lower than the outer edges. Field experience has shown that many dams are not constructed to promote this "weir" effect. Stormwater flows are then forced to the stone-soil interface, thereby promoting scour at that point and subsequent failure of the structure to perform its intended function.

4. For added stability, the base of the check dam can be keyed into the soil approximately 6 inches.

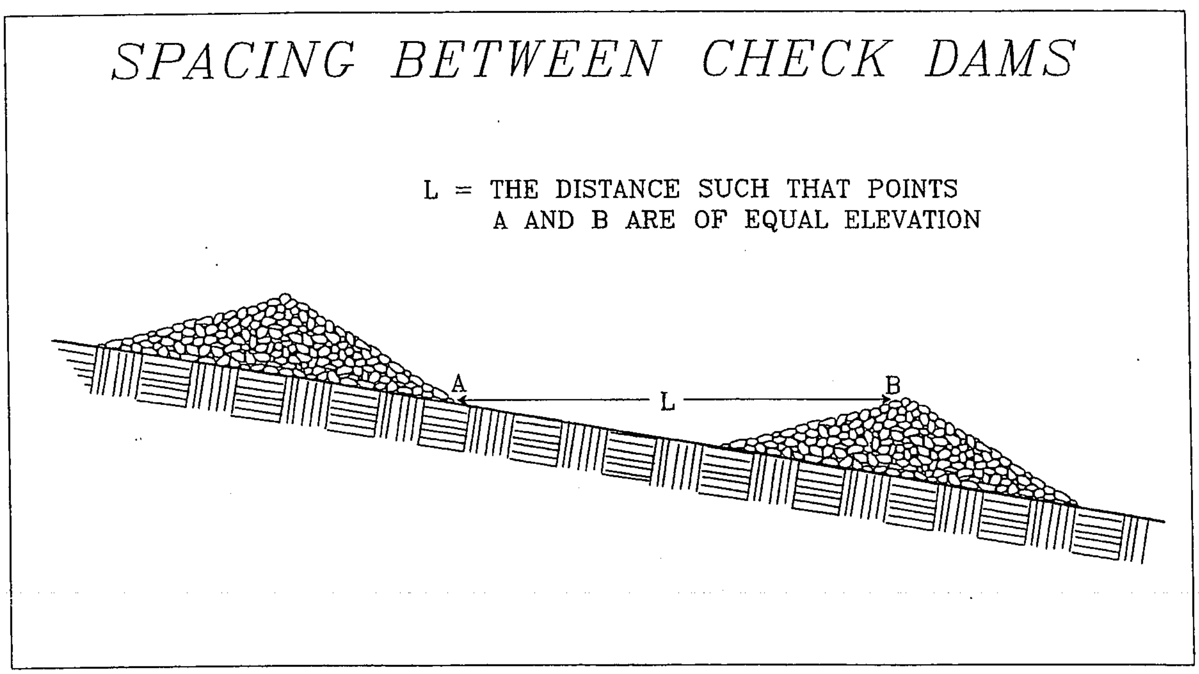
5. The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam (see Plate 3.20-2).

6. Stone should be placed according to the configuration in Plate 3.20-1. Hand or mechanical placement will be necessary to achieve complete coverage of the ditch or swale and to insure that the center of the dam is lower than the edges.

7. Filter cloth may be used under the stone to provide a stable foundation and to facilitate the removal of the stone. See Std. and Spec. 3.19, RIPRAP, for required physical properties of the filter cloth.

Sediment Removal

Sediment should be removed from behind the check dams when it has accumulated to one half of the original height of the dam.



Source: Va. DSWC Plate 3.20-2

Removal of Practice

Unless they will be incorporated into a permanent stormwater management control, check dams must be removed when their useful life has been completed. In temporary ditches and swales, check dams should be removed and the ditch filled in when they are no longer needed. In permanent structures, check dams should be removed when a permanent lining can be installed. In the case of grass-lined ditches, check dams should be removed when the grass has matured sufficiently to protect the ditch or swale. The area beneath the check dams should be seeded and mulched immediately after they are removed. The use of filter cloth underneath the stone will make the removal of the stone easier.

Maintenance

Check dams should be checked for sediment accumulation after each runoff-producing storm event. Sediment should be removed when it reaches one half of the original height of the measure.

Regular inspections should be made to insure that the center of the dam is lower than the edges. Erosion caused by high flows around the edges of the dam should be corrected immediately.

STD & SPEC 3.21

LEVEL SPREADER

LS

Definition

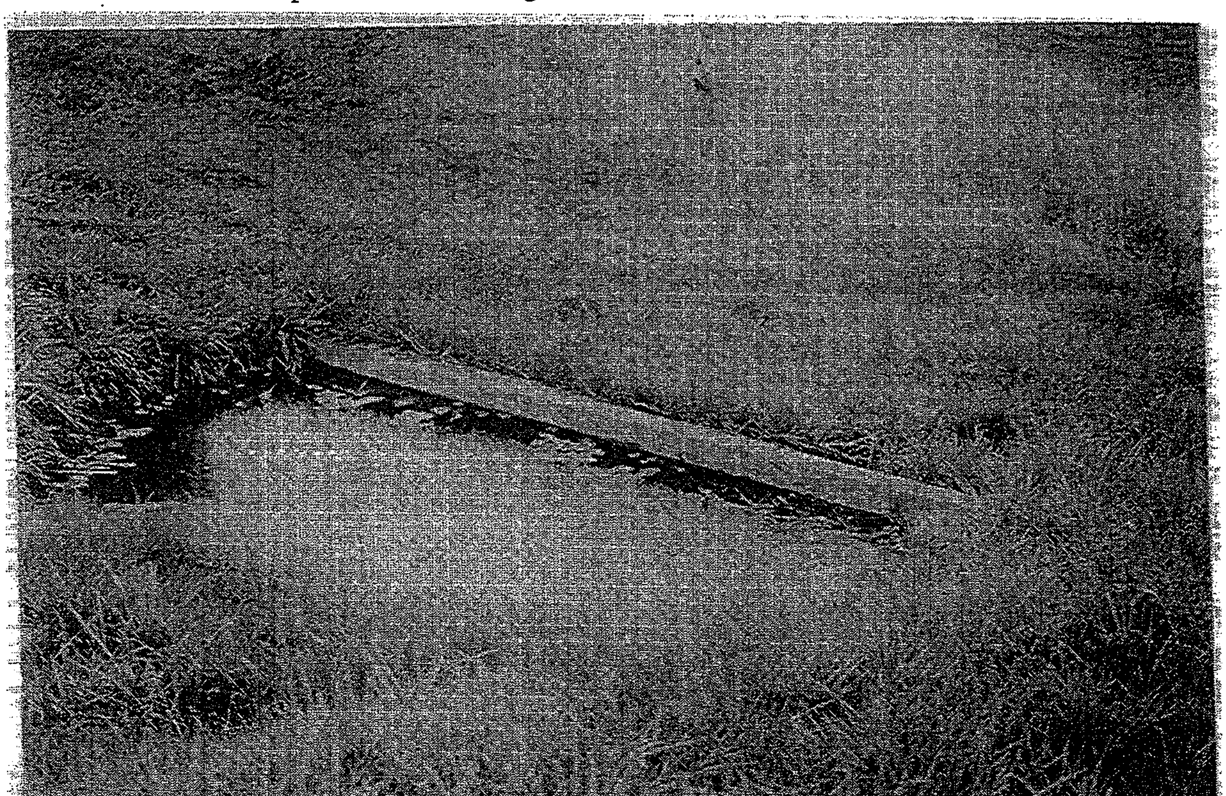
An outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope.

Purpose

To convert concentrated runoff to sheet flow and release it uniformly onto areas stabilized by existing vegetation.

Conditions Where Practice Applies

Where there is a need to divert stormwater away from disturbed areas to avoid overstressing erosion control measures; where sediment-free storm runoff can be released in sheet flow down a stabilized slope without causing erosion.



This practice applies only in those situations where the spreader can be constructed on undisturbed soil and the area below the level lip is uniform with a slope of 10% or less and is stabilized by natural vegetation. The runoff water should not be allowed to reconcentrate after release unless it occurs during interception by another measure (such as a permanent pond or detention basin) located below the level spreader.

Planning Considerations

The TEMPORARY DIVERSION DIKE, (Std.& Spec. 3.09) and the TEMPORARY RIGHT-OF-WAY DIVERSION, (Std. & Spec. 3.11) each call for a stable outlet for concentrated stormwater flows. The level spreader is a relatively low-cost structure to release small volumes of concentrated flow where site conditions are suitable (see Plate 3.21-1).

The outlet area must be uniform and well-vegetated with slopes 10% or less. Particular care must be taken to construct the outlet lip completely level in a stable, undisturbed soil. Any depressions in the lip will concentrate the flow, resulting in erosion. Under higher design flow conditions, a rigid outlet lip design should be used to create the desired sheet flow conditions. Runoff water containing high sediment loads must be treated in a sediment trapping device before being released to a level spreader.

Design Criteria

No formal design is required. The following criteria must be met:

Spreader Dimensions

Determine the capacity of the spreader by estimating the peak flow expected from a 10-year storm (Q_{10}).

Select the appropriate length, width and depth of the spreader from Table 3.21-A.

For design flows greater than 20 cfs, the measure should be designed by a qualified engineer.

A 20-foot transition section should be formed in the diversion channel so that the width of the diversion will smoothly tie in with the width of the spreader to ensure more uniform outflow.

The depth of the level spreader, as measured from the lip, shall be at least 6 inches. The depth may be made greater to increase temporary storage capacity, improve trapping of debris and to enhance settling of any suspended solids.

TABLE 3.21-A

MINIMUM DIMENSIONS FOR LEVEL SPREADER

Design Flow, Q_{10} (cfs)	Depth (ft.)	Width of Lower Side Slope of Spreader (ft.)	Length (ft.)
0-10	0.5	6	10
10-20	0.6	6	20

Source: Va. DSWC

Grade

1. The grade of the channel for the last 20 feet of the dike or diversion entering the level spreader shall be less than or equal to 1% (see Plate 3.21-1).

2. The grade of the level spreader channel shall be 0%.

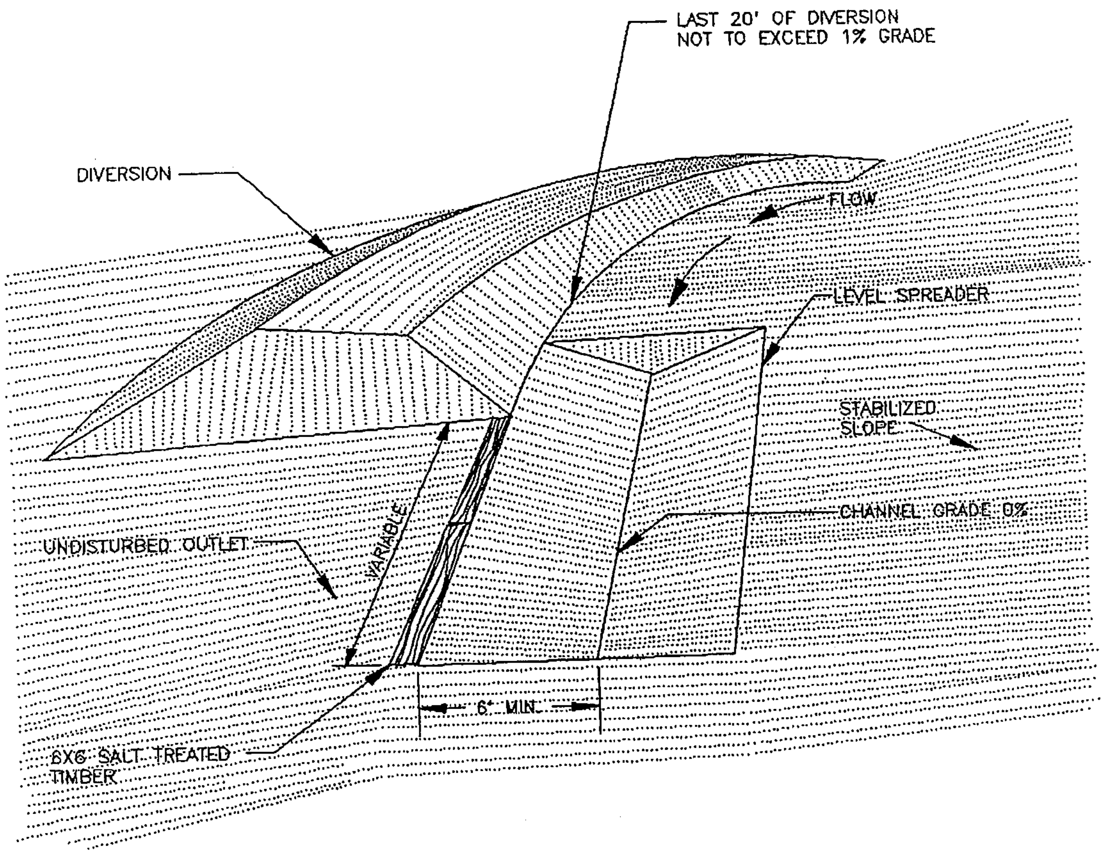
Spreader Lip

The release of the stormwater will be over the level lip onto an undisturbed well-vegetated area with a maximum slope of 10%. The level lip should be of uniform height and zero grade over the length of the spreader.

The level spreader lip may be stabilized by vegetation or may be of a rigid non-erodible material depending on the expected design flow:

Spreader Lip	Design Flow (cfs)
Vegetated	0 - 4
Rigid	5 - 20

LEVEL SPREADER



PERSPECTIVE VIEW

NOTE: ALL TEMPORARY BERMS, SWALES AND LEVEL SPREADER DITCH MUST RECEIVE TEMPORARY SEEDING IMMEDIATELY AFTER INSTALLATION

Source: Adapted from N.C. Erosion and Sediment Control Planning and Design Manual

Plate 3.21-1

A vegetated level lip must be constructed with an erosion-resistant material, such as jute or excelsior blankets, to inhibit erosion and allow vegetation to become established (see Plate 3.21-2).

For higher design flows and permanent installations, a rigid lip of non-erodible material, such as pressure-treated timbers or concrete curbing, should be used (see Plate 3.21-2).

Construction Specifications

1. Level spreaders must be constructed on undisturbed soil (not fill material).

2. The entrance to the spreader must be shaped in such a manner as to insure that runoff enters directly onto the 0% channel.

3. Construct a 20-ft. transition section from the diversion channel to blend smoothly to the width and depth of the spreader.

4. The level lip shall be constructed at <u>0% grade to insure uniform spreading of stormwater runoff</u>.

5. Protective covering for vegetated lip should be a minimum of 4 feet wide extending 6 inches over the lip and buried 6 inches deep in a vertical trench on the lower edge. The upper edge should butt against smoothly cut sod and be securely held in place with closely spaced heavy duty wire staples (see Plate 3.21-2).

6. Rigid level lip should be entrenched at least 2 inches below existing ground and securely anchored to prevent displacement. An apron of VDOT #1, #2 or #3 Coarse Aggregate should be placed to top of level lip and extended downslope at least 3 feet. Place filter fabric under stone and use galvanized wire mesh to hold stone securely in place (see Plate 3.21-2).

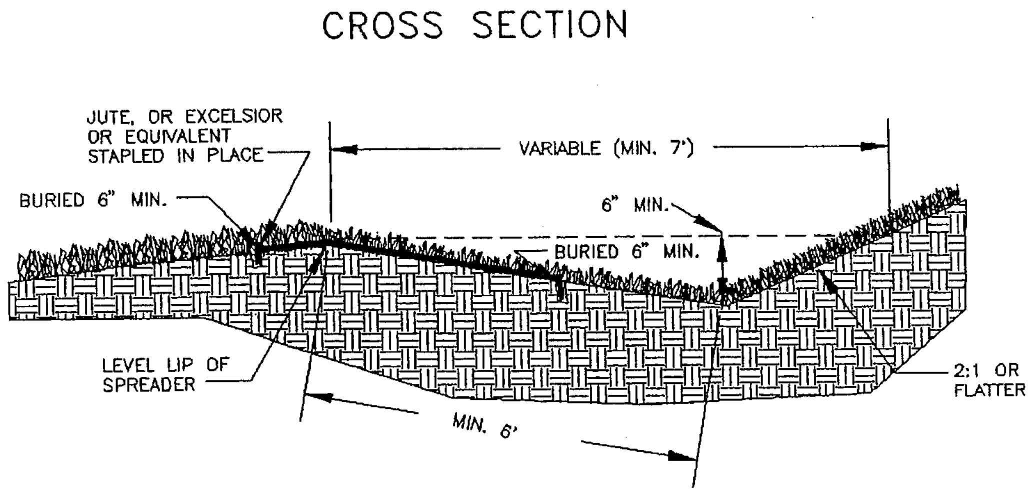
7. The released runoff must outlet onto undisturbed stabilized areas with slope not exceeding 10%. Slope must be sufficiently smooth to preserve sheet flow and prevent flow from concentrating.

8. Immediately after its construction, appropriately seed and mulch the entire disturbed area of the spreader.

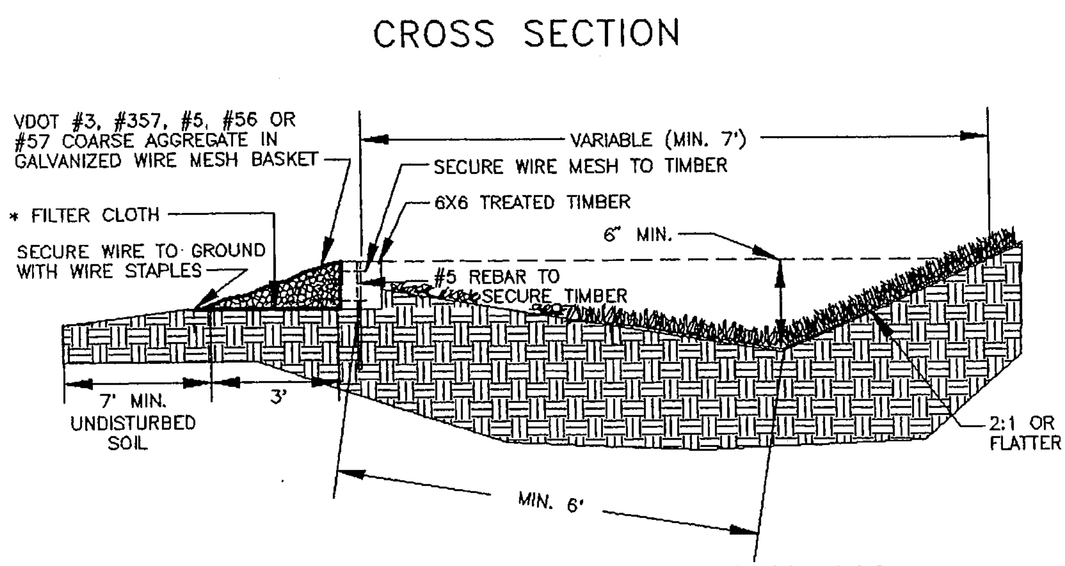
Maintenance

The measure shall be inspected after every rainfall and repairs made, if required. Level spreader lip must remain at 0% slope to allow proper function of measure. The contractor should avoid the placement of any material on and prevent construction traffic across the structure. If the measure is damaged by construction traffic, it shall be repaired immediately.

LEVEL SPREADER



LEVEL SPREADER WITH VEGETATED LIP



LEVEL SPREADER WITH RIGID LIP

* MIN. PHYSICAL REQUIREMENTS OF FILTER CLOTH NOTED IN STD. & SPEC. 3.19, RIPRAP

Source: Va. DSWC and N.C. Erosion and Sediment Control Planning and Design Manual

Plate 3.21-2

STD & SPEC 3.22

VEGETATIVE STREAMBANK STABILIZATION

VSS

Definition

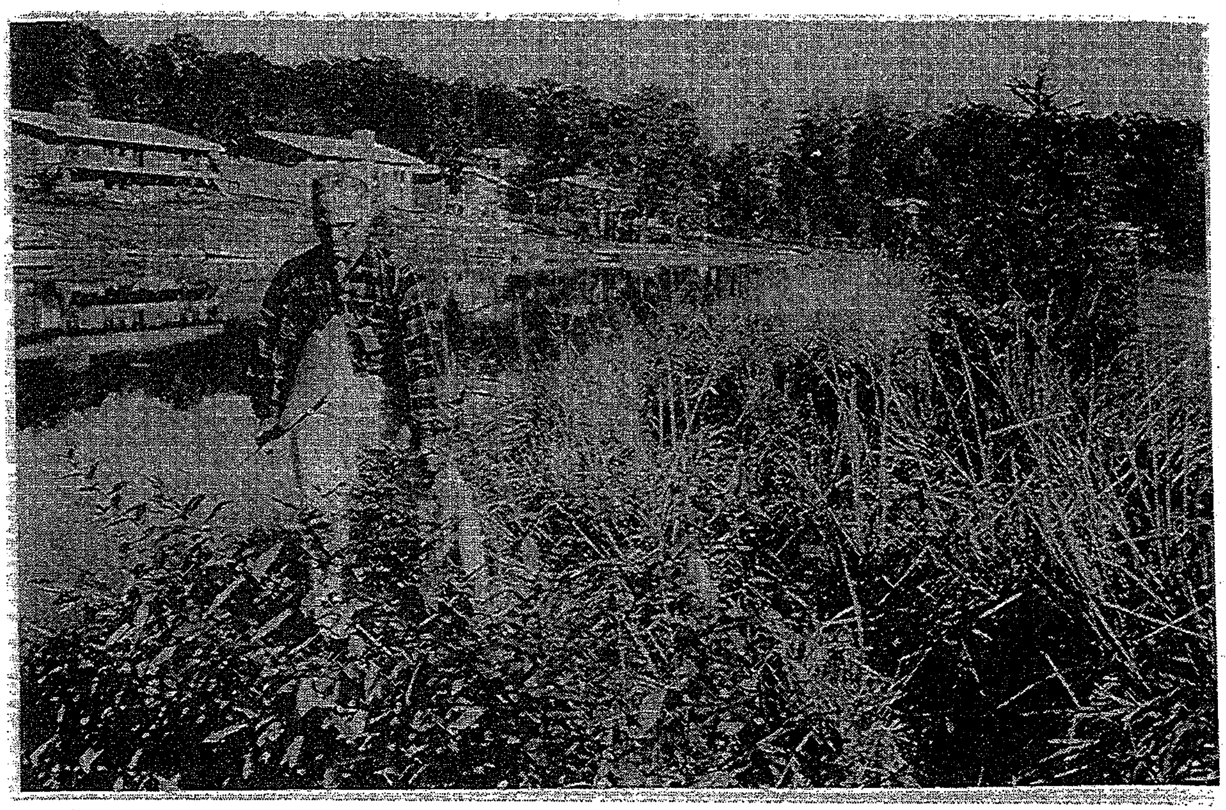
The use of vegetation in stabilizing streambanks.

Purpose

To protect streambanks from the erosive forces of flowing water.

Conditions Where Practice Applies

Along banks in creeks, streams and rivers subject to erosion from excess runoff. This practice is generally applicable where bankfull flow velocity does not exceed 5 ft./sec. and soils are erosion resistant. Above 5 ft./sec., structural measures are generally required. This practice does not apply where tidal conditions exist.



Planning Considerations

A primary cause of stream channel erosion is the increased frequency of bank-full flows which often result from upstream development. Most natural stream channels are formed with a bank-full capacity to pass the runoff from a storm with a 1½ to 2-year recurrence interval. However, in a typical urbanizing watershed, stream channels are subject to a 3- to 5-fold increase in the frequency of bank-full flows. As a result, stream channels that were once parabolic in shape and covered with vegetation are often transformed into wide rectangular channels with barren banks.

In recent years, a number of structural measures have evolved to strengthen and protect the banks of rivers and streams. These methods, if employed correctly, immediately insure a satisfactory protection of the banks. However, many such structures are expensive to build and to maintain and frequently cause downstream velocity problems. Without constant upkeep, they are exposed to progressive deterioration by natural agents. The materials used often prevent the re-establishment of native plants and animals, especially when the design is executed according to standard cross-sections which ignore natural variations of the stream system. Very often these structural measures destroy the appearance of the site.

In contrast, the utilization of living plants instead of or in conjunction with structures has many advantages. The degree of protection, which may be low to start with, increases as the plants grow and spread. The repair and maintenance of structures is unnecessary where self-maintaining streambank plants are established. The protection provided by natural vegetation is more reliable and effective where the cover consists of natural plant communities which are native to the site. Planting vegetation is less damaging to the environment than installing structures. Vegetation also provides habitat for fish and wildlife and is aesthetically pleasing. Plants provide erosion protection to streambanks by reducing stream velocity, binding soil in place with a root mat and covering the soil surface when high flows tend to flatten vegetation against the banks. For these reasons, vegetation should always be considered first.

One disadvantage of vegetation is that it lowers the carrying capacity of the channel, which may promote flooding. Therefore, maintenance needs and the consequences of flooding should be considered. The erosion potential for the stream needs to be evaluated to determine the best solutions. The following items should be considered in the evaluation:

1. The frequency of bankfull flow based on anticipated watershed development.

2. The channel slope and flow velocity, by design reaches.

3. The antecedent soil conditions.

4. Present and anticipated channel roughness ("n") values.

5. The location of channel bends along with bank conditions.

6. The location of unstable areas and trouble spots. Steep channel reaches, high erosive banks and sharp bends may require structural stabilization measures such as riprap, while the remainder of the streambank may require only vegetation.

Where streambank stabilization is required and velocities appear too high for the use of vegetation, one should consider structural measures (see Std. & Spec. 3.23, STRUCTURAL STREAMBANK STABILIZATION) or the use of permanent erosion control matting (see Std. & Spec. 3.36, SOIL STABILIZATION MATTING). Notably, any applicable approval or permits from other state or federal agencies must be obtained prior to working in such areas.

Vegetation Zones Along Watercourses

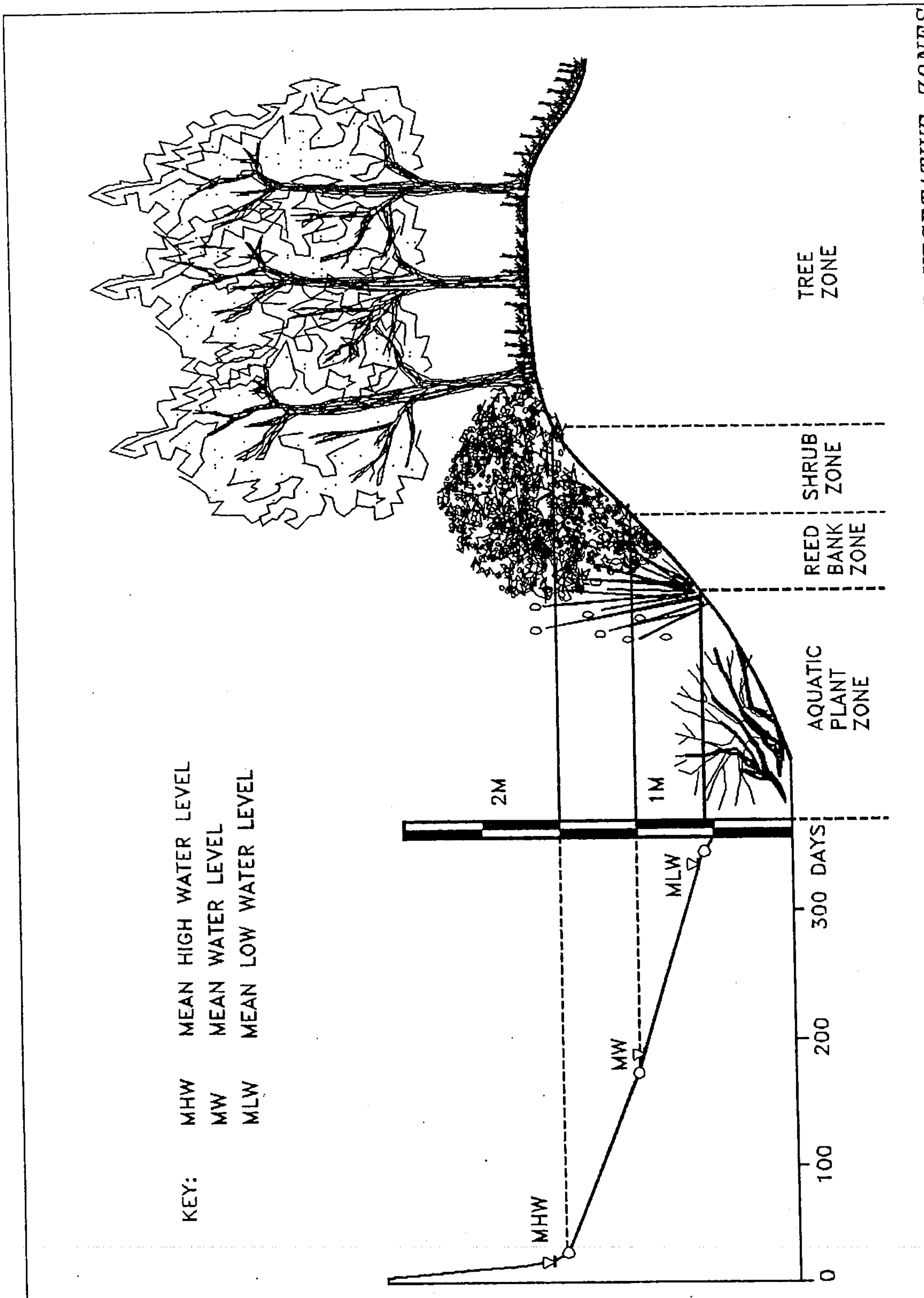
At the edge of all natural watercourses, plant communities exist in a characteristic succession of vegetative zones, the boundaries of which are dependent upon site conditions such as the steepness and shape of the bank and the seasonal and local variations in water depth and flow rate. Streambanks commonly exhibit the following zonation (see Plate 3.22-1):

1. Aquatic Plant Zone - This zone is normally permanently submerged. In Virginia, this zone is inhabited by plants such as pondweeds and water lilies, which reduce the water's flow rate by friction. The roots of these plants help to bind the soil, and they further protect the channel from erosion because the water flow tends to flatten them against the banks and bed of the stream.

2. Reed-Bank Zone - The lower part of this zone is normally submerged for only about half the year. In Virginia, this zone is inhabited by rushes, reed grasses, cattails, and other plants which bind the soil with their roots, rhizomes and shoots and slow the water's flow rate by friction.

3. Shrub Zone - This zone is flooded only during periods of average high water. In Virginia, the shrub zone is inhabited by trees and shrubs--such as willow, alder, dogwood and viburnum--with a high regenerative capacity. These plants hold the soil with their root systems and slow water speed by friction. They also protect tree trunks from damage caused by breaking ice and help to prevent the formation of strong eddies around large trees during flood flows. Shrub zone vegetation is particularly beneficial along the impact bank of a stream meander, where maximum scouring tends to occur. Infringement of shrub vegetation into the channel tends to reduce the channel width, increasing probability of floods. However, brief flooding of riverside woods and undeveloped bottomlands does no significant damage, and the silt deposits in these wooded areas are less of a problem than failed banks.

4. Tree Zone - This zone is flooded only during periods of very high water (i.e., the 2-year bank-full flow or greater flows). Typical plants in Virginia are trees in the ash-elm, alder-ash, and oak-horn-beam associations. These trees hold soil in place with their root systems.



TYPICAL ANNUAL CURVE OF WATER LEVELS CORRELATED WITH TYPICAL VEGETATIVE ZONES

Source: <u>Importance of Natural Vegetation for the Protection of the Banks of Streams, Rivers and Canals</u>, Seibert

Plate 3.22-1

Design Criteria

Table 3.22-A provides general guidelines for maximum allowable velocities in streams to be protected by vegetation.

1. Ensure that channel bottoms are stable before stabilizing channel banks.

2. Keep velocities at bankfull flow non-erosive for the site conditions.

3. Provide mechanical protection such as rip-rap on the outside of channel bends if bankfull stream velocities approach the maximum allowable for site conditions.

4. Be sure that requirements of other state or federal agencies are met in the design in the case that other approvals or permits are necessary.

TABLE 3.22-A

CONDITIONS WHERE VEGETATIVE STREAMBANK STABILIZATION IS ACCEPTABLE

Frequency of Bankfull Flow	Max. Allowable Velocity for Highly Erodible Soil	Maximum Allowable Velocity (Erosion Resistant Soil)
> 4 times/yr.	4 ft./sec.	5 ft./sec.
1 to 4 times/yr.	5 ft./sec.	6 ft./sec.
< 1 time/yr.	6 ft./sec.	6 ft./sec.

Source: Va. DSWC

Planting Guidelines

Guidelines will be presented only for the reed-bank and shrub zones. The aquatic plant zone is difficult to implant and establish naturally when reed-bank vegetation is present. There are presently many experts in this field at the federal, state, and private sector levels who can be consulted concerning successful establishment of plants in the aquatic zone. The tree zone is least significant in terms of protecting banks from more frequent erosion-force flows, since this zone is seldom flooded. Also, shade from trees in this zone can prevent adequate establishment of vegetation in other zones.

1. Establishing Reed-Bank Vegetation

There are various ways of planting reed-bank vegetation. The following plants are considered suitable:

Common Reed	(Phragmites communis)
Reed Canary Grass	(Phalaris arundinacae)
Great Bulrush	(Scirpus lacustris)
Common Cattail	(Typha latifolia)

The greatest protection seems to be provided by the Common Reed. It is a very robust plant whose stems become woody in the autumn, resulting in continued protection during the winter. Because the shoots and rhizomes are deeply and strongly rooted and densely intertwined, they bind the soil more firmly than any other reed. The stems and roots have dormant buds at the nodes and are capable of sprouting when planted. However, the Common Reed does grow high and thick, and periodic maintenance may be needed in order to achieve a neat appearance.

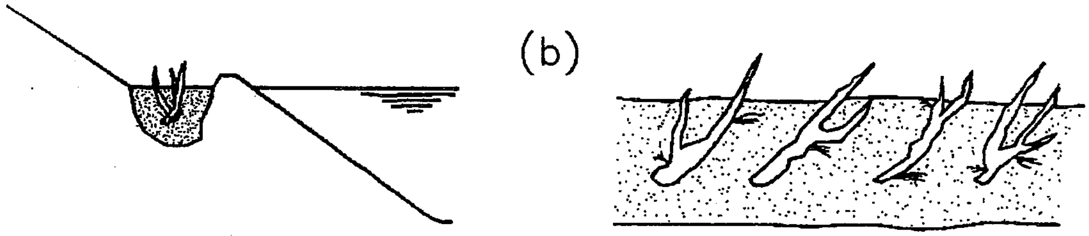
a. Planting in Clumps: The oldest and most common method of planting reeds is planting in clumps (see Plate 3.22-2 (a)). The stems of the reed colony are scythed. Then square clumps are cut out of the ground and placed in pits prepared in advance on the chosen site. The clumps are planted at a depth where they will be submerged to a maximum of two-thirds of their height.

b. Planting Rhizomes and Shoots: Less material is needed for the planting of rhizomes and shoots, a procedure which can be used to establish the Common Reed, Reed Grass, Bulrush, Cattail and other plants. Slips are taken from existing beds during the dormant season, after the stems have been cut. Rhizomes and shoots are carefully removed from the earth without bruising the buds or the tips of the sprouts. They are placed in holes or narrow trenches, along the line of the average summer water level, so that only the stem sprouts are showing above the soil.

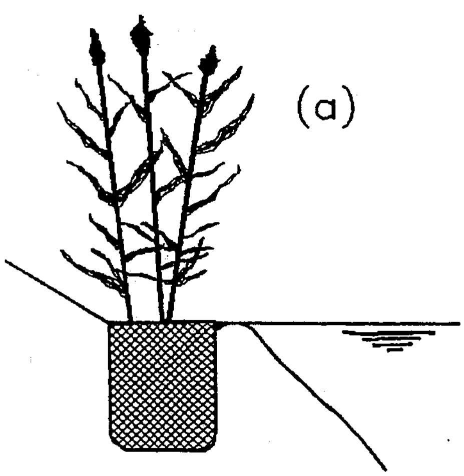
c. Planting Stem Slips: It is possible to plant stem slips of the Common Reed along slow-moving streams (see Plate 3.22-2 (b)). Usually, three slips are set in a pit 12 to 20 inches deep. If the soil is packed or strong, the holes must be made with a dibble bar or some other metal planting tool. The pits should be located approximately 1 foot apart.

d. Reed Rolls: In many cases, the previously described methods do not consolidate the banks sufficiently during the period immediately after planting. Combined structures have therefore been designed, in which protection of the bank is at first insured by structural materials. Along slow to fairly fast

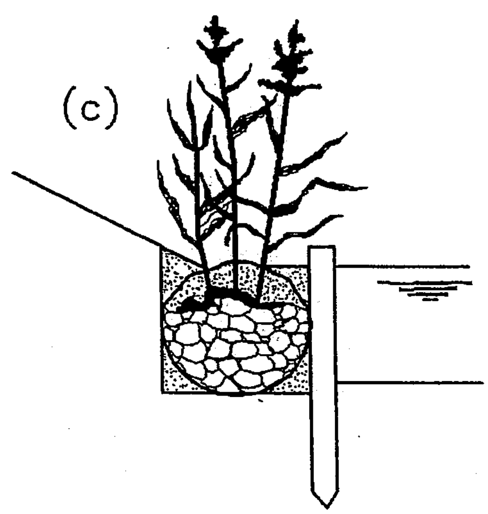
METHODS OF ESTABLISHING REED BANK VEGETATION



PLANTING STEM SLIPS



PLANTING CLUMPS



REED ROLLS

Source: Importance of Natural Vegetation for the Protection of the Banks of Streams, Rivers and Canals, Seibert

Plate 3.22-2

streams, the most effective method of establishing reed-bank vegetation has been found to be the use of Reed Rolls (see Plate 3.22-2 (c)). A trench 18 inches wide and deep is dug behind a row of stakes. Wire netting, such as ½-inch hardware cloth, is then stretched from both sides of the trench between upright planks. Onto this netting is dumped fill material such as coarse gravel, sod, or soil and other organic material. This material is then covered by reed clumps until the two edges of the wire netting can just be held together with wire. The upper edge of the roll should be no more than 2 inches above the level of the water. Finally, the planks are taken out, and any gaps along the sides of the roll are filled in with earth. This method provides greater protection from the possibility of a heavy flow washing away the vegetative materials before they have a chance to become established.

e. Seeding: Reed Canary Grass can be sown 1/2-inch deep on very damp bank soil, provided that the seeded surface is not covered by water for six months after sowing. Seed at a rate of 12-15 lbs./acre. Reed Canary Grass is a cool season grass and should not be seeded in the summer.

f. Vegetation and Stone Facing: Reed-bank and other types of vegetation can be planted in conjunction with rip-rap or other stone facing by planting clumps, rhizomes or shoots in the crevices and gaps along the line of the average summer water level.

2. Establishing Shrub Zone Vegetation: Stands of full-grown trees are of little use for protecting streambanks apart from the binding of soil with their roots. Shrubwood provides much better protection; and in fact, riverside stands of willow trees are often replaced naturally by colonies of shrub-like willows. Plants should be used which can easily adapt to the stream and site conditions.

a. Seeding and Sodding: Frequently, if the stream is small and a good seedbed can be prepared, grasses can be used alone to stabilize the streambanks. To seed the shrub zone, first grade eroded or steep streambanks to a maximum slope of 2:1 (3:1 preferred). Existing trees greater than 4 inches in diameter should be retained whenever possible. Topsoil should be conserved for re-use. Seeding mixtures should be selected and operations performed according to Std. & Spec. 3.32, PERMANENT SEEDING. Some type of erosion control blanket, such as jute netting, excelsior blankets, or equivalent should be installed according to Std. & Spec. 3.36, SOIL STABILIZATION BLANKETS & MATTING. Sod can also be placed in areas where grass is suitable. Sod should be selected and installed according to Std. & Spec. 3.33, SODDING. Turf should only be used where the grass will provide adequate protection, necessary maintenance can be provided, and establishment of other streambank vegetation is not practical or possible.

b. Planting Cuttings and Seedlings: Shrub willows, shrub dogwoods and alders can be put into the soil as cuttings, slips or stems. In dense shade, shrubs such as the Blue Arctic Willow (Salix purpurea nana) and the Silky Dogwood (Cornus amomum) or evergreen ground covers such as Lily Turf (Liriope Muscari) or Hall's Honeysuckle (Linicera hallsiana) are appropriate. The Silky Dogwood also works well in sunny areas. On larger streams, "Streamco" Purpleosier Willow (Salix purpurea "Streamco") and Bankers' Dwarf Willow (Salix x Cotteti) have been widely used with success. Two native river alders (Alnus serrulata and Alnus rugosa), which occur throughout the northeast, also show great promise for streambank stabilization, although they have not been fully tested. Again, the first step in the planting process is to grade eroded or steep slopes to a maximum slope of 2:1 (3:1 preferred), removing overhanging bank edges.

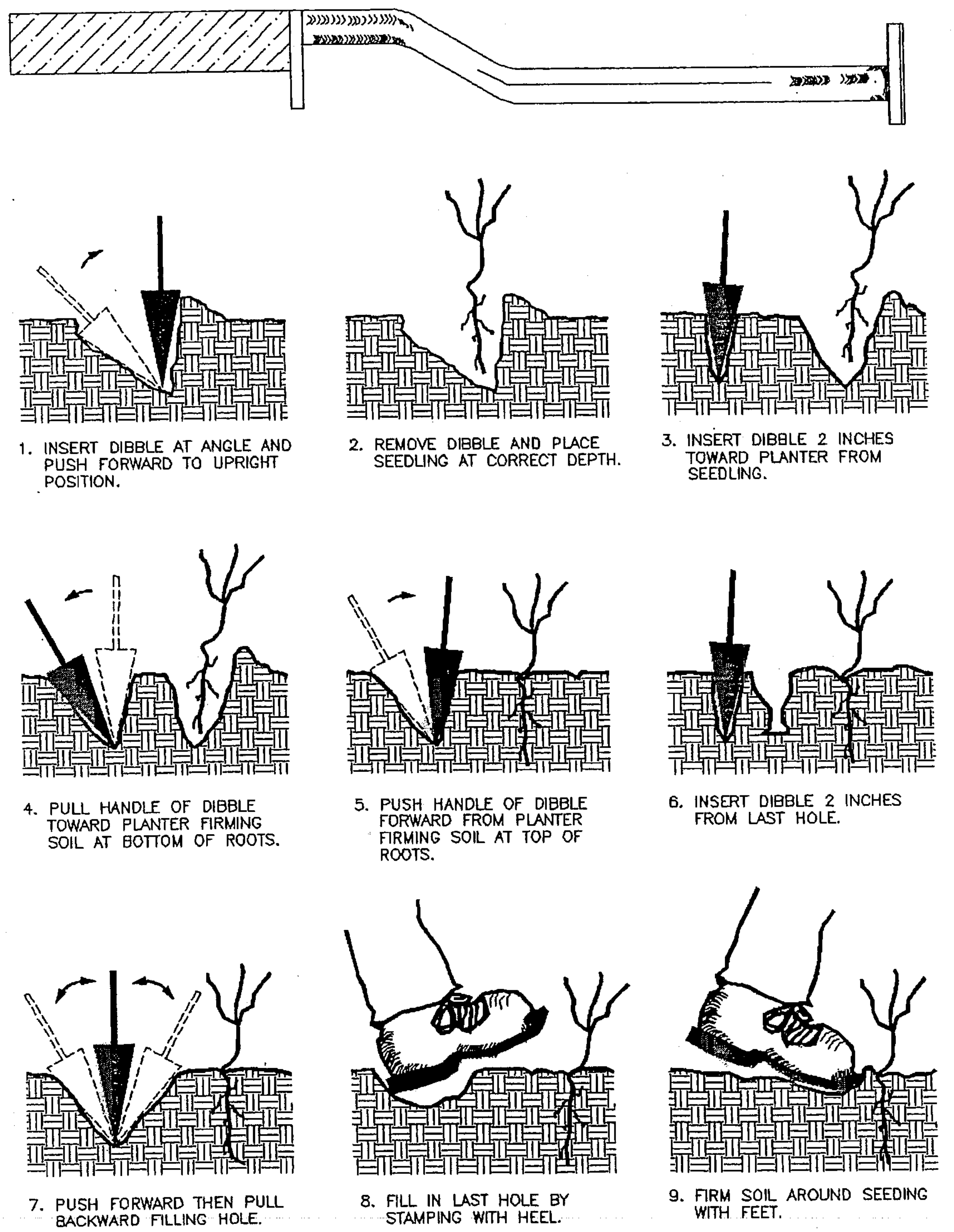
Willows can be planted as 1-year old, nursery-grown, rooted cuttings or as fresh hardwood cuttings gathered from local mother-stock plantings. Silky Dogwood and the alders should be nursery-grown seedlings 1 or 2 years old. Fresh cuttings should be 3/8- to 1/2-inch thick and 12 to 18 inches long. They should be kept moist. If not used at once, they should be stored in cool moist sand.

Streambanks are often difficult to plant, even when they are well-sloped. This is especially true in gravelly or strong banks. Where mattocks or shovels are unsatisfactory tools, a stiff steel bar, such as a crowbar, is better. The best tool for this purpose is a dibble bar, a heavy metal tool with a blade and a foot pedal. It is thrust into the ground to make a hole for the plant (see Plate 3.22-3).

Rooted cuttings should be planted vertically in the bank with 1 or 2 inches of wood protruding above the ground surface. They should be stuck in a hole large enough to accommodate the root system when well spread. The plant roots must be maneuvered into the bottom of the hole so they will grow down instead of up. The roots should not be twisted, nor should they be exposed above the ground surface. After the plant is placed, the dibble bar can be installed a few inches away from the plant to close the hole. Slow-release fertilizer should be applied on the surface, <u>not in the hole</u>. The soil should be tamped adequately to provide complete contact between the soil and the cutting. Cuttings should be planted 1 foot on center in at least 3 rows located at the top, middle and bottom of the shrub zone.

Plant seedings of the river alders vertically in the bank to the depth they were growing in the nursery. Use the same procedure described previously. Plant one row of alders at 2-foot intervals at the base of the shrub zone, not more than 1.5 to 3 feet from the average summer water level or from the reeds. A greater distance is of no use unless a belt of tall perennial herb colonies is established between the reeds and the alders. Plant the next row 2 feet up

DIBBLE PLANTING



Source: A Guide For Vegetating Surface-Mined Lands For Wildlife in Eastern Kentucky and West Virginia, USDI-Fish and Wildlife Service

Plate 3.22-3

the slope, with a third row 4 feet up the slope. Plant at least 3 rows. Locate the plants in a diamond pattern.

Since these plants are generally not effective for the first two years, grasses can be seeded immediately following their planting to provide initial streambank protection. The seed mixtures noted in Table 3.22-B are appropriate plantings.

TABLE 3.22-B

INITIAL STREAMBANK PLANTINGS: SEED MIXTURES BY REGION*

Appalachian Region	Piedmont Region	Coastal Plain
Kentucky-31 Tall Fescue: 65 lbs./acre Creeping Red Fescue: 15 lbs./acre Redtop Grass: 5 lbs./acre	Kentucky-31 Tall Fescue: 80 lbs./acre. Redtop Grass: 5 lbs./acre	Kentucky-31 Tall Fescue: 65 lbs./acre Bermudagrass: 15 lbs./acre Redtop Grass: 5 lbs./acre

* Physiographic Regions are described in Std. & Spec. 3.32, PERMANENT SEEDING.

Source: Va. DSWC

The seedbed should be roughened with rakes and fertilized with 500 to 1000 pounds per acre of 10-10-10, adjusted to meet the needs of the site. Special care should be used when fertilizing next to water sources to avoid any unnecessary introduction of nitrogen/phosphorus into the water. Seed should be broadcast, covered lightly and mulched with 2 tons of straw per acre (2-3 bales per 1000 square feet) or a minimum of 1500 pounds of wood fiber mulch per acre (2000 pounds per acre preferred). If straw is used, it should be properly anchored with netting or an effective tackifier. Erosion control blankets/mats are often very effective aids in the establishment of grasses or plant material along streambanks (see Std. & Spec. 3.36, SOIL STABILIZATION BLANKETS & MATTING).

Willows and other softwoods can also be bound together in various ways in order to insure immediate protection of the streambank.

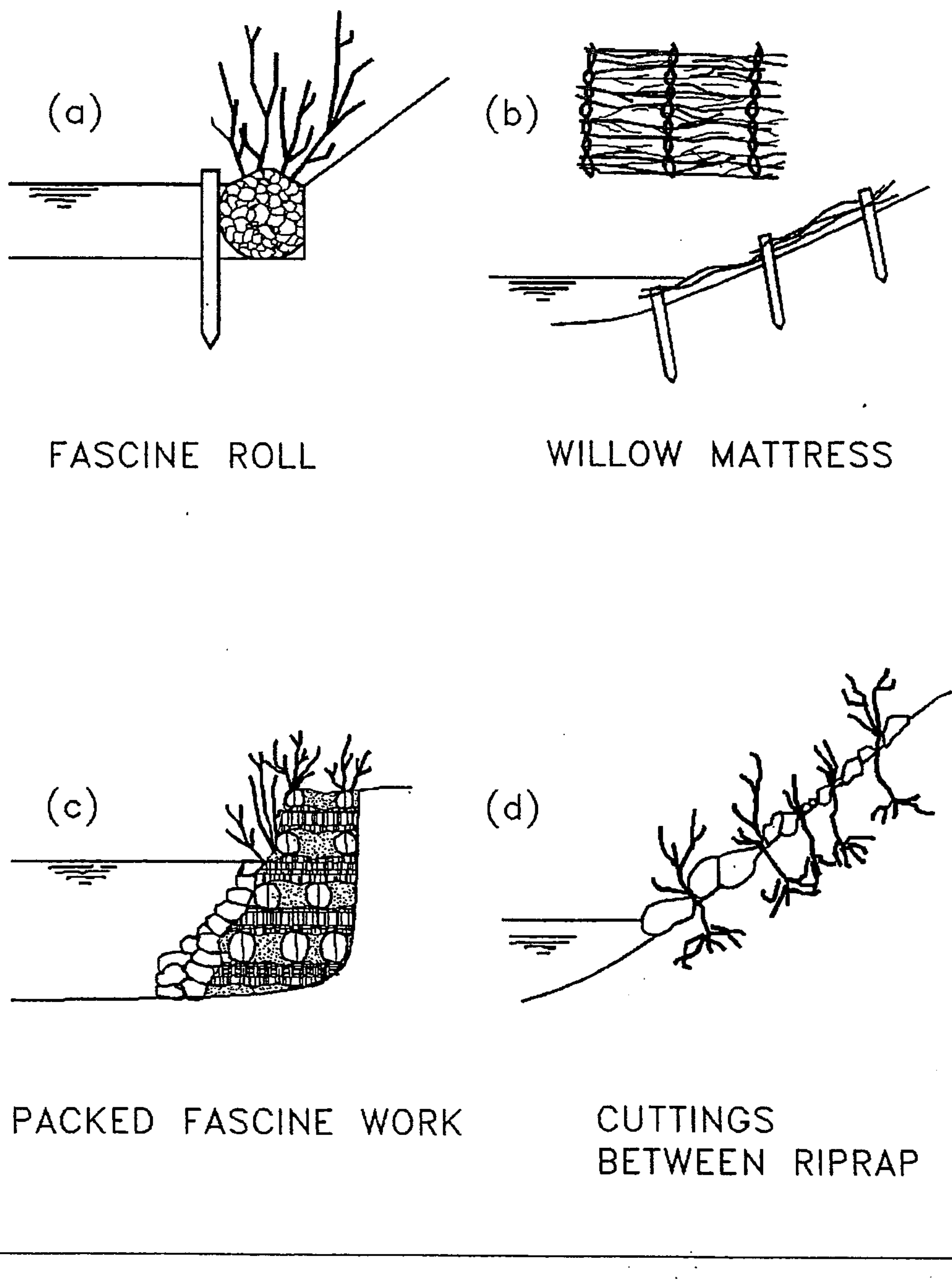
c. Fascine Rolls: Fascine rolls are bundles of brushwood and sticks, without branches if possible, that are filled with coarse gravel and rubble and wired tightly around the outside. They are 4 to 20 yards long and 4 to 16 inches in diameter. They are set against the bank so that the parts which are to take root touch the ground above the water level and are able to get sufficient moisture. Covering with earth improves the contact with the ground and retards the loss of moisture from the wood (see Plate 3.22-4 (a)).

d. Willow Mattresses: The degree of streambank protection can be increased by using willow mattresses or packed fascine work. Willow mattresses consist of 4- to 8-inch thick layers of growing branches set perpendicular to the direction of the current or sloping downstream. with the broad ends of the branches oriented downwards. The branches are held together with interweaving wire or other branches at intervals of 24 to 32 inches, set parallel to the direction of the current or at an angle of 30 degrees. If several layers of mattress are necessary, the tops of the lower layers should cover the bases of the upper layers. The bottom layer is fixed at the base in a trench previously dug at the base of the softwood zone. The whole mattress structure should be covered with 2 to 10 inches of earth or fine gravel (Plate 3.22-4 (b)).

e. Packed Fascine-Work: Packed fascine-work [Plate 3.22-4 (c)] consists essentially of layers of branches laid one across the other to a depth of 8 to 12 inches and covered with fascine rolls. The spaces between the fascine rolls are filled with gravel, stones and soil so that no gaps remain; and a layer of soil and gravel 8 to 12 inches thick is added on top. Packed fascine-work is particularly suitable for repairing large breaches in the banks of streams with high water levels.

f. Combination with Stone Facing: In many places, the bank is not adequately protected by vegetation until the roots are fully developed, and temporary protection must be provided by inanimate materials. There is a wide choice of methods, including the planting of woody plants in the crevices of stone facing (Plate 3.22-4 (d)). For structural protection measures, see Std. & Spec. 3.23, STRUCTURAL STREAMBANK PROTECTION.

METHODS OF ESTABLISHING SHRUB ZONE VEGETATION



Source: Importance of Natural Vegetation for the Protection of the Banks of Streams, Rivers and Canals, Seibert

Plate 3.22-4

Maintenance

Streambanks are always vulnerable to new damage. Repairs are needed periodically. Banks should be checked after every high-water event is over. Gaps in the vegetative cover should be fixed at once with new plants, and mulched if necessary. Fresh cuttings from other plants on the bank can be used, or they can be taken from mother-stock plantings if they are available. Trees that become established on the bank should be removed at once.

STD & SPEC 3.23

STRUCTURAL STREAMBANK STABILIZATION

SSS

Definition

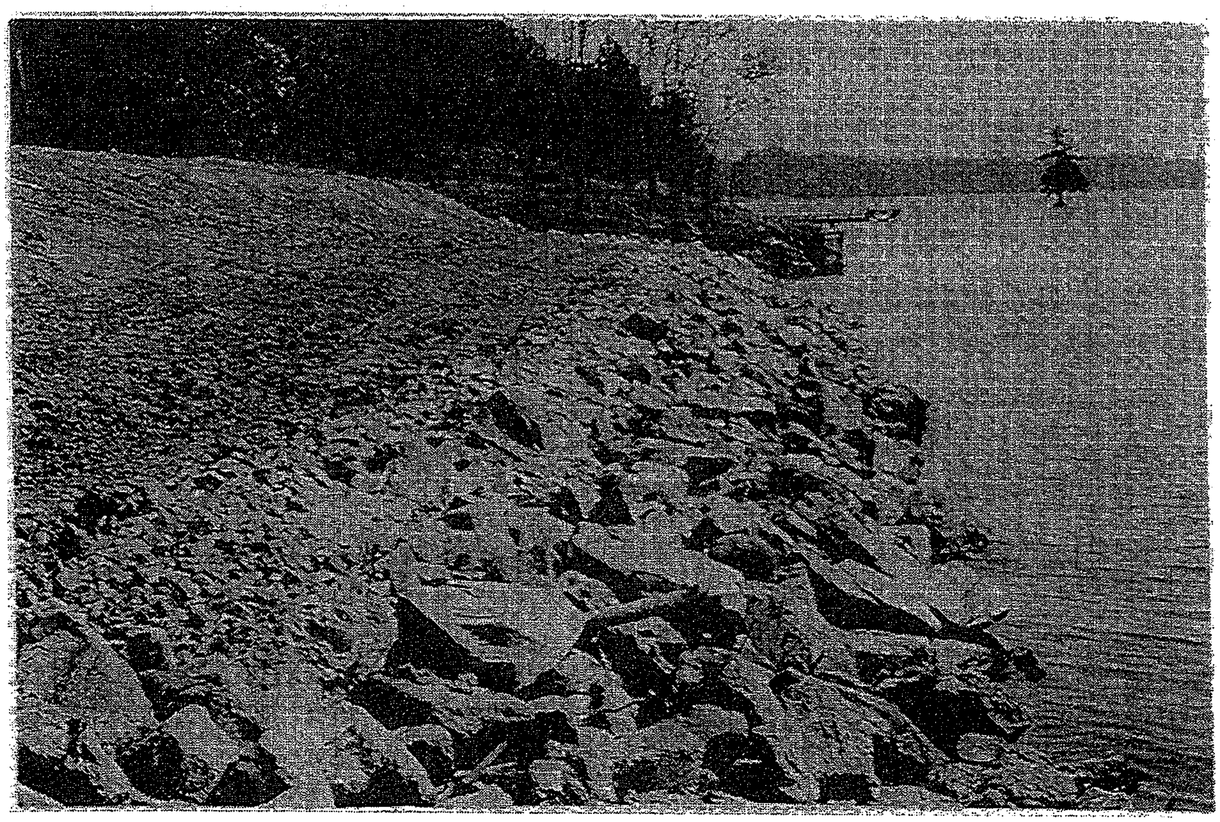
Methods of stabilizing the banks of live streams with permanent structural measures.

Purpose

To protect streambanks from the erosive forces of flowing water.

Conditions Where Practice Applies

Applicable to streambank sections which are subject to excessive erosion due to increased flows or disturbance during construction. Generally applicable where flow velocities exceed 5 ft./sec. or where vegetative streambank protection is inappropriate.



Planning Considerations

Stream channel erosion problems vary widely in type and scale and there are many different structural stabilization techniques which have been employed with varying degrees of effectiveness. The purpose of this specification is merely to point out some of the practices which are available and to establish some broad guidelines for their selection and design. Such structures should be planned and designed in advance by an engineer or some other qualified individual with appropriate experience. Many of the practices referenced here involve the use of manufactured products and should be designed and installed in accordance with the manufacturers' specifications.

Before selecting a structural stabilization technique, the designer should carefully evaluate the possibility of using vegetative stabilization (Std. & Spec. 3.22) alone or in conjunction with structural measures, to achieve the desired protection. Vegetative techniques are generally less costly and more compatible with natural stream characteristics.

General Guidelines

Since each reach of channel requiring protection is unique, measures for streambank protection should be installed according to a plan and adapted to the specific site. Designs should be developed according to the following principles:

1. Protective measures to be applied shall be compatible with improvements planned or being carried out by others.
2. The bottom scour should be controlled, by either natural or artificial means, before any permanent type of bank protection can be considered feasible. This is not necessary if the protection can be safely and economically constructed to a depth well below the anticipated lowest depth of bottom scour.
3. Streambank protection should be started and ended at a stabilized or controlled point on the stream.
4. Changes in channel alignment shall be made only after an evaluation of the effect upon land use, interdependent waste water systems, hydraulic characteristics and existing structures.
5. Special attention should be given to maintaining and improving habitat for fish and wildlife.
6. The design velocity should be that of the peak discharge of the 10-year storm. Structural measures must be effective for this design flow and must be capable of withstanding greater flows without serious damage.

7. All requirements of state law and permit requirements of local, state and federal agencies must be met.

8. Stabilize all areas disturbed by construction as soon as the structural measures are complete.

Streambank Protection Measures

Riprap - heavy angular stone placed (preferably) or dumped onto the streambank to provide armor protection against erosion. Riprap shall be designed and installed according to the practice entitled RIPRAP (Std. & Spec. 3.19).

Gabions - rectangular, rock-filled wire baskets are pervious, semi-flexible building blocks which can be used to armor the bed and/or banks of channels or to divert flow away from eroding channel sections. Gabions should be designed and installed in accordance with manufacturer's standards and specifications (see Plate 3.23-1). At a minimum, they should be constructed of a hexagonal triple twist mesh of heavily galvanized steel wire (galvanized wire may also receive a poly-vinyl chloride coating). The design water velocity for channels utilizing gabions should not exceed that given below:

Gabion Thickness (feet)	Maximum Velocity (feet per second)
1/2	6
3/4	11
1	14

Deflectors (groins or jetties) - Structural barriers which project into the stream to divert flow away from eroding streambank sections. Plate 3.23-2 contains general guidelines for designing and installing deflectors.

Installation of Structures Under Wave and/or Tidal Action

The installation of riprap, gabions or deflectors under significant wave action or under tidal conditions requires special design considerations to ensure stability of the measure and the area it protects. The design/installation of these measures for tidal areas is beyond the scope of the Virginia Erosion and Sediment Control Law and Virginia Erosion and Sediment Control Regulations. The DSWC's Shoreline Programs Bureau can be consulted in regard to minimum design parameters for tidal installations. For situations where there is significant wave action affecting the shoreline of a nontidal lake or pond, the design parameters presented in Std. & Spec. 3.19, RIPRAP, should be used. Notably, there are many other site specific factors which should be incorporated into a design; hence, it is recommended that the design parameters presented only be used as minimum requirements and that a qualified professional be consulted when the installation of such a structure is contemplated.

Reinforced Concrete - may be used to armor eroding sections of the streambank by constructing retaining walls or bulk heads. Positive drainage behind these structures must be provided. Reinforced concrete may also be used as a channel lining (see Std. & Spec. 3.17, STORMWATER CONVEYANCE CHANNEL).

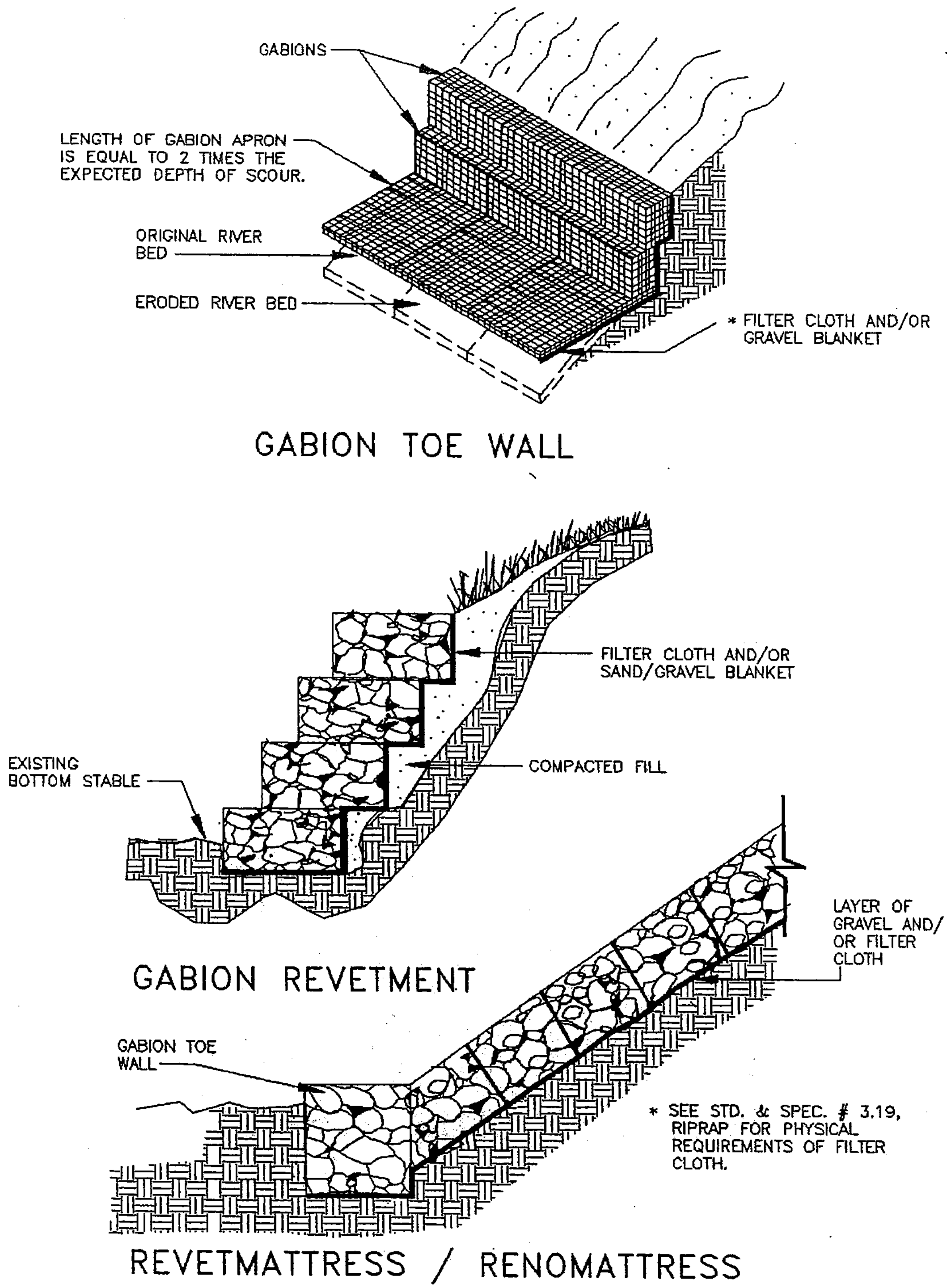
Log Cribbing - a retaining structure built of logs to protect streambanks from erosion. Log cribbing is normally built on the outside of stream bends to protect the streambank from the impinging flow of the stream (see Plate 3.23-3).

Grid Pavers - modular concrete units with interspersed void areas which can be used to armor the streambank while maintaining porosity and allowing the establishment of vegetation. These structures may be obtained in pre-cast blocks or mats, or they may be formed and poured in place. Design and installation should be in accordance with manufacturer's instructions (see Plate 3.23-4).

Maintenance

All structures should be maintained in an "as built" condition. Structural damage caused by storm events should be repaired as soon as possible to prevent further damage to the structure or erosion of the streambank.

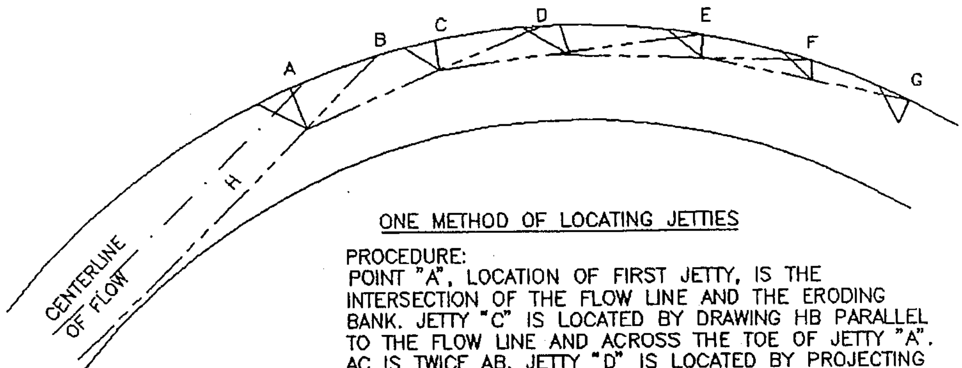
GABIONS



Source: Adapted from product literature of Bekaert Gabions

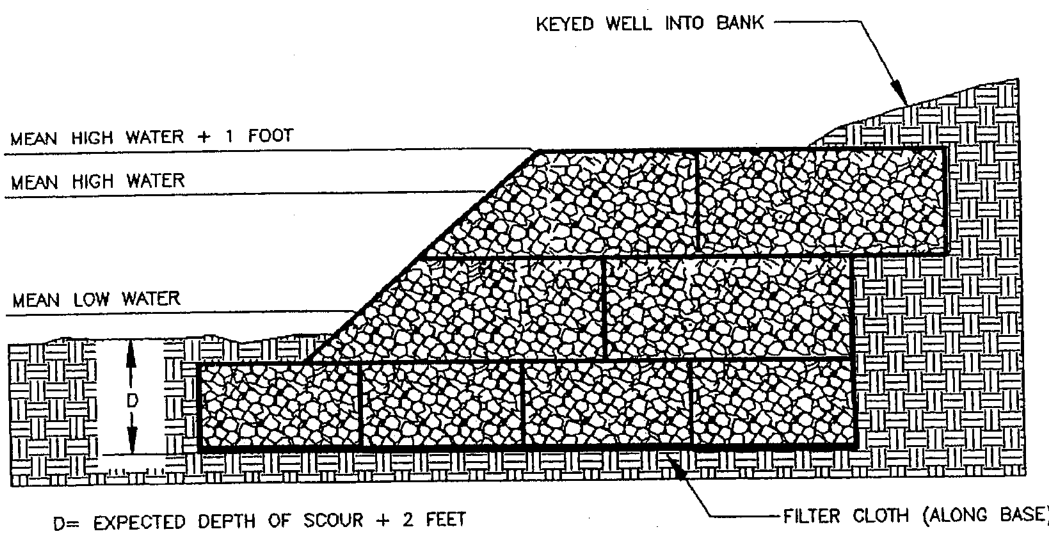
Plate 3.23-1

DEFLECTORS



ONE METHOD OF LOCATING JETTIES

PROCEDURE:
POINT "A", LOCATION OF FIRST JETTY, IS THE INTERSECTION OF THE FLOW LINE AND THE ERODING BANK. JETTY "C" IS LOCATED BY DRAWING HB PARALLEL TO THE FLOW LINE AND ACROSS THE TOE OF JETTY "A". AC IS TWICE AB. JETTY "D" IS LOCATED BY PROJECTING A LINE ACROSS THE TOE OF JETTIES "A" AND "C". THE REMAINING JETTIES ARE LOCATED THE SAME AS "D". SUPPLEMENTARY JETTY "K" IS LOCATED AC DISTANCE UPSTREAM FROM "A".

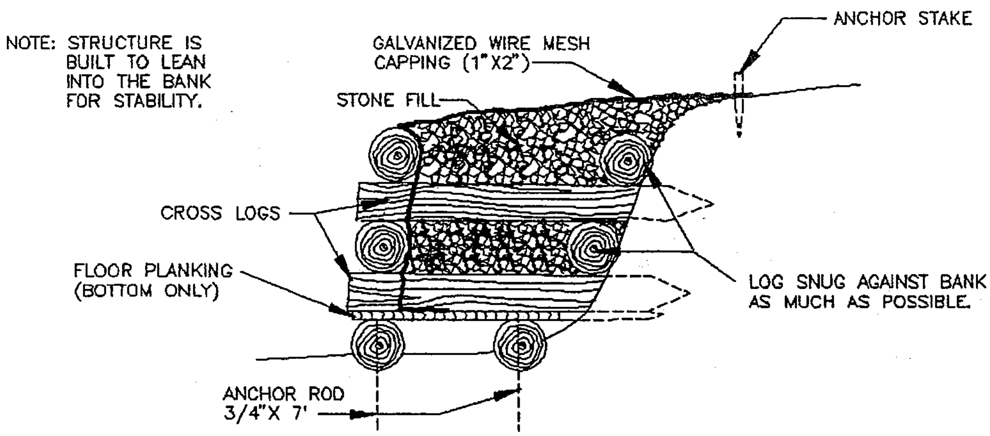


TYPICAL GABION DEFLECTOR

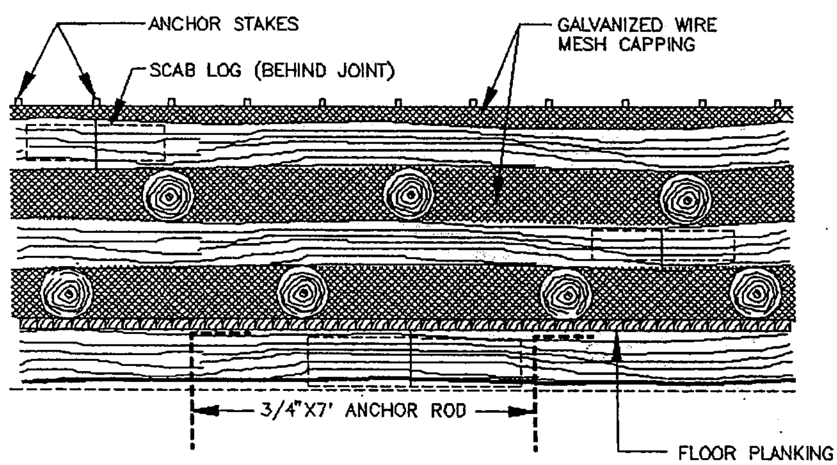
Source: Adapted from product literature of Bekaert Gabions

Plate 3.23-2

LOG CRIBBING



SIDE VIEW

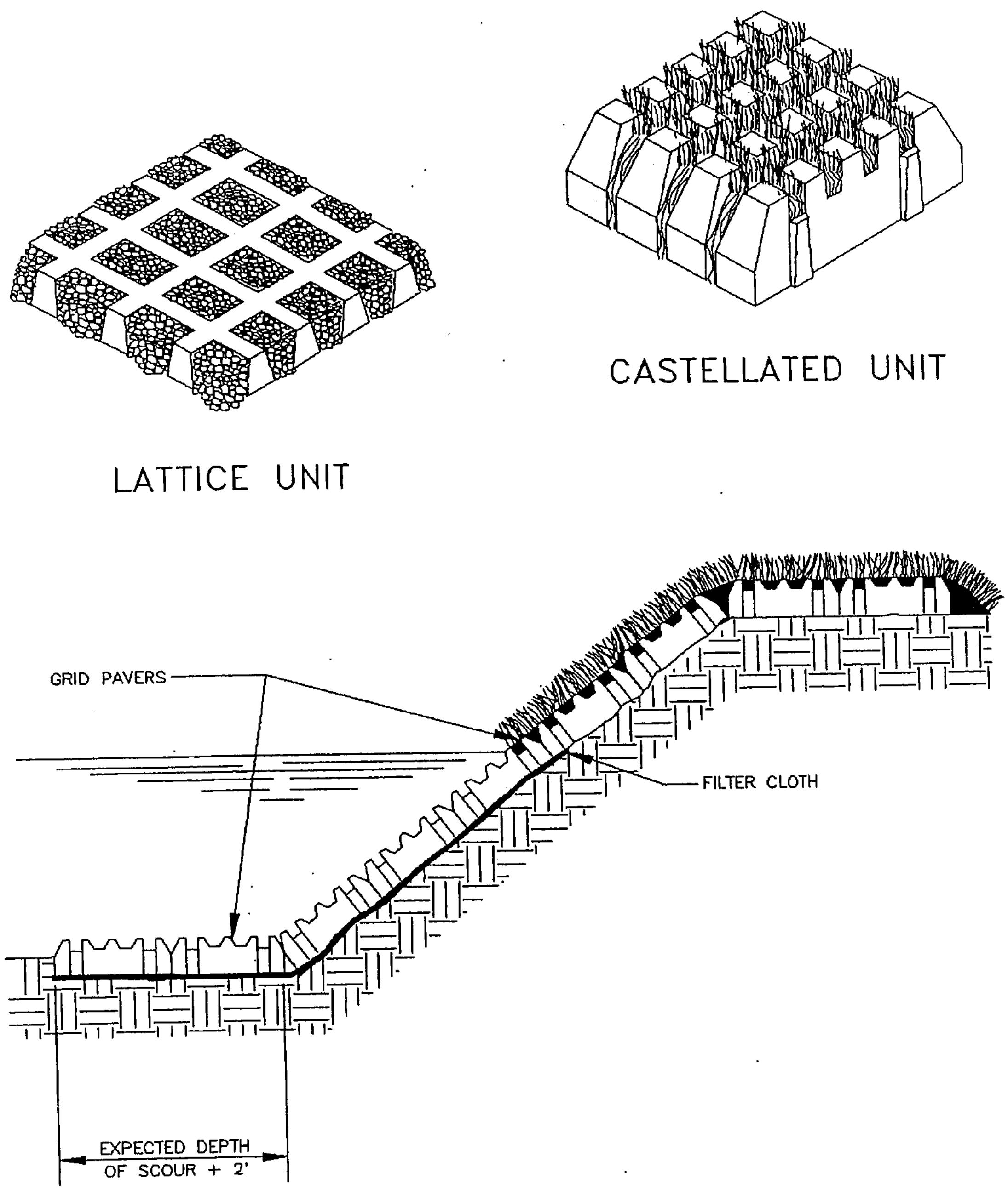


FRONT VIEW

Source: Introductory Guide to Stream Improvement

Plate 3.23-3

GRID PAVERS



Source: Va. DSWC

Plate 3.23-4

STD & SPEC 3.24

TEMPORARY VEHICULAR STREAM CROSSING

SC

Definition

A temporary structural span installed across a flowing watercourse for use by construction traffic. Structures may include bridges, round pipes, pipe arches, or oval pipes.

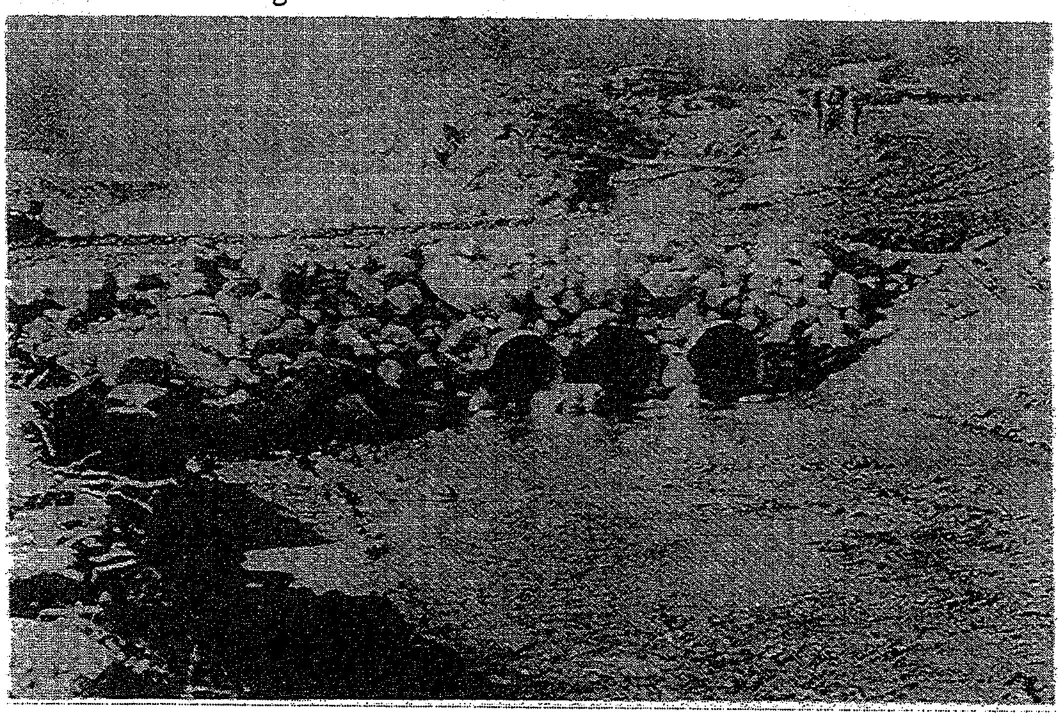
Purposes

1. To provide a means for construction traffic to cross flowing streams without damaging the channel or banks.

2. To keep sediment generated by construction traffic out of the stream.

Conditions Where Practice Applies

Generally applicable to flowing streams with drainage areas less than 1 square mile. Structures which must handle flow from larger drainage areas should be designed by methods which more accurately define the actual hydrologic and hydraulic parameters which will affect the functioning of the structure.



Planning Considerations

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and continually tracking sediment and other pollutants into the flow regime. These structures are, however, also undesirable in that they represent a channel constriction which can cause flow backups or washouts during periods of high flow. For this reason, the temporary nature of stream crossings is stressed. They should be planned to be in service for the shortest practical period of time and to be removed as soon as their function is completed.

The specifications contained in this section pertain primarily to flow capacity and resistance to washout of the structure. From a safety and utility standpoint, the designer must also be sure that the span is capable of withstanding the expected loads from heavy construction equipment which will cross the structure. The designer must also be aware that such structures are subject to the rules and regulations of the U. S. Army Corps of Engineers for in-stream modifications (404 permits).

A temporary bridge crossing is a structure made of wood, metal, or other materials which provides access across a stream or waterway. It is the preferred method for temporary waterway crossings. Normally, bridge construction causes the least amount of disturbance to the stream bed and banks when compared to the other types of crossings. They can also be quickly removed and reused. In addition, temporary bridges pose the least chance for interference with fish migration when compared to the other temporary access waterway crossings. A temporary culvert crossing is a structure consisting of stone and a section(s) of circular pipe, pipe arches, or oval pipes of reinforced concrete, corrugated metal, or structural plate, which is used to convey flowing water through the crossings. Temporary culverts are used where the channel is too wide for normal bridge construction or the anticipated loading of construction vehicles may prove unsafe for single span bridges. There is some disturbance within the stream during construction and removal of the temporary culvert crossing. The stone, along with the temporary culverts, can be salvaged and reused.

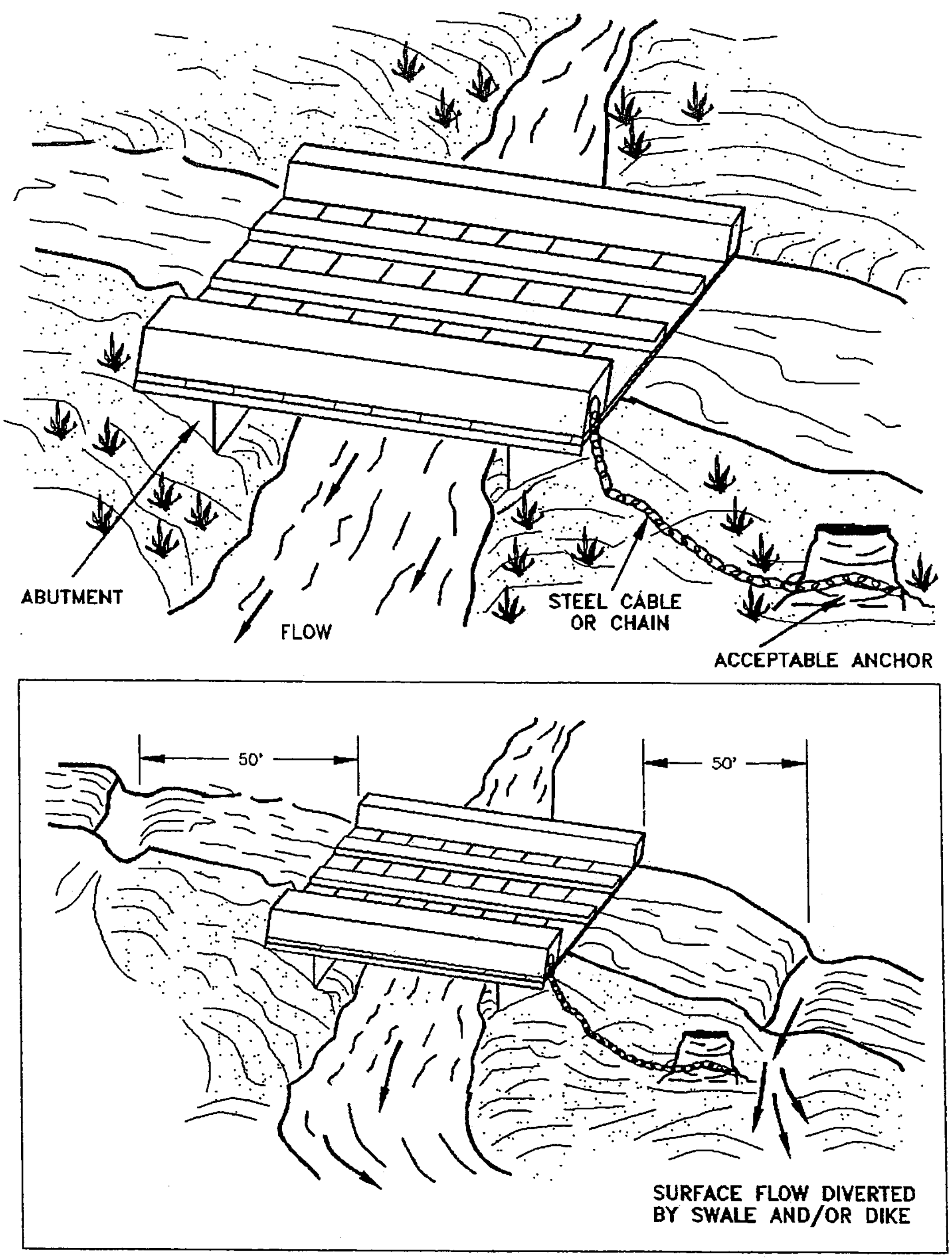
Design Criteria

1. Temporary Bridge Crossing

   a. Structures may be designed in various configurations. However, the materials used to construct the bridge must be able to withstand the anticipated loading of the construction traffic. Plate 3.24-1 shows on example of such a crossing.

   b. Crossing Alignment - The temporary waterway crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15° from a line drawn perpendicular to the center line of the stream at the intended crossing location.

TEMPORARY BRIDGE CROSSING



Source: 1983 Maryland Standards and Specifications for Soil Erosion and Sediment Control

Plate 3.24-1

c. The centerline of both roadway approaches shall coincide with the crossing alignment centerline for a minimum distance of 50 feet from each bank of the waterway being crossed. If physical or right-of-way restraints preclude the 50 feet minimum, a shorter distance may be provided. All fill materials associated with the roadway approach shall be limited to a maximum height of 2 feet above the existing flood plain elevation.

d. A water diverting structure such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. Design criteria for this diverting structure shall be in accordance with Std. & Spec. 3.11, TEMPORARY RIGHT OF WAY DIVERSION or Std. & Spec. 3.09, TEMPORARY DIVERSION DIKE. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

e. Appropriate perimeter controls such as SILT FENCE (Std. & Spec. 3.05) or TURBIDITY CURTAIN (Std. & Spec. 3.27) must be employed when necessary along banks of stream parallel to the same.

f. All crossings shall have one traffic lane. The minimum width shall be 12 feet with a maximum width of 20 feet.

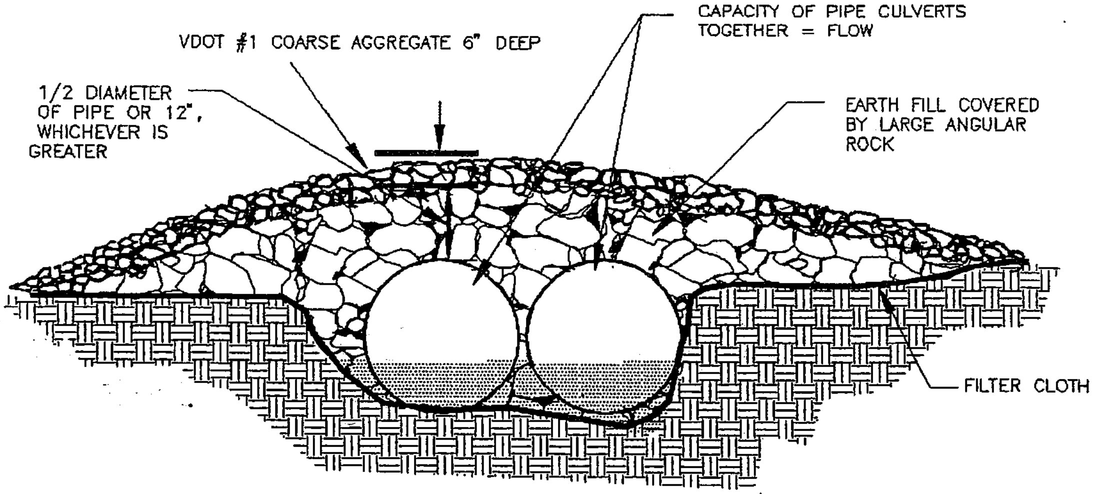
g. Further design/construction recommendations for temporary bridge construction may be found in Construction Specifications.

2. <u>Temporary Culvert Crossing</u>

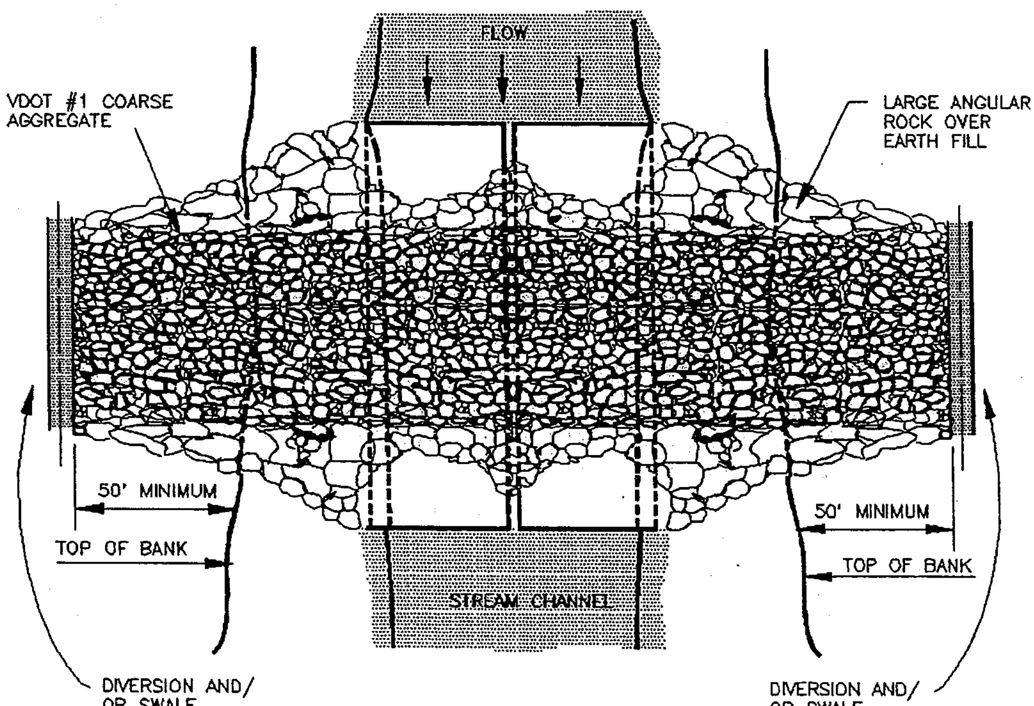
a. Where culverts are installed, VDOT #1 Coarse Aggregate <u>or larger</u> will be used to form the crossing. The depth of stone cover over the culvert shall be equal to one-half the diameter of the culvert or 12 inches, whichever is greater. To protect the sides of the stone from erosion, riprap shall be used and designed in accordance with Std. & Spec. 3.19, RIPRAP (see Plate 3.24-2).

b. If the structure will remain in place for <u>up to 14 days</u>, the culvert shall be large enough to convey the flow from a 2-year frequency storm without appreciably altering the stream flow characteristics. See Table 3.24-A for aid in selecting an appropriate culvert size (note all assumptions). If the structure will remain in place <u>14 days to 1 year</u>, the culvert shall be large enough to convey the flow from a 10-year frequency storm. In this case, the hydrologic calculation and subsequent culvert size must be done for the specific watershed characteristics. If the structure must remain in place over 1 year, it must be designed as a permanent measure by a qualified professional.

TEMPORARY CULVERT CROSSING



ELEVATION



PLAN VIEW

Source: Va. DSWC

Plate 3.24-2

c. Multiple culverts may be used in place of one large culvert if they have the equivalent capacity of the larger one. The minimum-sized culvert that may be used is 18 inches.

d. All culverts shall be strong enough to support their cross-sectioned area under maximum expected loads.

e. The length of the culvert shall be adequate to extend the full width of the crossing, including side slopes.

f. The slope of the culvert shall be at least 0.25 inch per foot.

g. Crossing Alignment - The temporary waterway crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15° from a line drawn perpendicular to the centerline of the stream at the intended crossing location.

h. The centerline of both roadway approaches shall coincide with the crossing alignment centerline for a minimum distance of 50 feet from each bank of the waterway being crossed. If physical or right-of-way restraints preclude the 50 feet minimum, a shorter distance may be provided. All fill materials associated with the roadway approach shall be limited to a maximum height of 2 feet above the existing flood plain elevation.

i. The approaches to the structure shall consist of stone pads meeting the following specifications:

   1) Stone: VDOT #1
   2) Minimum thickness: 6 inches
   3) Minimum width: equal to the width of the structure

j. A water diverting structure such as a swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. Design criteria for this diverting structure shall be in accordance with Std. & Spec. 3.11, TEMPORARY RIGHT OF WAY DIVERSION or Std. & Spec. 3.09, TEMPORARY DIVERSION DIKE. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

TABLE 3.24-A
PIPE DIAMETER (INCHES) FOR STREAM CROSSINGS[a]

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

[a] Note: Table is based on USDA-SCS Graphical Peak Discharge Method for 2-year frequency storm event, CN = 65; Rainfall depth = 3.5 inches (average for Virginia).

Source: Va. DSWC

Construction Specifications

1. Temporary Bridge Crossing (see Plate 3.24-1)

   a. Clearing and excavation of the stream bed and banks shall be kept to a minimum.

b. The temporary bridge structure shall be constructed at or above bank elevation to prevent the entrapment of floating materials and debris.

c. Abutments shall be placed parallel to and on stable banks.

d. Bridges shall be constructed to span the entire channel. If the channel width exceeds 8 feet (as measured from top-of-bank to top-of-bank), then a footing, pier or bridge support may be constructed within the waterway. One additional footing, pier or bridge support will be permitted for each additional 8-foot width of the channel. No footing, pier or bridge support, however, will be permitted within the channel for waterways which are less than 8 feet wide.

e. Stringers shall either be logs, sawn timber, prestressed concrete beams, metal beams, or other approved materials.

f. Decking materials shall be of sufficient strength to support the anticipated load. All decking members shall be placed perpendicular to the stringers, <u>butted tightly</u>, and securely fastened to the stringers. Decking materials must be butted tightly to prevent any soil material tracked onto the bridge from falling into the waterway below.

g. Run planking (optional) shall be securely fastened to the length of the span. One run plank shall be provided for each track of the equipment wheels. Although run planks are optional, they may be necessary to properly distribute loads.

h. Curbs or fenders may be installed along the outer sides of the deck. Curbs or fenders are an option which will provide additional safety.

i. Bridges shall be securely anchored at only one end using steel cable or chain. Anchoring at only one end will prevent channel obstruction in the event that floodwaters float the bridge. Acceptable anchors are large trees, large boulders, or driven steel anchors. Anchoring shall be sufficient to prevent the bridge from floating downstream and possibly causing an obstruction to the flow.

j. All areas disturbed during installation shall be stabilized within 7 calendar days of that disturbance in accordance with MS #1.

k. When the temporary bridge is no longer needed, all structures including abutments and other bridging materials should be removed immediately.

l. Final clean-up shall consist of removal of the temporary bridge from the waterway, protection of banks from erosion, and removal of all construction materials. All removed materials shall be stored outside flood plain of the stream. Removal of the bridge and clean-up of the area shall be accomplished without construction equipment working in the waterway channel.

2. Temporary Culvert Crossing

a. Clearing and excavation of the stream bed and banks shall be kept to a minimum.

b. The invert elevation of the culvert shall be installed on the natural streambed grade to minimize interference with fish migration.

c. Filter cloth shall be placed on the streambed and streambanks prior to placement of the pipe culvert(s) and aggregate. The filter cloth shall cover the streambed and extend a minimum of six inches and a maximum of one foot beyond the end of the culvert and bedding material. Filter cloth reduces settlement and improves crossing stability. See Std. & Spec. 3.19, RIPRAP, for required physical qualities of the filter cloth.

d. The culvert(s) shall extend a minimum of one foot beyond the upstream and downstream toe of the aggregate placed around the culvert. In no case shall the culvert exceed 40 feet in length.

e. The culvert(s) shall be covered with a minimum of one foot of aggregate. If multiple culverts are used, they shall be separated by at least 12 inches of compacted aggregate fill. At a minimum, the bedding and fill material used in the construction of the temporary access culvert crossings shall conform with the aggregate requirements cited in part "i" under "Temporary Culvert Crossing."

f. When the crossing has served its purpose, all structures including culverts, bedding and filter cloth materials shall be removed. Removal of the structure and clean-up of the area shall be accomplished without construction equipment working in the waterway channel.

g. Upon removal of the structure, the stream shall immediately be shaped to its original cross-section and properly stabilized.

Maintenance

Both structures shall be inspected after every rainfall and at least once a week, whether it has rained or not, and all damages repaired immediately.

STD & SPEC 3.25

UTILITY STREAM CROSSING

USC

Definition

A strategy for crossing small waterways when in-stream utility construction is involved.

Purposes

1. To help protect sediment from entering the stream from construction within approach areas.

2. To minimize the amount of disturbance within the stream itself.

Conditions Where Practice Applies

Generally applicable to flowing streams with drainage areas less than one square mile. Structures or methodology for crossing streams with larger drainage areas should be designed by methods which more accurately define the actual hydrologic and hydraulic parameters which will affect the functioning of the structure.

A *Diversion Channel* may be utilized to allow "work in the dry".

Planning Considerations

Utility construction, by virtue of its sprawling, linear nature, frequently crosses and impacts live streams. There is a potential for excessive sediment loss into a stream by both the disturbance of the approach areas and by the work with the stream-bed and banks.

It is often a difficult task to decide what type of control to use as a utility stream crossing. A method such as the "boring and jacking" of pipe below a streambed, which would prevent disturbance within the watercourse, is a preferred method if it is practical. However, in cases where in-stream work is unavoidable, consideration must be given to providing adequate mitigation of sediment loss while <u>minimizing</u> the amount of encroachment (MS #12) and time spent working in the channel. There is some "give and take" as far as the installation of controls - sometimes there is less damage to the environment created by providing substantial controls for the approach areas and refraining from installing extensive measures in the stream itself. However, when the installation of the utility line within streambed and banks will take an extended period of construction time, consideration should be given to substantial in-stream controls or stream diversion in order to prevent excessive sedimentation damage.

As a result of the difficulty in choosing the right method for a utility stream crossing, designers and plan reviewers should always make site visits of proposed crossing to ensure that the most appropriate method is chosen. The designer and plan reviewer should also be aware that such modifications are subject to other state and federal construction permits.

The following are several methods for dealing with utility stream crossings (with varying construction time and stream size scenarios) which allow for "work in the dry" to prevent excessive sedimentation damage. <u>By no means are these methods all-inclusive.</u> As with other control measures, site-specific design and innovative variations are encouraged.

Design Criteria (All methods)

1. The drainage area should be no greater than one square mile (640 acres).

2. All filter cloth used in the construction of the utility crossing must conform to physical requirements noted in Std. & Spec. 3.19, RIPRAP.

3. Water diverting structures should be used at all trenching and/or construction road approaches (50 feet on either side of the crossing) as per Std. & Spec. 3.24, VEHICULAR STREAM CROSSING.

4. Design criteria more specific to each particular crossing can be found in Plates 3.25-1 through 3.25-4.

Construction Specifications

1. Diversion Channel Crossing - Preferred method if construction will remain in area of stream for an extended period (longer than 72 hours) and site conditions (such as width of stream) make diversion practical.

   a. The diversion channel crossing must be operational before work is done in the stream (construction will be performed "in the dry").

   b. Minimum width of bottom shall be six feet or equal to bottom width of existing streambed, whichever is less. Refer to Plates 3.25-1 and 3.25-2.

   c. Maximum steepness of side slopes shall be 2:1. Depth and grade may be variable, dependent on site conditions, but shall be sufficient to ensure continuous flow of water in the diversion.

   d. There are three types of diversion channel linings which can be used, based upon expected velocity of bankfull flow. Refer to Plate 3.25-2 and the following table:

TABLE 3.25-A

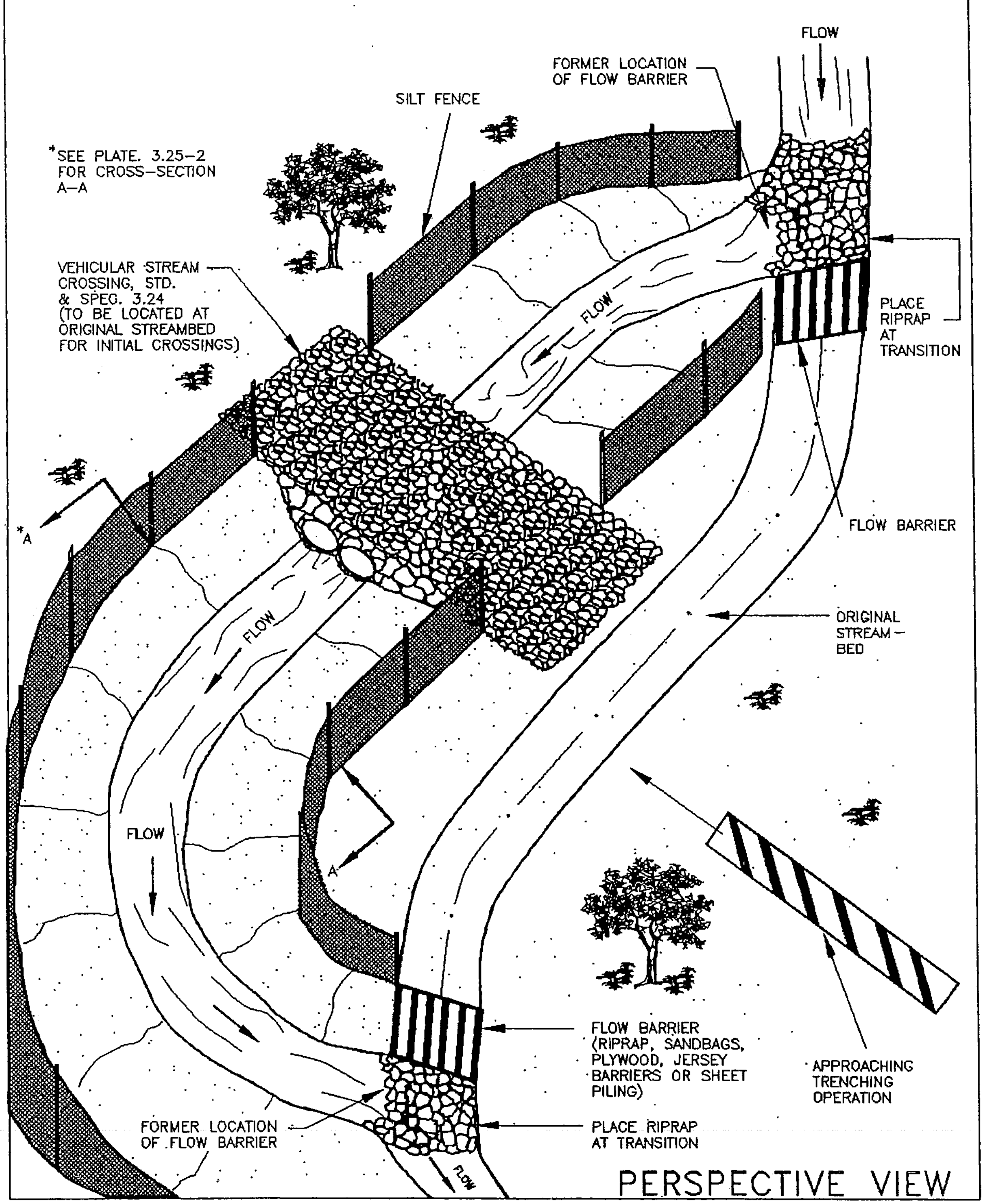
DIVERSION CHANNEL LININGS

Lining Material	Classification	Acceptable Velocity Range
Filter Cloth*, Polyethylene or Grass	TYPE A	0 - 2.5 f.p.s.
Filter Cloth*	TYPE B	2.5 - 9.0 f.p.s.
Class I Riprap and Filter Cloth*	TYPE C	9.0 - 13.0 f.p.s.

* Filter Cloth must meet the minimum physical requirements noted in Std. & Spec. 3.19, RIPRAP.

Source: VDOT Standard Sheets

DIVERSION CHANNEL CROSSING

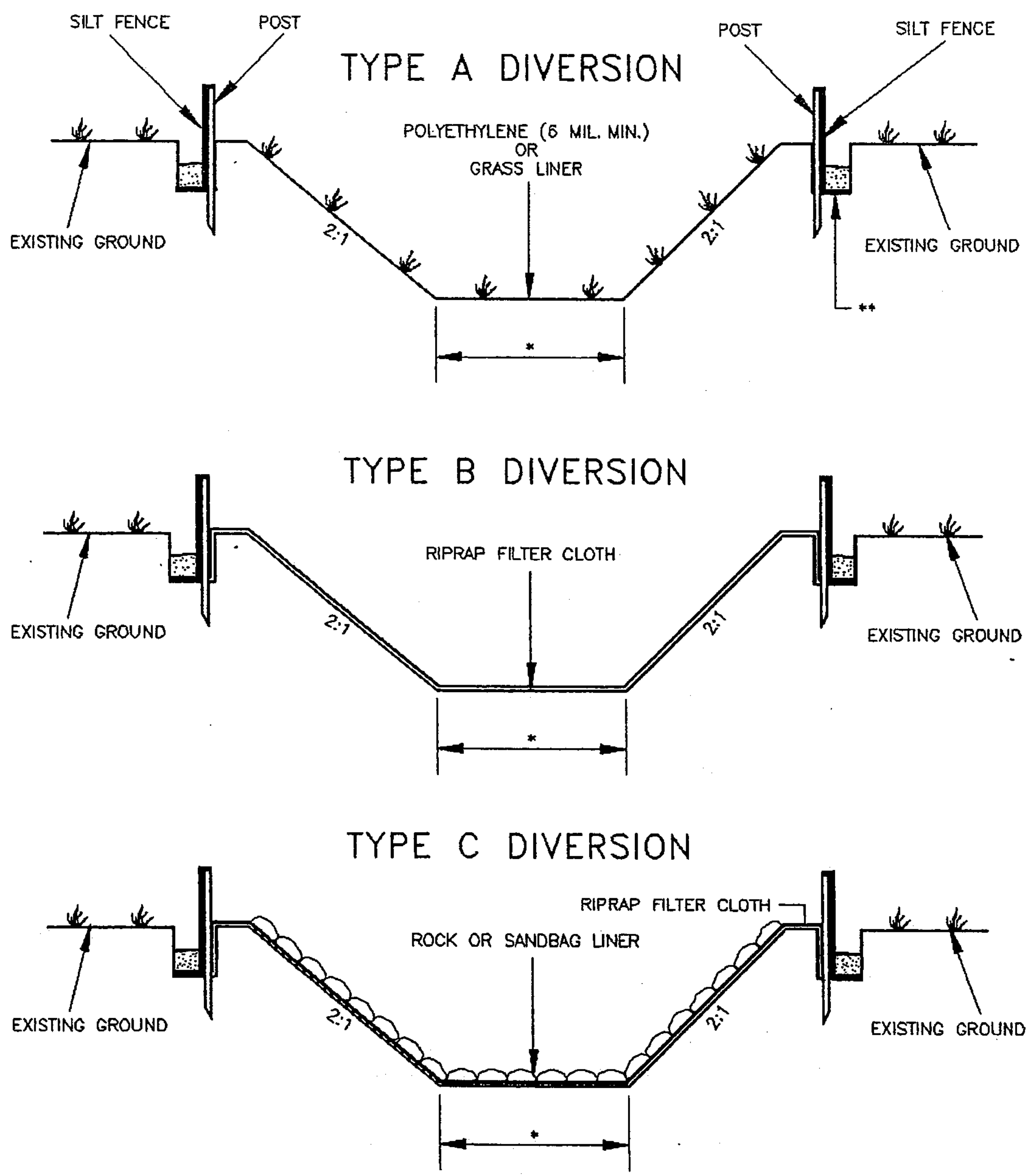


Source: Va. DSWC

Plate 3.25-1

DIVERSION CHANNEL CROSSING

ACCEPTABLE LININGS
(CROSS SECTION A-A OF PLATE 3.25-1)



* 6' MINIMUM OR WIDTH OF EXISTING STREAM WHICHEVER IS LESS

** ENTRENCH SILT FENCE AND FILTER CLOTH IN SAME TRENCH

Source: Adapted from VDOT Standard Sheets

Plate 3.25-2

e. Type A stream diversions may be seeded with a standard seed mix for the type of soils encountered and the time of year seed is sown. An average growth of two inches in height shall be achieved throughout the diversion with an 85% cover before water is turned through it.

f. Stream diversion liners shall be secured at the upstream and downstream sides with non-erodible weights such as riprap. These weights shall allow normal flow of the stream. Soil shall not be mixed in with stream diversion weights. Weights may also be needed along the stream diversion's length to secure liner.

g. Stream diversion liners should be overlapped when a single or continuous liner is not available or is impractical. Overlaps should be such that continuous flow of the steam is maintained. An upstream section should overlap a downstream section by a minimum of 18 inches. Overlaps along the cross-section should be made such that a liner is placed in the steam diversion bottom first and additional pieces of liner on the slopes overlap the bottom piece by a minimum of 18 inches.

h. Stream diversion liners shall be entrenched at the top of the diversion slopes (slopes breaks) along with a line of silt fence. Silt fence may be excluded if the diversion liner is extended to such a point that siltation of the stream will not occur. If silt fence is excluded, the diversion liner must be secured. Liners shall extend from slope break to slope break as shown in Plate 3.25-2.

i. Staples used in securing SOIL STABILIZATION BLANKETS AND MATTING (see Std. & Spec. 3.36) or non-erodible weights (riprap) shall be used as necessary to anchor stream diversion liners to the side slopes of the diversion. Wooden stakes should not be used on the diversion's bottom or side slopes.

j. Non-erodible materials such as riprap, jersey barriers, sandbags, plywood, or sheet piling, shall be used as flow barriers to divert the stream away from its original channel and to prevent or reduce water backup into a construction area.

k. The downstream flow barrier is to be removed prior to the upstream barrier when opening a stream diversion for the transport of water.

l. Streams should be rediverted upon completion of the utility crossing for which the diversion was built. Prior to rediversion, any materials (flow barrier) used to prevent water backup into the downstream end of the original streambed shall be removed. This material should not be placed in the downstream end of the diversion until after water has been rediverted to the original waterway. The stream should then be rediverted by removing all of the materials damming the upstream end of the original streambed and then placing it in the upstream end of the stream diversion. The diversion should be sealed off at the downstream end and then backfilled.

Once started, any work to relocate a stream shall not be discontinued until it is completed.

m. Stream should be rediverted only after backfilling and restabilization of original streambed and banks is completed. Restabilization shall consist of the installation of ungrouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of its utility trench, whichever is greater) with slopes of 3:1 or greater. Refer to Std. & Spec. 3.19, RIPRAP, for installation requirements. For slopes of 3:1 or less, vegetative stabilization may be used, pending approval by the Plan-Approving Authority or inspection authority. Stabilization of its streambed and banks and the approach areas should occur immediately following the attainment of final grade.

n. Any dewatering discharge from this operation shall be placed into an approved DEWATERING STRUCTURE (see Std. & Spec. 3.26).

2. Flume Pipe Crossing - To be used when in-stream construction will last less than 72 hours and stream is narrow (less than 10 feet wide), making "cofferdam" construction impractical.

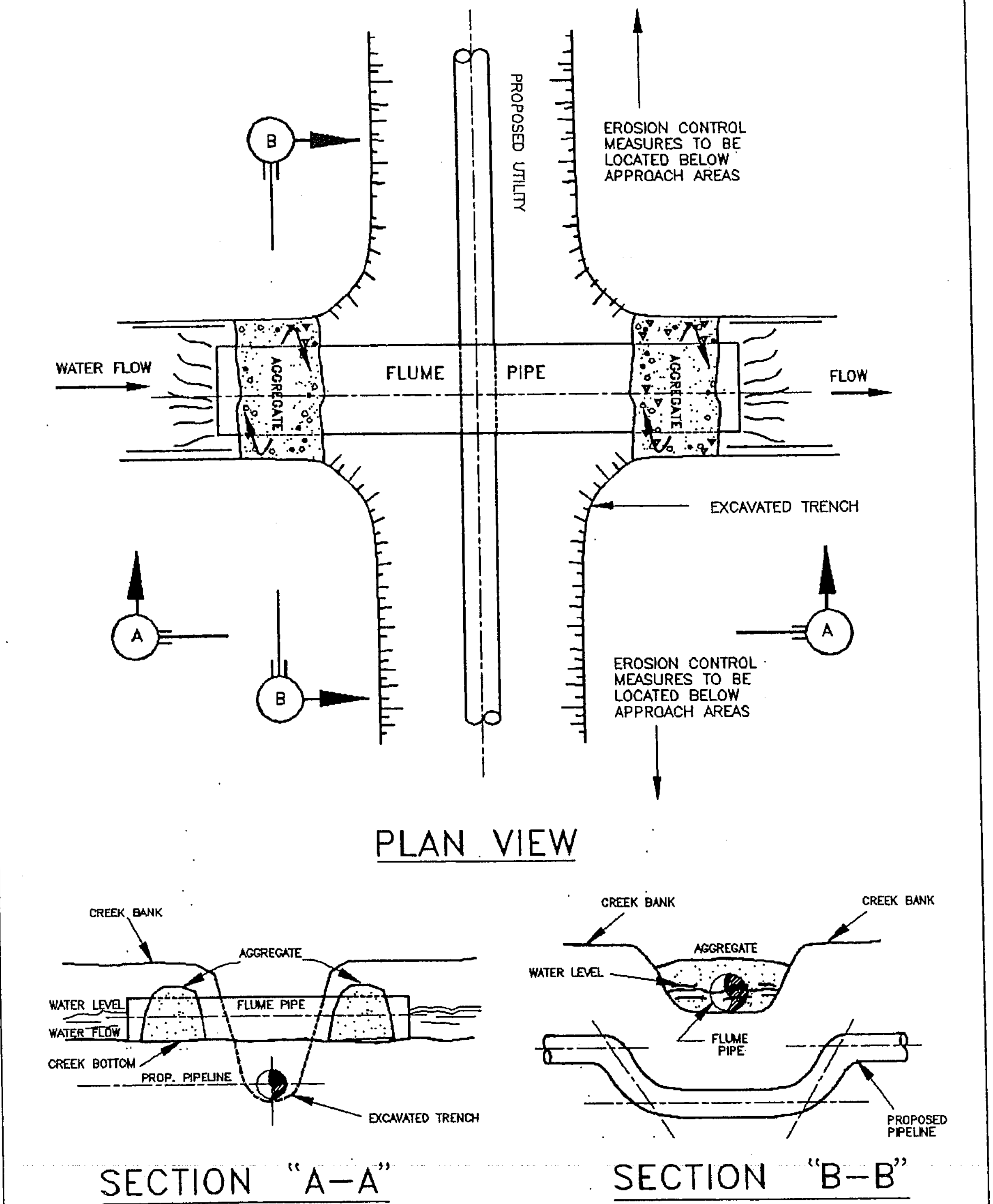
a. The flume pipe crossing must be made operational prior to the start of construction in the stream.

b. The materials used (culvert(s), stone and filter fabric) must meet the physical constraints of those used in VEHICULAR STREAM CROSSING, Std. & Spec. 3.24.

c. A large flume pipe (or culvert) of an adequate size to support normal water channel flow (see Table 3.24-A) shall then be installed in the stream bed across the proposed pipeline trench centerline. VDOT #1 Coarse Aggregate (minimum size) or riprap shall be placed close to each end of the flume pipe so as to dam off the creek forcing the water to flow through the flume pipe (see Plate 3.25-3).

d. The entrapped water can then be pumped from the creek within the dammed-off area and in the proposed trench centerline into an approved DEWATERING STRUCTURE (see Std. & Spec. 3.26). The trench can then be dug under the flume pipe. The pipe sections will then be installed to the proper depth under the flume pipe. After pipe sections are installed, the ditch will be backfilled and restabilization shall be carried out.

FLUME PIPE CROSSING



Source: Va. DSWC

Plate 3.25-3

e. Restabilization shall consist of the installation of ungrouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of the utility trench, whichever is greater) with slopes of 3:1 or greater. Refer to Std. & Spec. 3.19, RIPRAP, for installation requirements. For slopes of 3:1 or less, vegetative stabilization may be used, pending approval by the Plan-Approving Authority or inspection authority. Stabilization of its streambed and banks and the approach areas should occur immediately following the attainment of final grade.

f. After completion of backfilling operation and restoration of stream/creek banks and leveling of stream bed, the flume pipe can then be removed. The gravel can be removed or spread in the stream bed depending on permit requirements. Sediment control in approach areas shall not be removed until all construction is completed in stream/creek crossing area. All ground contours shall be returned to their original condition.

3. Cofferdam Utility Crossing - To be used when stream diversion is not practical and stream is wide enough (10 feet or wider) to make cofferdam installation practical.

a. Construction is to be performed in low flow periods.

b. Crossing shall be accomplished in a manner that will not prohibit the flow of the stream. (See Plate 3.25-4).

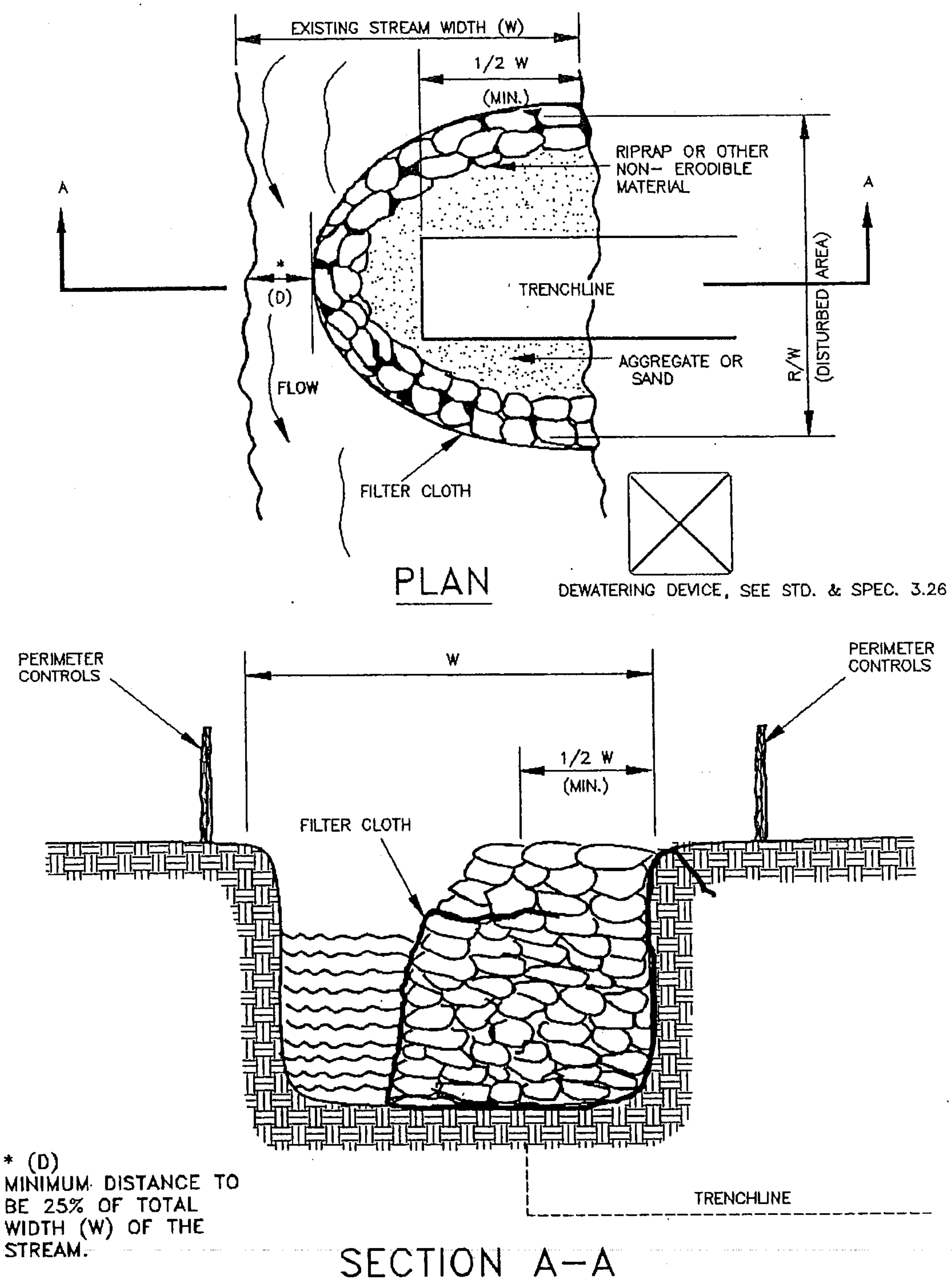
c. As with all utility line crossings, approach areas must be controlled with perimeter measures such as silt fence or straw bales.

d. Remove large rocks, woody vegetation, or other material from the streambed and banks that may get in the way of placing the riprap, sandbags, sheet metal, or wood planks or installing the utility pipe or line.

e. Form a cofferdam by placing the riprap (or other non-erodible materials) in a semicircle along the side of the stream in which the utility installation will begin. It must be surrounded and underlain with filter cloth as shown in Plate 3.25-4. The height of and area within the dam will depend upon the size of the work area and the amount of steam flow. Stack materials as high as will be necessary to keep water from overtopping the dam and flooding the work area. When the stream flow is successfully diverted by the cofferdam, dewater the work area and stabilize it with aggregate (VDOT #57 or #68 Coarse Aggregate) or sand. Make sure to discharge the water into a sediment trapping device (see DEWATERING STRUCTURE, Std. & Spec. 3.26).

g. Install the utility pipe or line in half the streambed as noted in Plate 3.25-4. Remove the riprap or other materials and begin placing them on the other side of the stream.

COFFERDAM CROSSING



Source: Va. DSWC

Plate 3.25-4

h. Restabilization shall consist of the installation of ungrouted riprap on all disturbed streambank areas (or on the area 6 feet on both sides of the centerline of its utility trench, whichever is greater) with slopes of 3:1 or greater. Refer to Std. & Spec. 3.19, RIPRAP, for installation requirements. For slopes of 3:1 or less, vegetative stabilization may be used, pending approval by Plan-Approving Authority or inspection authority. Stabilization of its streambed and banks and the approach areas should occur immediately following the attainment of final grade.

Maintenance

Care must be taken to inspect any steam crossing area at the end of each day to make sure that the construction materials are positioned securely. This will ensure that the work area stays dry and that no construction materials float downstream.

STD & SPEC 3.26

DEWATERING STRUCTURE

DS

Definition

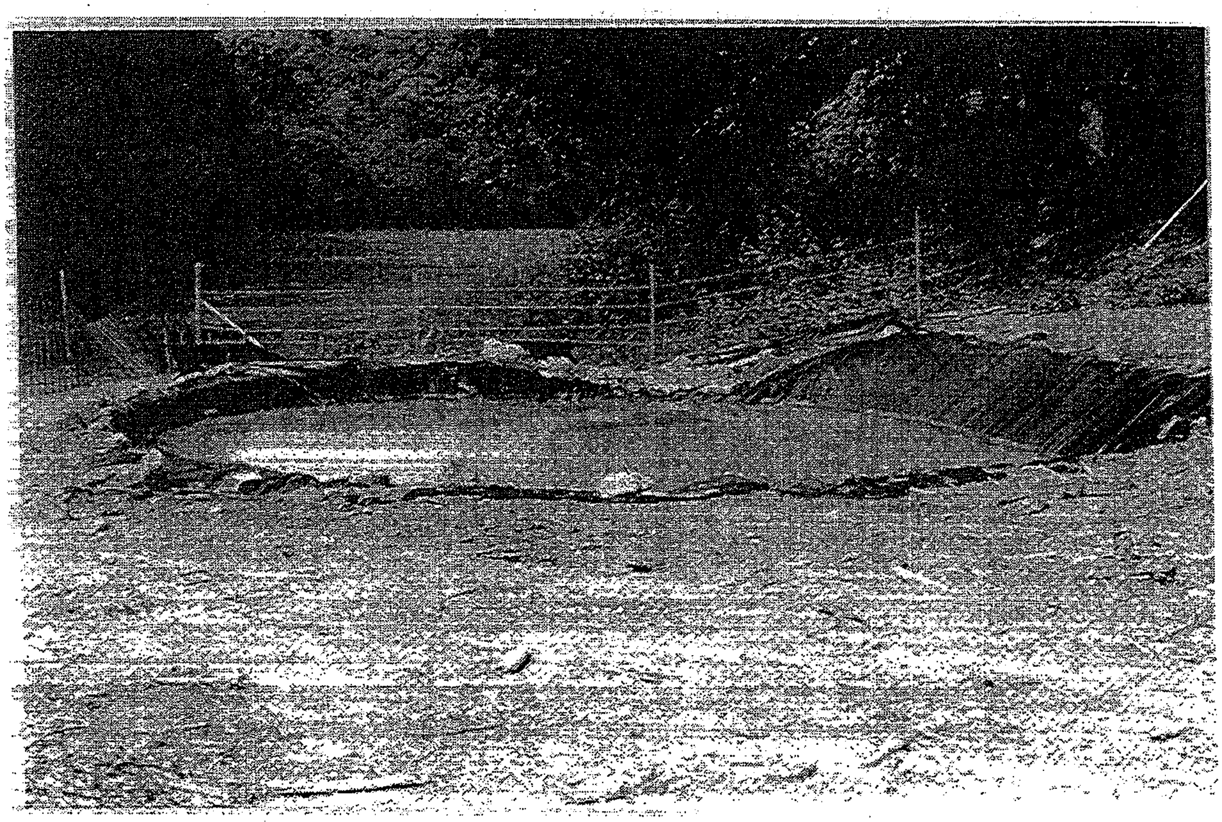
A temporary settling and filtering device for water which is discharged from dewatering activities.

Purpose

To filter sediment-laden water prior to the water being discharged off-site.

Conditions Where Practice Applies

Wherever sediment-laden water must be removed from a construction site by means of pumping.



Planning Considerations

Water which is pumped from a construction site usually contains a large amount of sediment. A dewatering structure is designed to remove the sediment before water is released off-site.

This practice includes several types of dewatering structures which have different applications dependent upon site conditions and types of operation. Other innovative techniques for accomplishing the same purpose are encouraged, but only after specific plans and details are submitted to and approved by the Plan-Approving Authority.

A dewatering structure may not be needed if there is a well- stabilized, vegetated area on-site to which water may be discharged. The area must be stabilized so that it can filter sediment and at the same time withstand the velocity of the discharged water without eroding. A minimum filtering length of 75 feet must be available in order for such a method to be feasible.

Design Criteria

1. A dewatering structure must be sized (and operated) to allow pumped water to flow through the filtering device without overtopping the structure.

2. Material from any required excavation shall be stored in an area and protected in a manner that will prevent sediments from eroding and moving off-site.

3. An excavated basin (applicable to "Straw Bale/Silt Fence Pit") may be lined with filter fabric to help reduce scour and to prevent the inclusion of soil from within the structure.

4. Design criteria more specific to each particular dewatering device can be found in Plates 3.26-1 through 3.26-3.

Construction Specifications

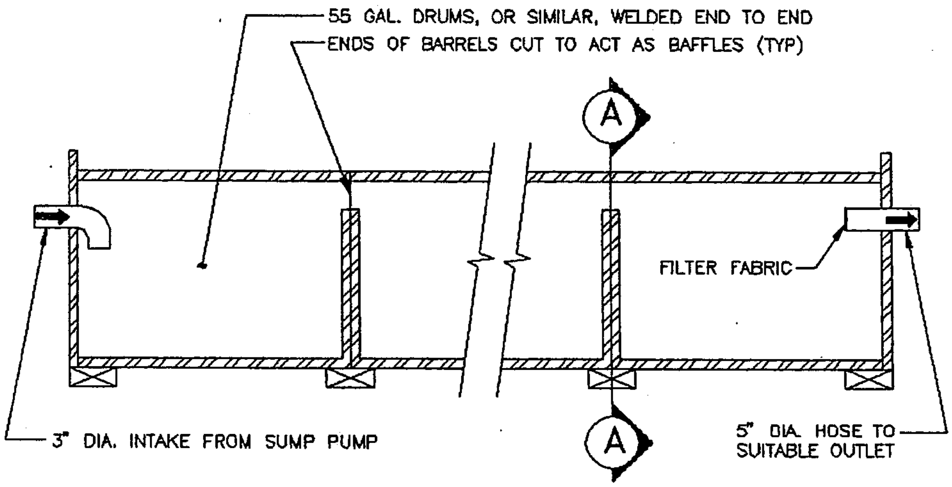
1. Portable Sediment Tank (see Plate 3.26-1)

    a. The structure may be constructed with steel drums, sturdy wood or other material suitable for handling the pressure exerted by the volume of water.

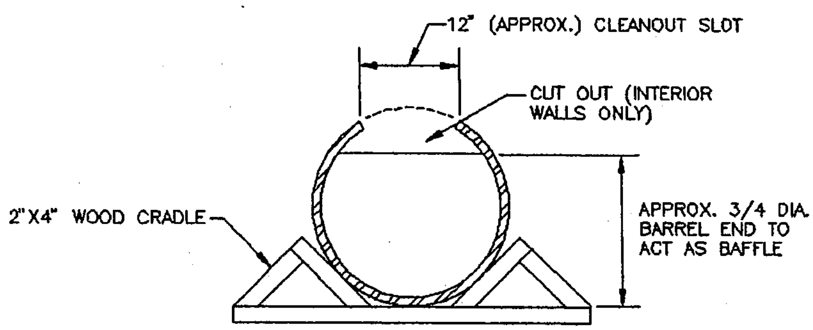
    b. Sediment tanks will have a minimum depth of two feet.

    c. The sediment tank shall be located for easy clean-out and disposal of the trapped sediment and to minimize the interference with construction activities.

PORTABLE SEDIMENT TANK



ELEVATION



CROSS-SECTION A-A

Source: USDA-SCS

Plate 3.26-1

d. The following formula shall be used to determine the storage volume of the sediment tank:

Pump discharge (g.p.m.) x 16 = cubic feet of storage required

e. Once the water level nears the top of the tank, the pump must be shut off while the tank drains and additional capacity is made available.

f. The tank shall be designed to allow for emergency flow over top of the tank.

g. Clean-out of the tank is required once one-third of the original capacity is depleted due to sediment accumulation. The tank shall be clearly marked showing the clean-out point.

2. Filter Box (see Plate 3.26-2)

a. The box selected should be made of steel, sturdy wood or other materials suitable to handle the pressure requirements imposed by the volume of water. Fifty-five gallon drums welded top to bottom are normally readily available and, in most cases, will suffice.

b. Bottom of the box shall be made porous by drilling holes (or some other method).

c. VDOT #3 Coarse Aggregate shall be placed over the holes at a minimum depth of 12 inches (metal "hardware" cloth may need to be placed between the aggregate and the holes if holes are drilled larger than the majority of the stone).

d. As a result of the fast rate of flow of sediment-laden water through the aggregate, the effluent must be directed over a well-vegetated strip of at least 50 feet after leaving the base of the filter box.

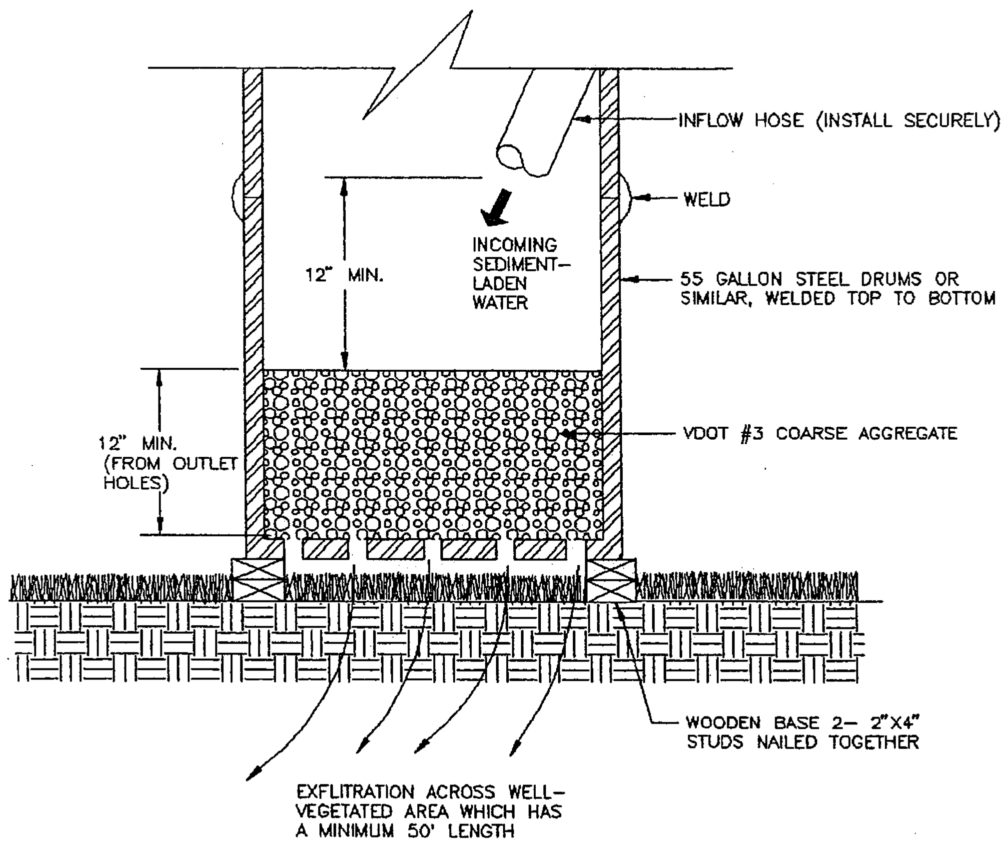
e. The box shall be sized as follows:

Pump discharge (g.p.m.) x 16 = cubic feet of storage required

f. Once the water level nears the top of the box, the pump must be shut off while the box drains and additional capacity is made available.

g. The box shall be designed/constructed to allow for emergency flow over the top of this box.

FILTER BOX



ELEVATION VIEW

Source: Va. DSWC

Plate 3.26-2

h. Clean-out of the box is required once one-third of the original capacity is depleted due to sediment accumulation. The tank shall be clearly marked showing the clean-out point.

i. If the stone filter does become clogged with sediment so that it no longer adequately performs its function, the stones must be pulled away from the inlet, cleaned and replaced.

Note: Using a filter box only allows for minimal settling time for sediment particles; therefore, it should only be used when site conditions restrict the use of the other methods.

3. Straw Bale/Silt Fence Pit (see Plate 3.26-3)

a. Measure shall consist of straw bales, silt fence, a stone outlet (a combination of VDOT Class AI Riprap and VDOT #25 or #26 Aggregate) and a wet storage pit oriented as shown in Plate 3.26-3.

b. The structure must have a capacity which is dictated by the following formula:

Pump discharge (g.p.m.) x 16 = cubic feet of storage required

In calculating the capacity, one should include the volume available from the floor of the excavation to the crest of the stone weir.

c. In any case, the excavated area should be a minimum of 3 feet below the base of the perimeter measures (straw bales or silt fence).

d. The perimeter measures must be installed as per the guidelines found in Std. & Spec. 3.04, STRAW BALE BARRIER and Std. & Spec. 3.05, SILT FENCE.

e. Once the water level nears the crest of the stone weir (emergency overflow), the pump must be shut off while the structure drains down to the elevation of the wet storage.

f. The wet storage pit may be dewatered only after a minimum of 6 hours of sediment settling time. This effluent should be pumped across a well-vegetated area or through a silt fence prior to entering a watercourse.

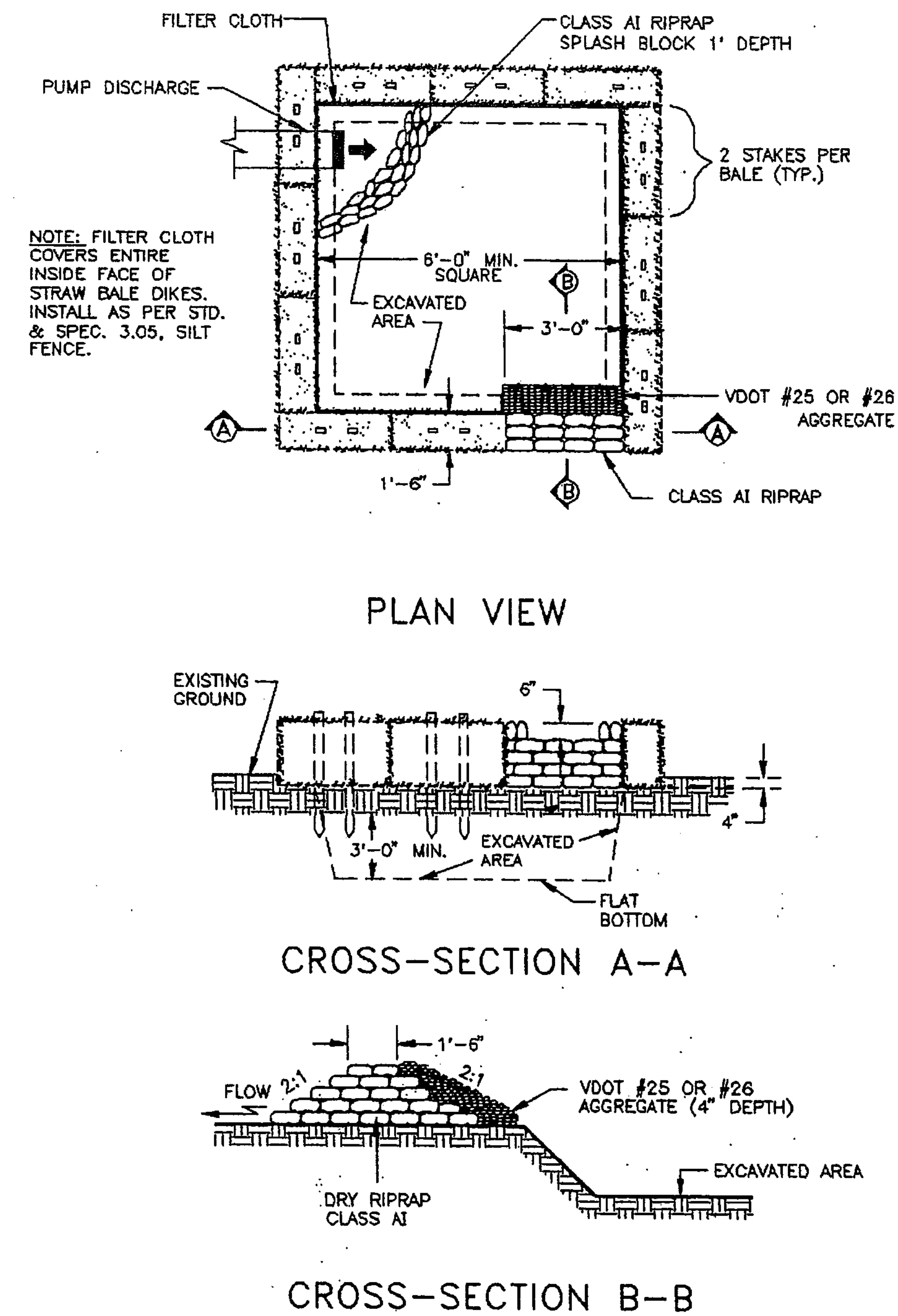
g. Once the wet storage area becomes filled to one-half of the excavated depth, accumulated sediment shall be removed and properly disposed of.

h. Once the device has been removed, ground contours will be returned to original condition.

Maintenance
(All dewatering structures)

1. The filtering devices must be inspected frequently and repaired or replaced once the sediment build-up prevents the structure from functioning as designed.

STRAW BALE/SILT FENCE PIT



Source: Va. DSWC

Plate 3.26-3

2. The accumulated sediment which is removed from a dewatering device must be spread on-site and stabilized or disposed of at an approved disposal site as per approved plan.

STD & SPEC 3.27

TURBIDITY CURTAIN

TC

Definition

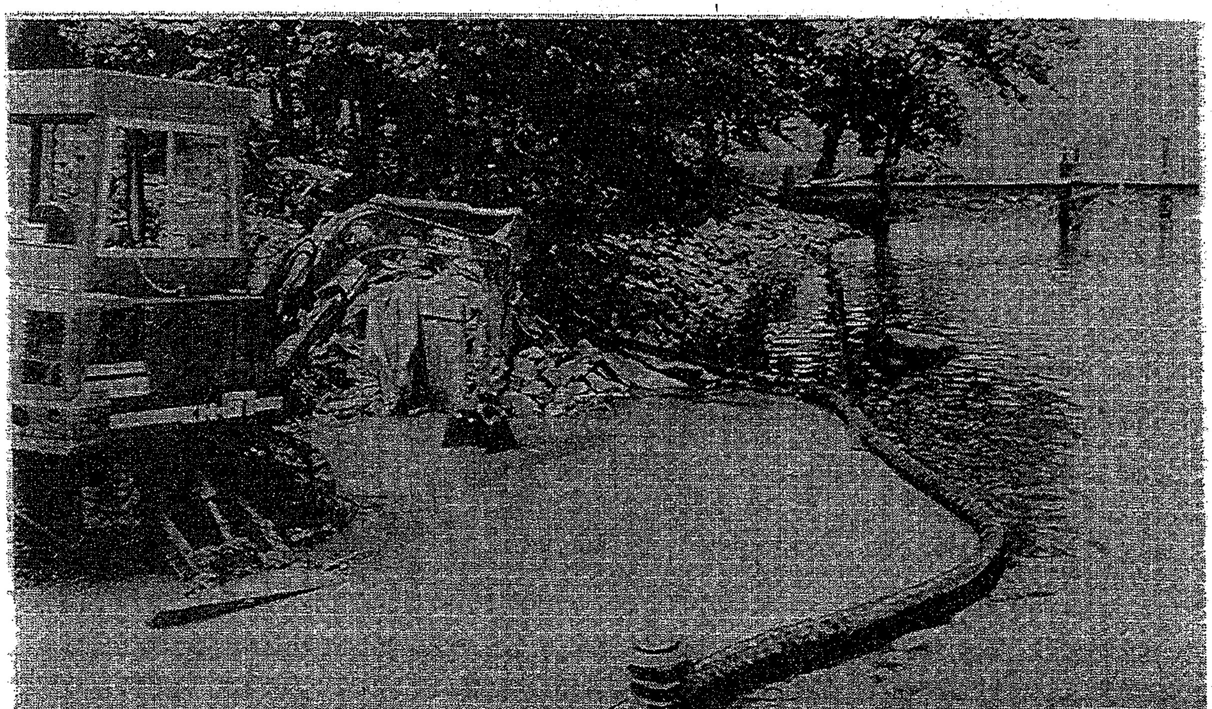
A floating geotextile material which minimizes sediment transport from a disturbed area adjacent to or within a body of water.

Purpose

To provide sedimentation protection for a watercourse from up-slope land disturbance or from dredging or filling within the watercourse.

Conditions Where Practice Applies

Applicable to non-tidal and tidal watercourses where intrusion into the watercourse by construction activities and subsequent sediment movement is unavoidable.



Planning Considerations

Soil loss into a watercourse results in long-term suspension of sediment. In time, the suspended sediment may travel large distances and affect wide-spread areas. A turbidity curtain is designed to deflect and contain sediment within a limited area and provide enough residence time so that soil particles will fall out of suspension and not travel to other areas.

Turbidity curtain types must be selected based on the flow conditions within the water body - whether it be a flowing channel, lake, pond, or a tidal watercourse. The specifications contained within this practice pertain to minimal and moderate flow conditions where the velocity of flow may reach 5 feet per second (or a current of approximately 3 knots). For situations where there are greater flow velocities or currents, a qualified engineer and product manufacturer should be consulted.

Consideration must also be given to the direction of water movement in channel flow situations. Turbidity curtains are not designed to act as water impoundment dams and can not be expected to stop the flow of a significant volume of water. They are designed and installed to trap sediment, not to halt the movement of the water itself. In most situations, <u>turbidity curtains should not be installed across channel flows</u>.

In tidal or moving water conditions, provisions must be made to allow the volume of water contained within the curtain to change. Since the bottom of the curtain is weighted and external anchors are frequently added, the volume of water contained within the curtain will be much greater at high tide verses low tide and measures must be taken to prevent the curtain from submerging. In addition to allowing for slack in the curtain to rise and fall, water must be allowed to flow through the curtain if the curtain is to remain in roughly the same spot and to maintain the same shape. Normally, this is achieved by constructing part of the curtain from a heavy woven filter fabric. The fabric allows the water to pass through the curtain, but retains the sediment pollutants. Consideration should be given to the volume of water that must pass through the fabric and sediment particle size when specifying fabric permeability.

Sediment which has been deflected and settled out by the curtain <u>may be removed</u> if so directed by the on-site inspector or the Plan-Approving Authority. However, consideration must be given to the probable outcome of the procedure - <u>will it create more of a sediment problem by resuspension of particles and by accidental dumping of the material by the equipment involved</u>? It is, therefore, recommended that the soil particles trapped by a turbidity curtain only be removed if there has been a significant change in the original contours of the affected area in the watercourse. Regardless of the decision made, soil particles should always be allowed to settle for <u>a minimum of 6-12 hours</u> prior to their removal by equipment or prior to removal of a turbidity curtain.

It is imperative that the intended function of the other controls in this chapter, to <u>keep sediment out of the watercourse</u>, be the strategy used in every erosion control plan. However, when proximity to the watercourse makes successfully mitigating sediment loss impossible, the use of the turbidity curtain during land disturbance is essential.

Design Criteria

1. Type I configuration (see Plate 3.27-1) should be used in protected areas where there is no current and the area is sheltered from wind and waves.

2. Type II configuration (see Plate 3.27-1) should be used in areas where there may be small to moderate current running (up to 2 knots or 3.5 feet per second) and/or wind and wave action can effect the curtain.

3. Type III configuration (see Plate 3.27-2) should be used in areas where considerable current (up to 3 knots or 5 feet per second) may be present, where tidal action may be present and/or where the curtain is potentially subject to wind and wave action.

4. Turbidity curtains should extend the entire depth of the watercourse whenever the watercourse in question is not subject to tidal action and/or significant wind and wave forces.

5. In tidal and/or wind and wave action situations, the curtain should never be so long as to touch the bottom. A minimum 1-foot "gap" should exist between the weighted lower end of the skirt and the bottom at "mean" low water. Movement of the lower skirt over the bottom due to tidal reverses or wind and wave action on the flotation system may fan and stir sediments already settled out.

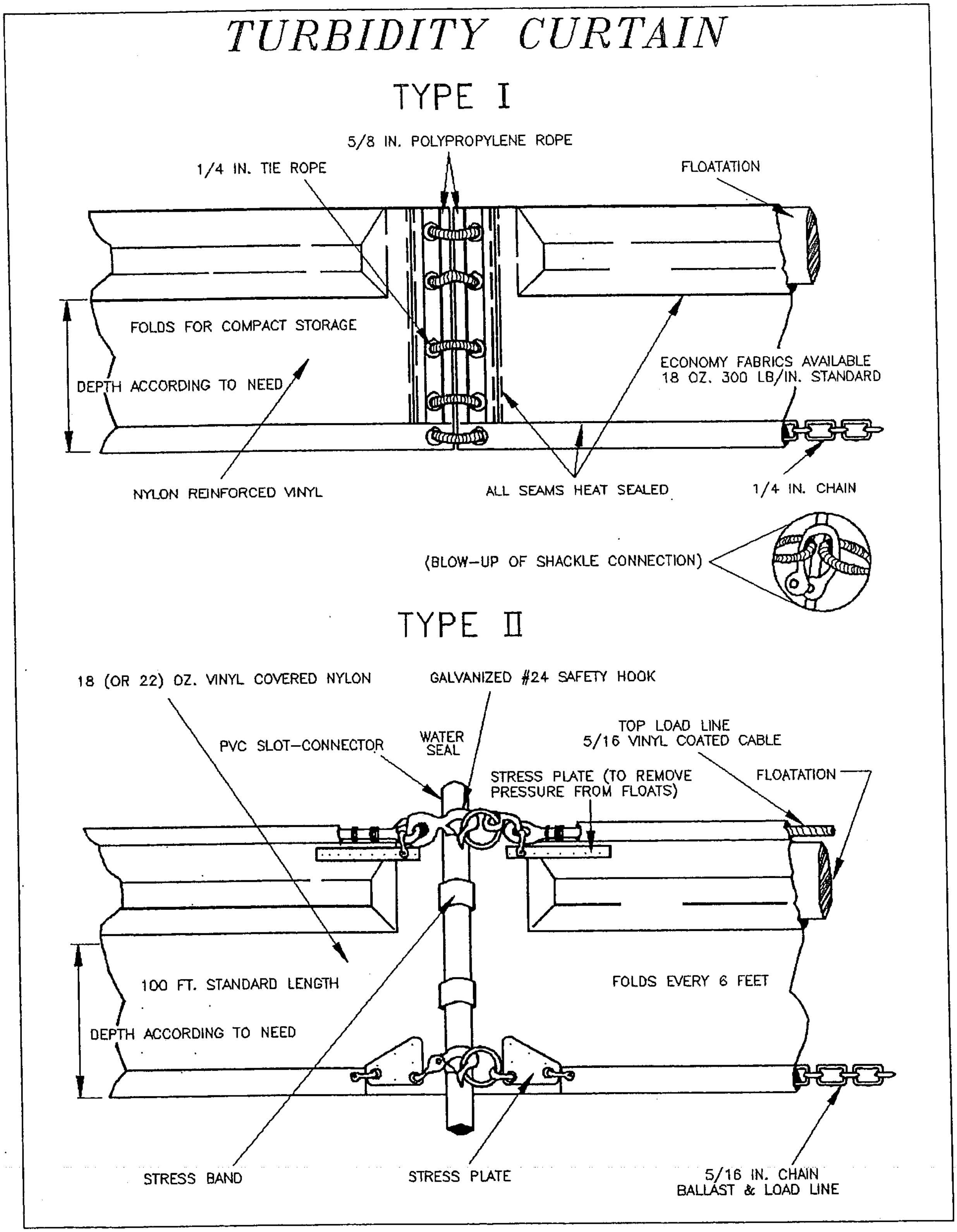
6. In tidal and/or wind and wave action situations, it is seldom practical to extend a turbidity curtain depth lower than 10 to 12 feet below the surface, even in deep water. Curtains which are installed deeper than this will be subject to very large loads with consequent strain on curtain materials and the mooring system. In addition, a curtain installed in such a manner can "billow up" towards the surface under the pressure of the moving water, which will result in an effective depth which is significantly less than the skirt depth.

7. Turbidity curtains should be located parallel to the direction of flow of a moving body of water. Turbidity Curtain should not be placed across the main flow of a significant body of moving water.

8. When sizing the length of the floating curtain, allow an additional 10-20% variance in the straight line measurements. This will allow for measuring errors, make installing easier and reduce stress from potential wave action during high winds.

9. An attempt should be made to avoid an excessive amount of joints in the curtain; a minimum continuous span of 50 feet between joints is a good "rule of thumb."

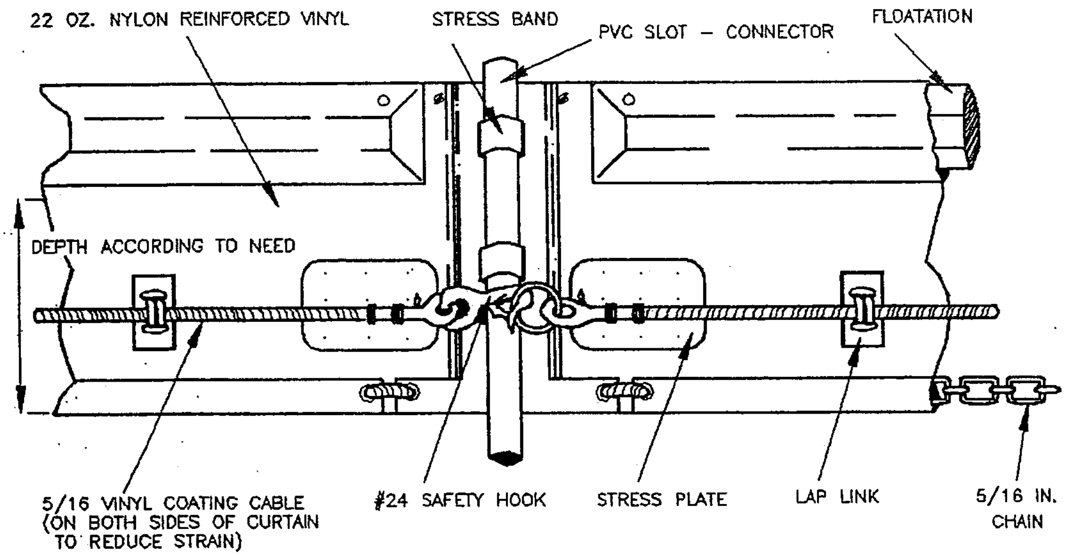
10. For stability reasons, a maximum span of 100 feet between joints (anchor or stake locations) is also a good rule to follow.



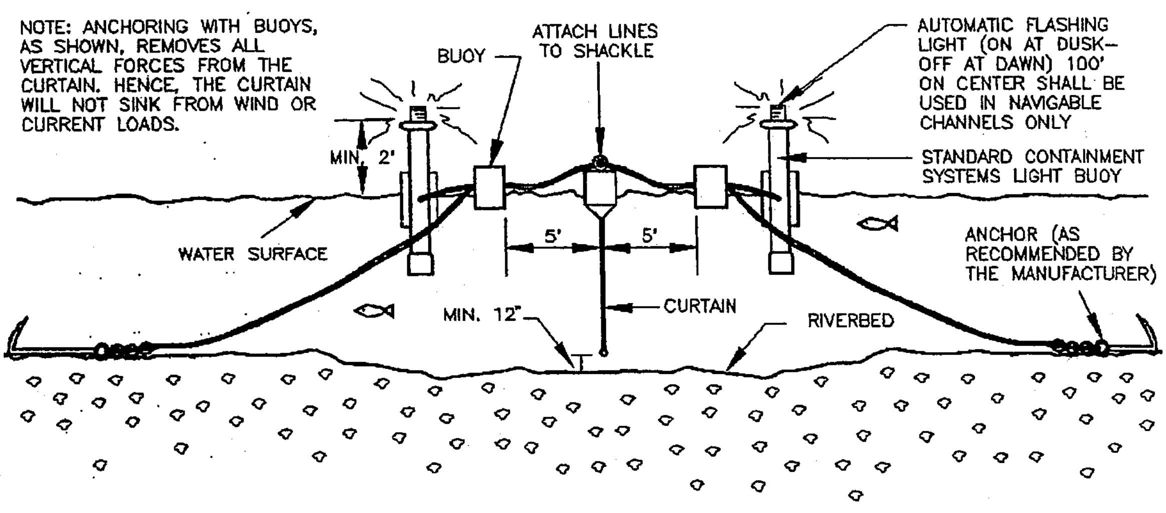
Source: American Boom and Barrier Corp. product literature Plate 3.27-1

TURBIDITY CURTAIN

TYPE III



ORIENTATION WHEN INSTALLED (TIDAL SITUATION – TYPE III)



Source: Adapted from American Boom and Barrier Corp. and VDOT Standard Sheets

Plate 3.27-2

11. The ends of the curtain, both floating upper and weighted lower, should extend well up into the shoreline, especially if high water conditions are expected. The ends should be secured firmly to the shoreline (preferably to rigid bodies such as trees or piles) to fully enclose the area where sediment may enter the water.

12. When there is a specific need to extend the curtain to the bottom of the watercourse in tidal or moving water conditions, a heavy woven pervious filter fabric may be substituted for the normally recommended impervious geotextile. This creates a "flow-through" medium which significantly reduces the pressure on the curtain and will help to keep it in the same relative location and shape during the rise and fall of tidal waters.

13. Typical alignments of turbidity curtains can be seen in Plate 3.27-3. The number and spacing of external anchors may vary depending on current velocities and potential wind and wave action; manufacturer's recommendations should be followed.

Construction Specifications

Materials

1. Barriers should be a bright color (yellow or "international" orange are recommended) that will attract the attention of nearby boaters.

2. The curtain fabric must meet the minimum requirements noted in Table 3.27-A.

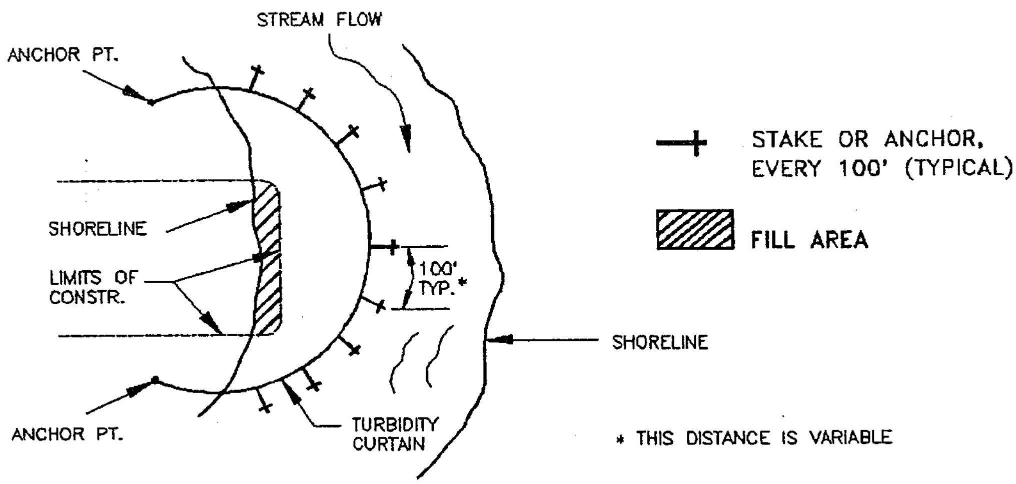
3. Seams in the fabric shall be either vulcanized welded or sewn, and shall develop the full strength of the fabric.

4. Floatation devices shall be flexible, buoyant units contained in an individual floatation sleeve or collar attached to the curtain. Buoyancy provided by the floatation units shall be sufficient to support the weight of the curtain and maintain a freeboard of at least 3 inches above the water surface level (see Plate 3.27-2).

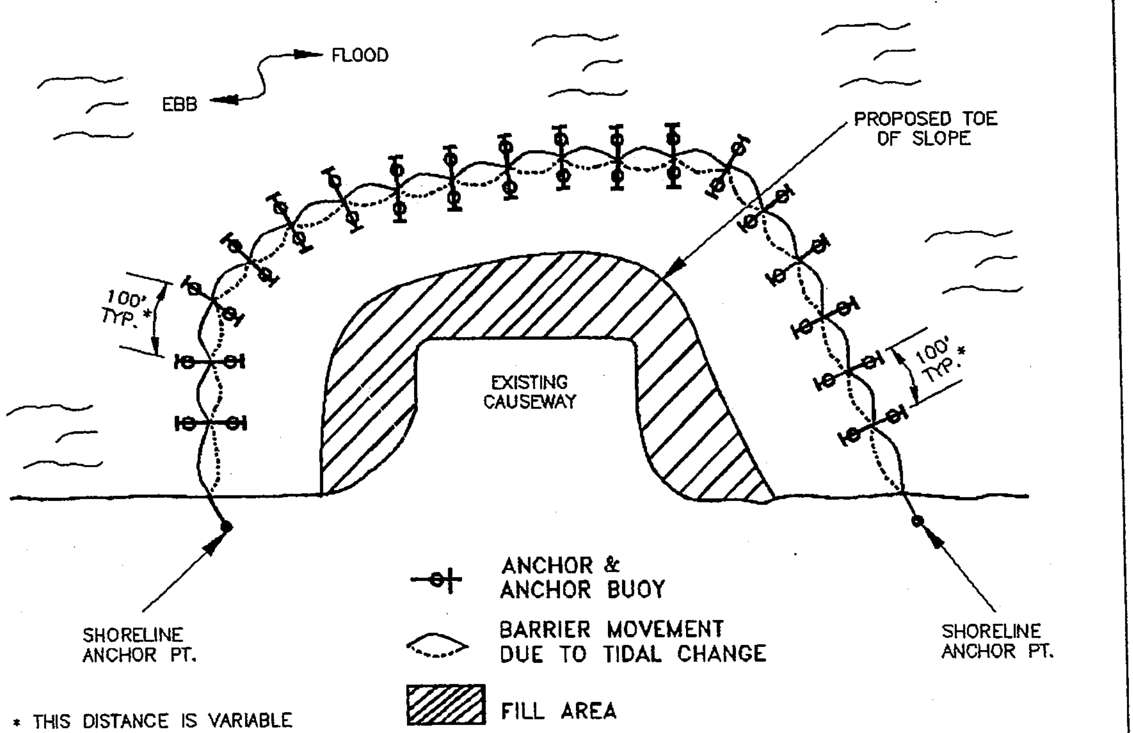
5. Load lines must be fabricated into the bottom of all floating turbidity curtains. Type II and Type III must have load lines also fabricated into the top of the fabric. The top load line shall consist of woven webbing or vinyl-sheathed steel cable and shall have a break strength in excess of 10,000 pounds. The supplemental (bottom) load-line shall consist of a chain incorporated into the bottom hem of the curtain of sufficient weight to serve as ballast to hold the curtain in a vertical position. Additional anchorage shall be provided as necessary. The load lines shall have suitable connecting devices which develop the full breaking strength for connecting to load lines in adjacent sections (see Plates 3.27-1 and 3.27-2 which portray this orientation).

TURBIDITY CURTAIN

TYPICAL LAYOUTS:
STREAMS, PONDS & LAKES (PROTECTED & NON-TIDAL)



TIDAL WATERS AND/OR HEAVY WIND & WAVE ACTION



Source: Adapted from Florida Department of Transportation Road and Design Specifications

Plate 3.27-3

TABLE 3.27-A

PHYSICAL PROPERTIES OF TURBIDITY CURTAIN FABRIC

Physical Property	Requirement
Thickness, mils	45
Weight/oz./sq. yd.:	
Type I	18
Type II	18 or 22
Type III	22
Grab Tensile Strength, lbs.	300
UV Inhibitor	Must be included

Source: Adapted from The Ralph Lemon Company product literature

6. External anchors may consist of wooden or metal stakes (2- x 4-inch or 2½-inch minimum diameter wood or 1.33 pounds/linear foot steel) when Type I installation is used; when Type II or Type III installations are used, bottom anchors should be used.

7. Bottom anchors must be sufficient to hold the curtain in the same position relative to the bottom of the watercourse without interfering with the action of the curtain. The anchor may dig into the bottom (grappling hook, plow or fluke-type) or may be weighted (mushroom type) and should be attached to a floating anchor buoy via an anchor line. The anchor line would then run from the buoy to the top load line of the curtain. When used with Type III installations, these lines must contain enough slack to allow the buoy and curtain to float freely with tidal changes without pulling the buoy or curtain down and must be checked regularly to make sure they do not become entangled with debris. As previously noted, anchor spacing will vary with current velocity and potential wind and wave action; manufacturer's recommendations should be followed. See orientation of external anchors and anchor buoys for tidal installation in Plate 3.27-2.

Installation

1. In the calm water of lakes or ponds (Type I installation) it is usually sufficient to merely set the curtain end stakes or anchor points (using anchor buoys if bottom anchors are employed), then tow the curtain in the furled condition out and attach it to these stakes or anchor points. Following this, any additional stakes or buoyed anchors required to maintain the desired location of the curtain may be set and these anchor points made fast to the curtain. Only then, the furling lines should be cut to let the curtain skirt drop.

2. In rivers or in other moving water (Type II and Type III installations) it is important to set all the curtain anchor points. Care must be taken to ensure that anchor points are of sufficient holding power to retain the curtain under the existing current conditions, prior to putting the furled curtain into the water. Again, anchor buoys should be employed on all anchors to prevent the current from submerging the flotation at the anchor points. If the moving water into which the curtain is being installed is tidal and will subject the curtain to currents in both directions as the tide changes, it is important to provide anchors on both sides of the curtain for two reasons:

   a) Curtain movement will be minimized during tidal current reversals.

   b) The curtain will not overrun the anchors and pull them out when the tide reverses.

   When the anchors are secure, the furled curtain should be secured to the upstream anchor point and then sequentially attached to each next downstream anchor point until the entire curtain is in position. At this point, and before unfurling, the "lay" of the curtain should be assessed and any necessary adjustments made to the anchors. Finally, when the location is ascertained to be as desired, the furling lines should be cut to allow the skirt to drop.

3. Always attach anchor lines to the flotation device, not to the bottom of the curtain. The anchoring line attached to the floatation device on the downstream side will provide support for the curtain. Attaching the anchors to the bottom of the curtain could cause premature failure of the curtain due to the stresses imparted on the middle section of the curtain.

4. There is an exception to the rule that turbidity curtains should not be installed across channel flows; it occurs when there is a danger of creating a silt build-up in the middle of a watercourse, thereby blocking access or creating a sand bar. Curtains have been used effectively in large areas of moving water by forming a very long-sided, sharp "V" to deflect clean water around a work site, confine a large part of the silt-laden water to the work area inside the "V" and direct much of the silt toward the shoreline.. Care must be taken, however, not to install the curtain perpendicular to the water current.

5. See Plate 3.27-3 for typical installation layouts.

Removal

1. Care should be taken to protect the skirt from damage as the turbidity curtain is dragged from the water.

2. The site selected to bring the curtain ashore should be free of sharp rocks, broken cement, debris, etc. so as to minimize damage when hauling the curtain over the area.

3. If the curtain has a deep skirt, it can be further protected by running a small boat along its length with a crew installing furling lines before attempting to remove the curtain from the water.

Maintenance

1. The developer/owner shall be responsible for maintenance of the filter curtain for the duration of the project in order to ensure the continuous protection of the watercourse.

2. Should repairs to the geotextile fabric become necessary, there are normally repair kits available from the manufacturers; manufacturer's instructions must be followed to ensure the adequacy of the repair.

3. When the curtain is no longer required as determined by the inspector, the curtain and related components shall be removed in such a manner as to minimize turbidity. Remaining sediment shall be sufficiently settled before removing the curtain. Sediment may be removed and the original depth (or plan elevation) restored. Any spoils must be taken to upland area and be stabilized.

STD & SPEC 3.28

SUBSURFACE DRAIN

SD

Definition

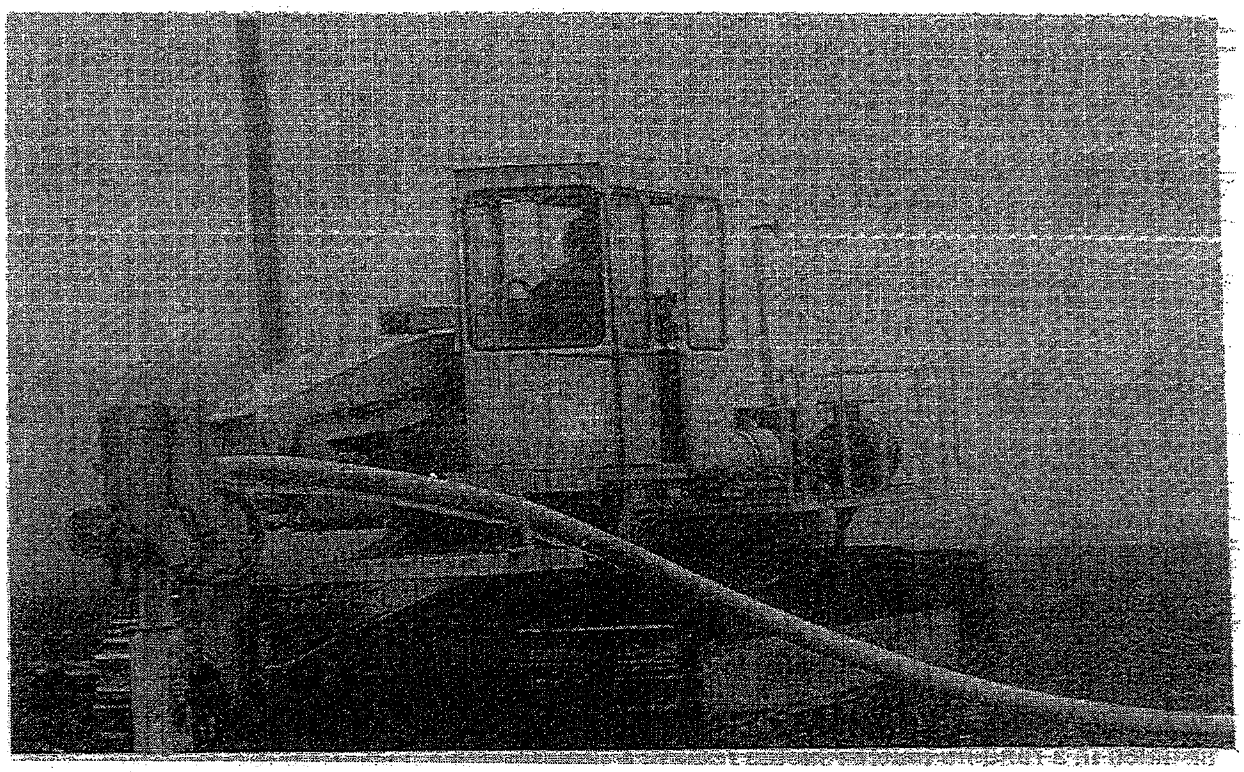
A perforated conduit such as pipe, tubing or tile installed beneath the ground to intercept and convey ground water.

Purposes

1. To prevent sloping soils from becoming excessively wet and subject to sloughing.

2. To improve the quality of the growth medium in excessively wet areas by lowering the water table.

3. To drain stormwater detention areas or structures.



Conditions Where Practice Applies

Wherever excess water must be removed from the soil. The soil must be deep and permeable enough to allow an effective system to be installed. Either a gravity outlet must be available or pumping must be provided. These standards do no apply to foundation drains.

Planning Considerations

Subsurface drainage systems are of two types, relief drains and interceptor drains. Relief drains are used either to lower the water table in order to improve the growth of vegetation, or to remove surface water. They are installed along a slope and drain in the direction of the slope. They can be installed in a gridiron pattern, a herringbone pattern, or a random pattern (see Plate 3.28-1).

Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. They are installed across a slope and drain to the side of the slope. They usually consist of a single pipe or series of single pipes instead of a patterned layout (see Plate 3.28-2).

Design Criteria

Location

Tree roots can often clog subsurface drain systems. Consequently, sub-surface drains should be located such that there are no trees within 50 feet of the drain.

Relief Drains - Relief drains should be located through the center of wet areas. They should drain in the same direction as the slope.

Interceptor drains - Interceptor drains should be located on the uphill side of wet areas . They should be installed across the slope and drain to the side of the slope.

Capacity of Drains

The required capacity of a subsurface drain depends upon its use.

Relief drains- Relief drains installed in a uniform pattern should remove a minimum of 1 inch of groundwater in 24 hours (0.042 cfs/acre). The design capacity must be increased accordingly to accommodate any surface water which enters directly into the system (see Plate 3.28-4).

Interceptor drains or relief drains in a random pattern- Interceptor drains or relief drains installed in a random pattern should remove a minimum of 1.5 cfs/1000 feet of length. This value should be increased for sloping land according to the values in Table 3.28-A. In addition, if a flowing spring or surface water enters directly into the system, this flow must be accommodated and the design capacity must be increased accordingly to take care of this flow (see Plate 3.28-4).

TABLE 3.28-A

WATER REMOVAL RATES FOR SLOPING LAND*

Land Slope	Water Removal Rates
2 - 5%	1.65 cfs/1000 ft.
6 - 12%	1.80 cfs/1000 ft.
> 12%	1.95 cfs/1000 ft.

* These rates depend on the soil types where the drains are installed. Heavier soils may result in slower water removal rates.

Source: Va. DSWC

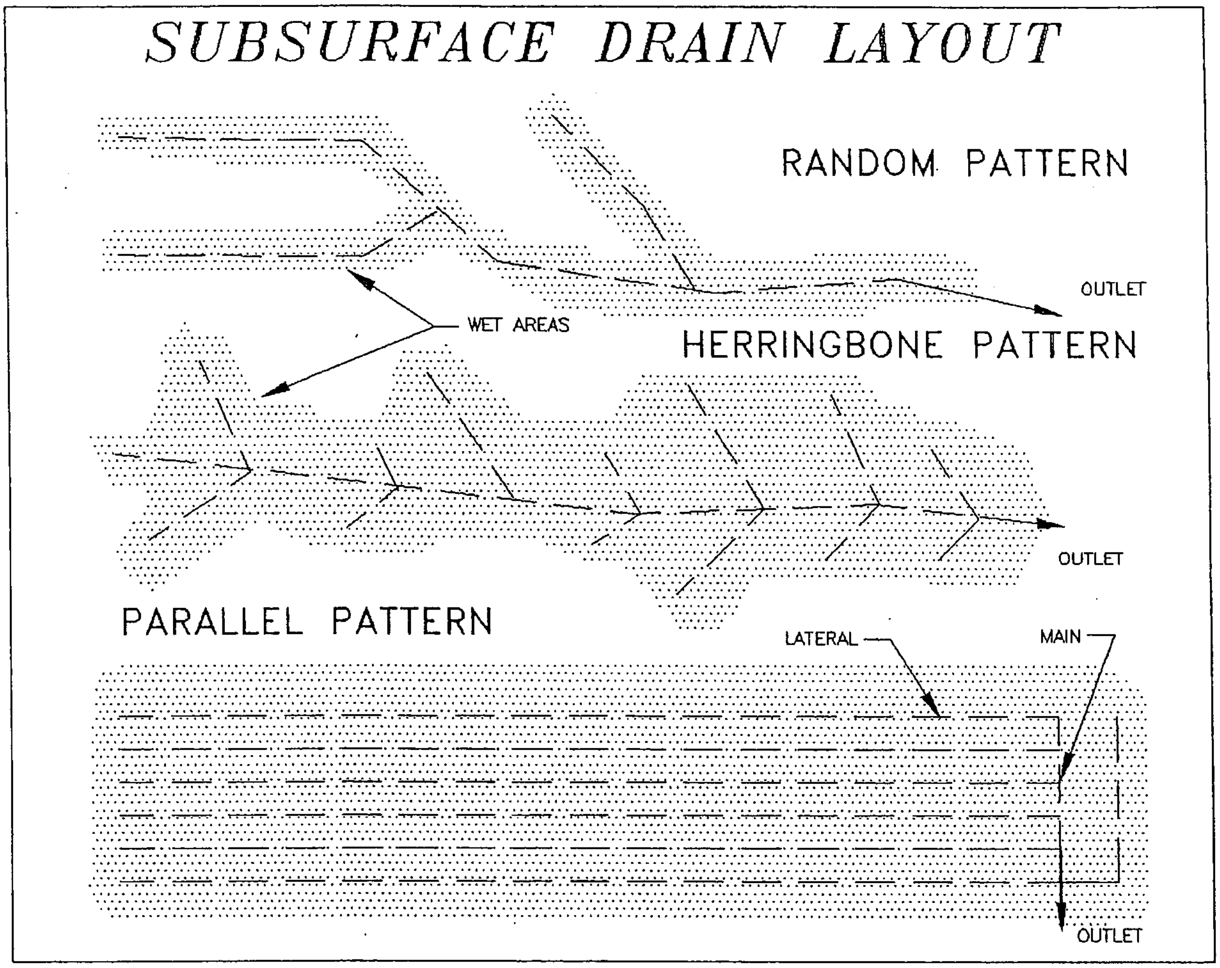
Size of Drains

Subsurface drains should be sized for the required capacity using Plates 3.28-6 and 3.28-7 in Appendix 3.28-a. The minimum diameter for a subsurface drain shall be 4 inches.

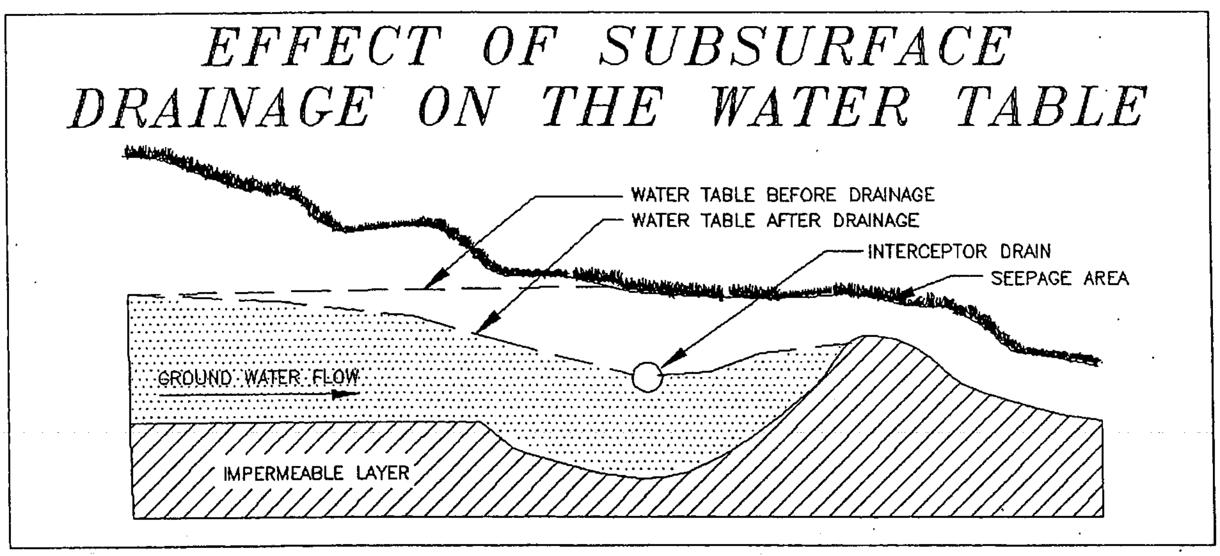
Depth and Spacing

Relief Drains - Relief drains installed in a uniform pattern should have equal spacing between drains and the drains should be at the same depth. Maximum depth is limited by the allowable load on the pipe, depth to impermeable layers in the soil, and outlet requirements. The minimum depth is 24 inches under normal conditions. Twelve inches is acceptable where the drain will not be subject to equipment loading or frost action. Spacing between drains is dependent on soil permeability and the depth of the drain. In general, however, a depth of 3 feet and a spacing of 50 feet will be adequate. A more economical system may be designed., if the necessary information is available, by using the equations found in Appendix 3.28-a.

Interceptor drain - The depth of installation of an interceptor drain is influenced mainly by the depth to which the water table is to be lowered. The maximum depth is limited by the allowable load on the pipe and the depth to an impermeable layer. Minimum depth should be the same as for relief drains.



Source: USDA-SCS Plate 3.28-1



Source: USDA-SCS Plate 3.28-2

One interceptor drain is usually sufficient. However, if multiple drains are to be used, determining the required spacing can be difficult. The best approach is to install the first drain - then if seepage or high water table problems occur downslope, install an additional drain a suitable distance downslope. This distance can be calculated from equations found in Appendix 3.28-a.

Velocity and Grade

The minimum velocity required to prevent silting is 1.4 ft./sec. The line should be graded to achieve at least this velocity. Steep grades should be avoided, however. Table 3.28-B lists maximum velocities for various soil textures.

TABLE 3.28-B

MAXIMUM VELOCITIES FOR VARIOUS SOIL TEXTURES

Soil Texture	Maximum Velocity (ft./sec.)
Sandy and Sandy Loam	3.5
Silt and Silt Loam	5.0
Silty Clay Loam	6.0
Clay and Clay Loam	7.0
Coarse Sand or Gravel	9.0

Source: Va. DSWC

Envelopes

Envelopes shall be used around all drains for proper bedding and improved flow of groundwater into the drain. The envelope shall consist of 3 inches of VDOT #68 aggregate placed completely around the drain. The stone shall be encompassed by a filter cloth separator in order to prevent the migration of surrounding soil particles into the drain (see Plate 3.28-3). Filter cloth must meet the physical requirements noted in Std. & Spec. 3.19, RIPRAP.

Surface Water

Plate 3.28-4 shows two types of surface water inlets. The grated inlet should not be used where excessive sedimentation might be a problem.

Outlet

The outlet of the subsurface drain shall empty into a channel or some other watercourse which will remove the water from the outlet. It shall be above the mean water level in the receiving channel. It shall be protected from erosion, undermining, damage from periods of submergence, and the entry of small animals into the drain.

The outlet shall consist of a 10-foot section of corrugated metal, cast iron, steel or schedule 40 PVC pipe without perforations. No envelope material shall be used around the pipe. At least two-thirds of the outlet pipe length shall be buried.

Materials

Acceptable materials for subsurface drains include perforated, continuous closed-joint conduits of corrugated plastic, concrete, corrugated metal, asbestos cement, and bituminous fiber. The strength and durability of the pipe shall meet the requirements of the site in accordance with the manufacturer's specifications.

Construction Specifications

1. The trench shall be constructed on a continuous grade with no reverse grades or low spots.

2. Soft or yielding soils under the drain shall be stabilized with gravel or other suitable material.

3. Deformed, warped, or otherwise unsuitable pipe shall not be used.

4. Envelopes or filter material shall be placed as specified with at least 3 inches of material on all sides of the pipe.

5. Backfilling shall be done immediately after placement of the pipe. No sections of pipe should remain uncovered overnight or during a rainstorm. Backfill material shall be placed in the trench in such a manner that the drain pipe is not displaced or damaged.

6. The outlet section of the drain shall consist of at least 10 feet of non-perforated corrugated metal, cast iron, steel or schedule 40 PVC pipe. At least two-thirds of its length shall be buried.

Maintenance

1. Subsurface drains should be checked periodically to ensure that they are free-flowing and not clogged with sediment.

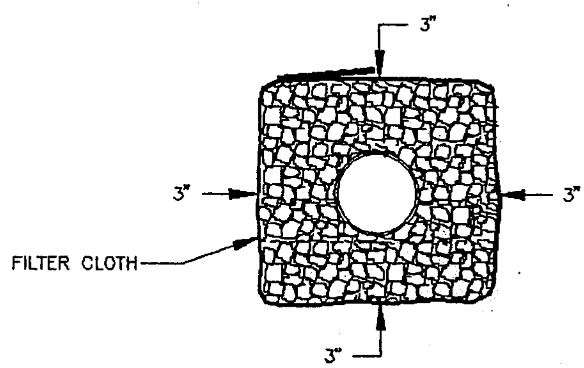
2. The outlet should be kept clean and free of debris.

3. Surface inlets should be kept open and free of sediment and other debris.

4. Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees.

5. Where drains are crossed by heavy vehicles, the line should be checked to ensure that it is not crushed.

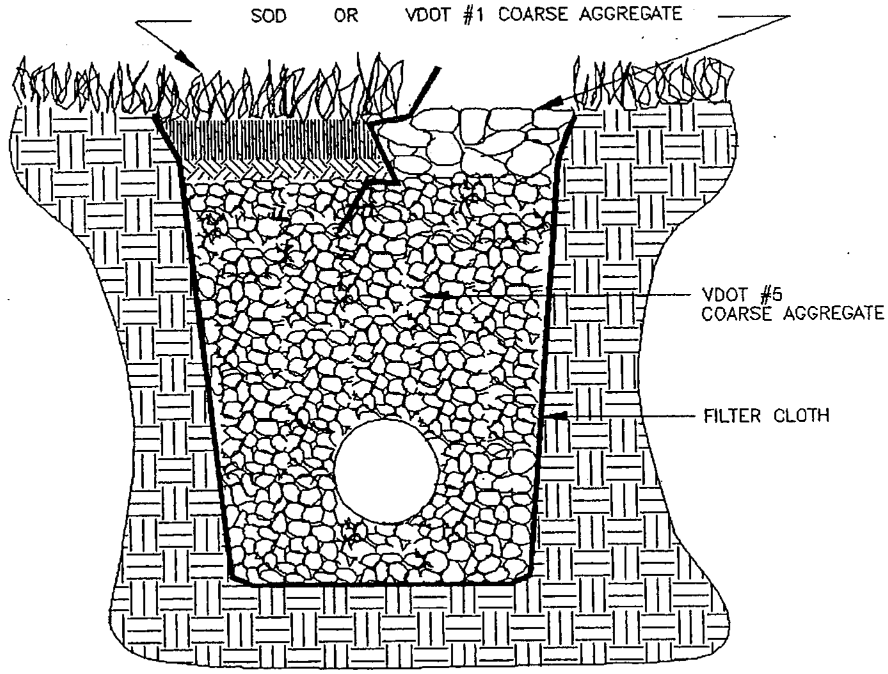
DRAINAGE ENVELOPE



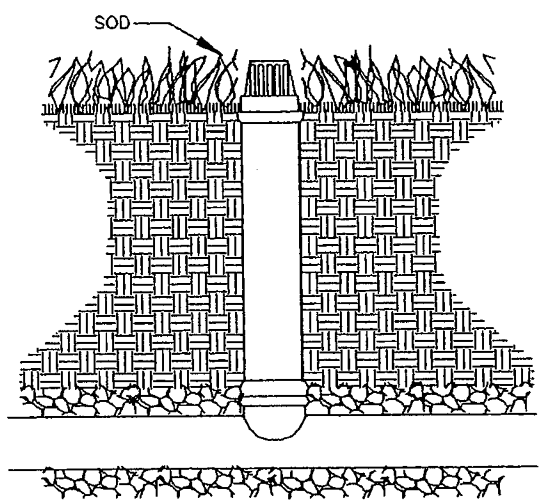
Source: USDA-SCS

Plate 3.28-3

SURFACE INLETS



NATURAL INLET



GRATED INLET

Source: USDA-SCS

Plate 3.28-4

APPENDIX 3.28-a

Subsurface drains are not generally designed to flow under pressure and the hydraulic gradient is parallel with the grade line. Consequently, the flow is considered to be open channel and Manning's Equation can be used. The required drain size can be determined by the following procedure:

1. Determine the flow the drain must carry.
2. Determine the gradient of the drain
3. From Table 3.28-C, determine "n" for the type of drain pipe to be used. Choose the correct Plate (3.28-5 through 3.28-7) for the "n" just determined.
4. Enter the appropriate plate with the gradient of the pipe and the flow in the pipe. The intersection of the two lines must be to the right of the line for 1.4 ft./sec. If it is not, increase the gradient or flow capacity or both.

Example 1

Given:

A random subsurface drain is to be installed on a 1.0% grade, 700 feet in length, and using corrugated plastic pipe.

Calculate:

The required size of the drain pipe.

Solution:

From the Std. & Spec., the required capacity of the pipe is:

$$1.5\ ft.^3/\text{sec.}/1000\ ft.$$

$$Capacity = \frac{700}{1000}\ x\ 1.5\ ft.^3/\text{sec.} = 1.05\ ft.^3/\text{sec.}$$

* From Table 3.28-C, n = 0.015 for corrugated plastic pipe.
* From Plate 3.28-6, choose an 8-inch pipe.

Example 2

Given:

A relief drain installed in a gridiron pattern of 8 laterals, 500 feet long, 0.5% grade, and 50 feet on centers. A main 400 feet in length on a 0.5% grade will connect to the laterals. Use bituminized fiber pipe for the main and laterals.

Calculate:

The required size of the drain pipe.

Solution:

The drainage area for each lateral is 25 feet on either side of the pipe times the length. Therefore:

$$\frac{50\ ft. \times 500\ ft.}{43{,}560\ ft.^2/acre} = 0.57\ acre$$

From the Std. & Spec., the drains must remove 1 inch of water in 24 hours or 0.042 $ft.^3$/sec./acre.

$$0.042\ ft.^3/\text{sec.}/acre \times 0.57\ acre = 0.02\ ft.^3/\text{sec.}$$

From Table 3.28-C, n = 0.013 for bituminized fiber pipe.

From Plate 3.28-5, a 4-inch pipe must be used for the laterals.

The first 25 feet of the main will drain 25 feet on either side of the pipe. The remaining 375 feet will drain only 25 feet on the side opposite from the laterals. In addition, the main will drain the laterals.

Drainage from main:

$$\frac{25\ ft. \times 50\ ft.}{43{,}560\ ft.^2/acre} + \frac{375\ ft. \times 25\ ft.}{43{,}560\ ft.^2/acre} = 0.24\ acre$$

Drainage from laterals:

$$8 \quad x \quad 0.57\ acre \quad = \quad 4.56\ acre$$

$$Total \quad = \quad 0.24 \quad + \quad 4.56 \quad = \quad 4.8\ acre$$

Required capacity:

$$0.042\ ft.^3/\text{sec.}/acre \quad x \quad 4.8\ acre \quad = \quad 0.20\ ft.^3/\text{sec.}$$

From Plate 3.28-5, choose a 5-inch pipe for the main.

TABLE 3.28-C

"n" VALUES FOR SUBSURFACE DRAIN PIPES

Composition of Pipe or Tubing	"n" Values
Asbestos Cement	0.013
Bituminized Fiber	0.013
Concrete	0.015
Corrugated Plastic	0.015
Corrugated Metal	0.025

Source: Va. DSWC

Spacing of Relief Drains

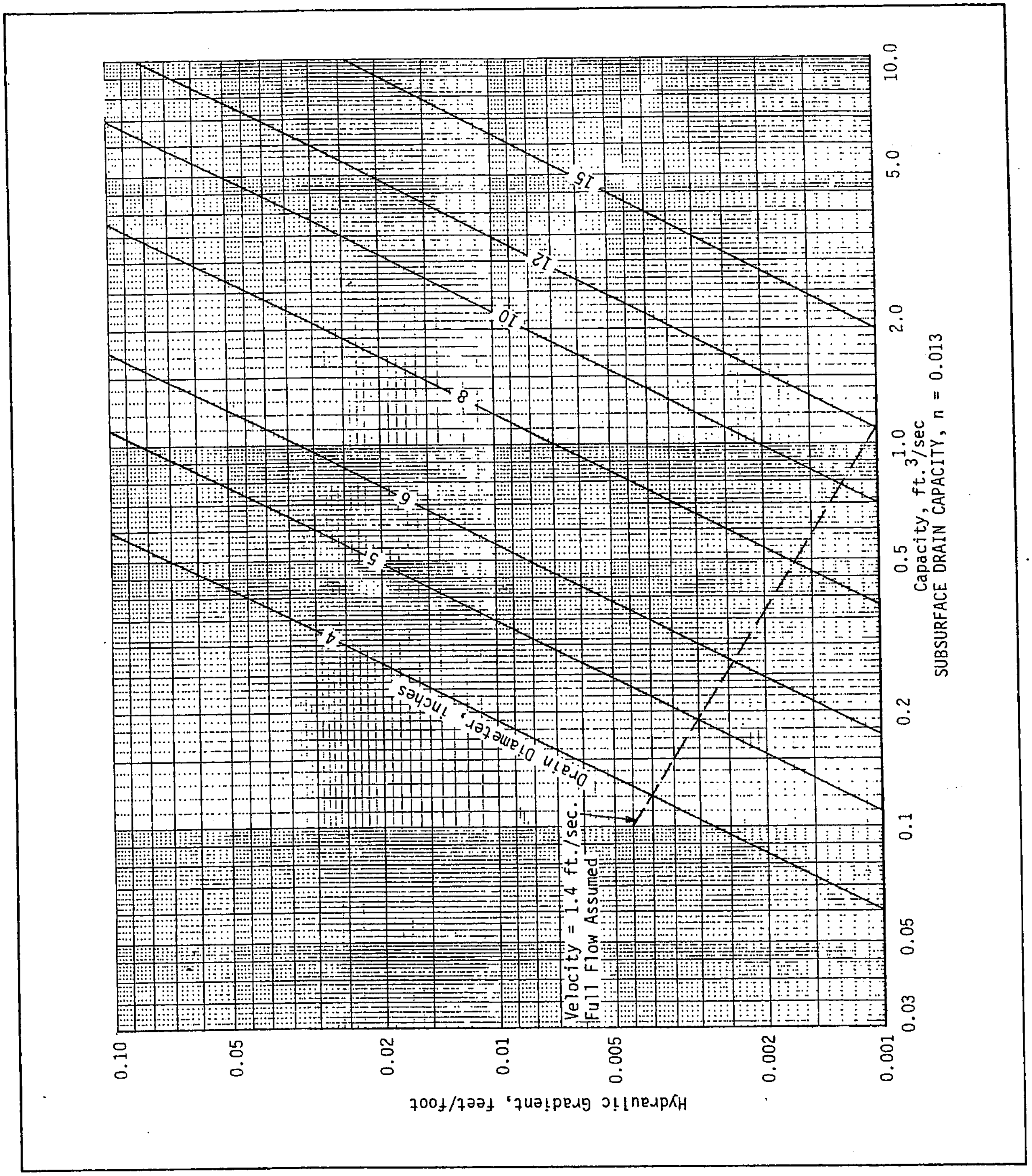
If the necessary information is known, the following equation can be used to calculate drain spacing in lieu of the recommended standard:

$$S = \sqrt{\frac{4k\ (M^2 + 2\ AM)}{q}}$$

Where,

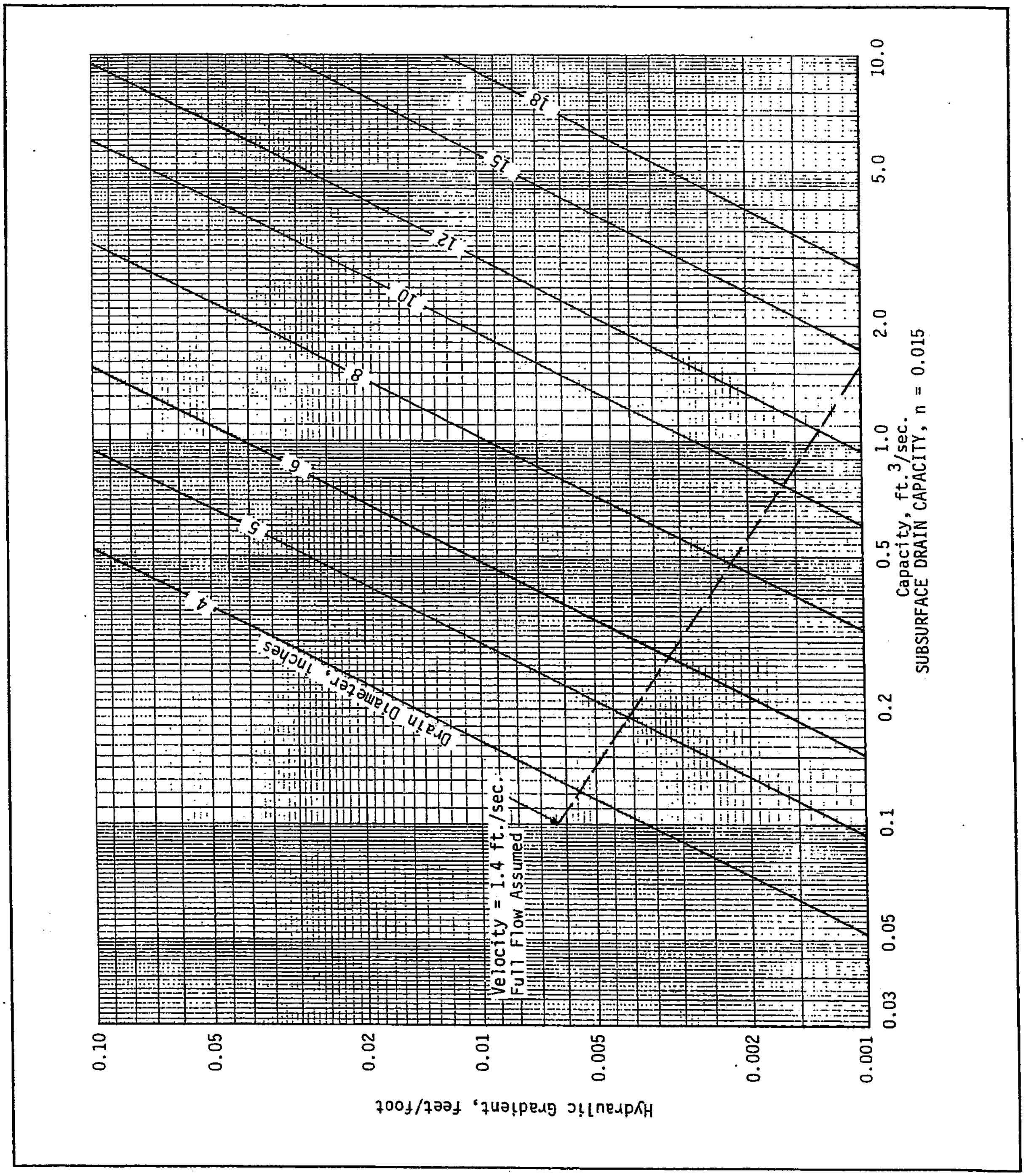
S = drain spacing, feet

k = average hydraulic conductivity, in./hr. (for practical purposes, hydraulic conductivity is equal to permeability).



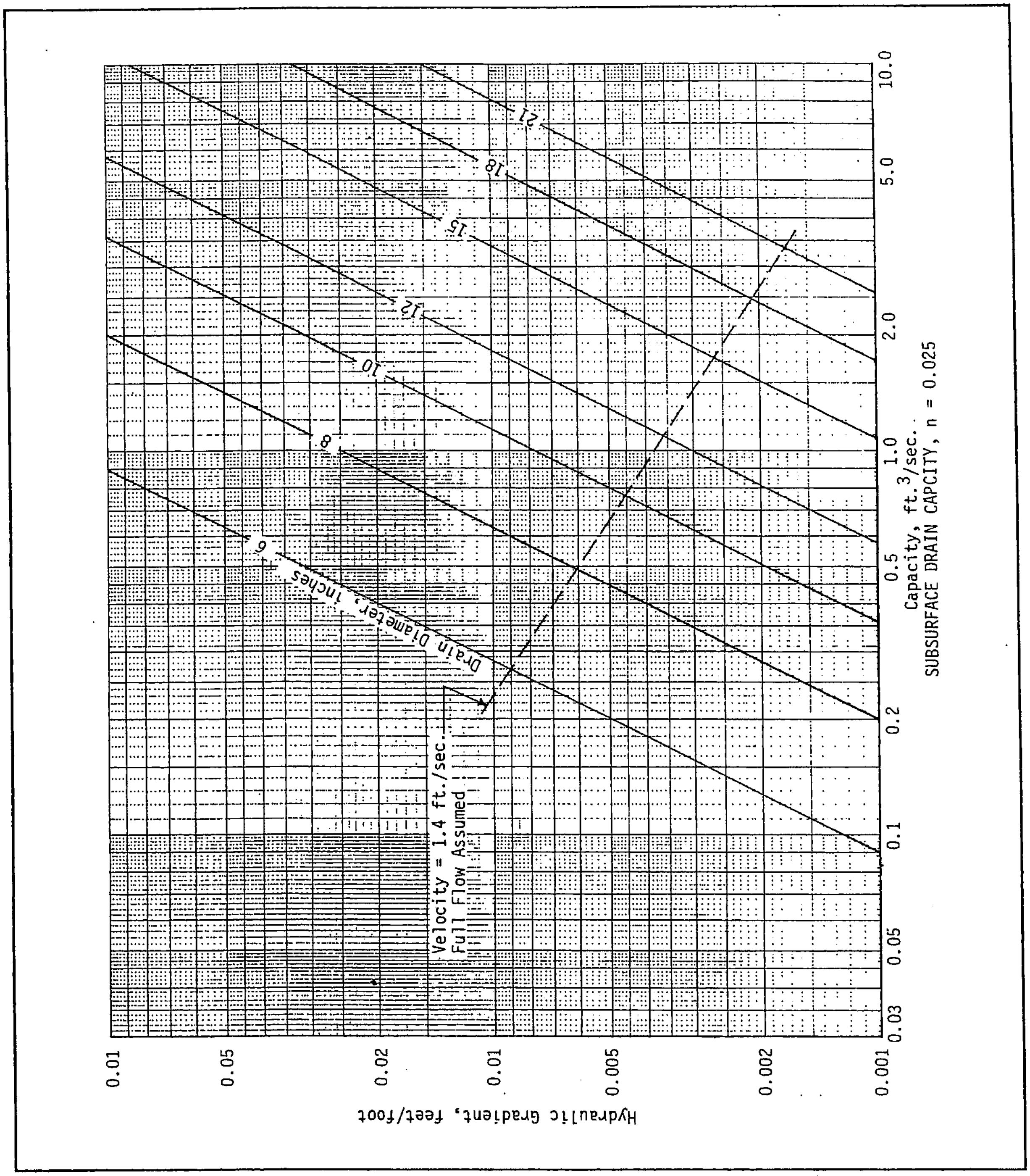
Source: USDA-SCS

Plate 3.28-5



Source: USDA-SCS

Plate 3.28-6



Source: USDA-SCS

Plate 3.28-7

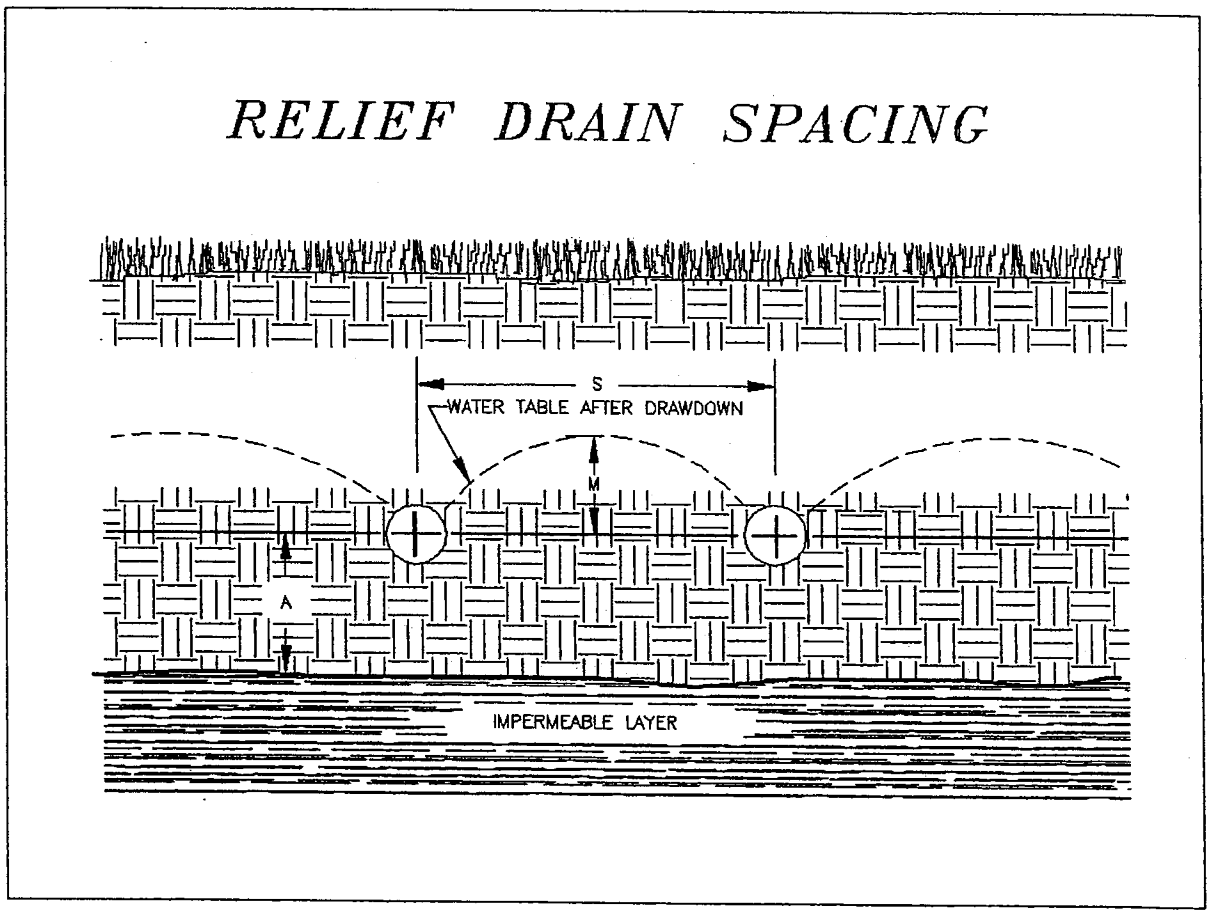
M = vertical distance, after drawdown, of water table above drain at mid-point between lines, feet.

A = depth of barrier below drain, feet.

q = drainage coefficient, rate of water removal, inch/hr.

Also, see Plate 3.28-8.

This equation is applicable to most areas in Virginia. Limitations of the equation are listed in the SCS National Engineering Handbook, Section 16, Drainage of Agricultural Land (66).



Source: USDA-SCS

Plate 3.28-8

Spacing of Interceptor Drains

If one interceptor drain is not sufficient, the spacing of multiple drains can be calculated by the following equation:

$$Le = \frac{k\,i}{q}\,(de - dw + W_2)$$

Where,

Le = the distance downslope from the drain to the point where the water table is at the desired depth after drainage, feet. The second drain should be located at this point.

k = the average hydraulic conductivity of the subsurface profile to the depth of the drain, in./hr.

q = drainage coefficient, rate of water removal, in./hr.

i = the hydraulic gradient of the water table before drainage, feet/foot.

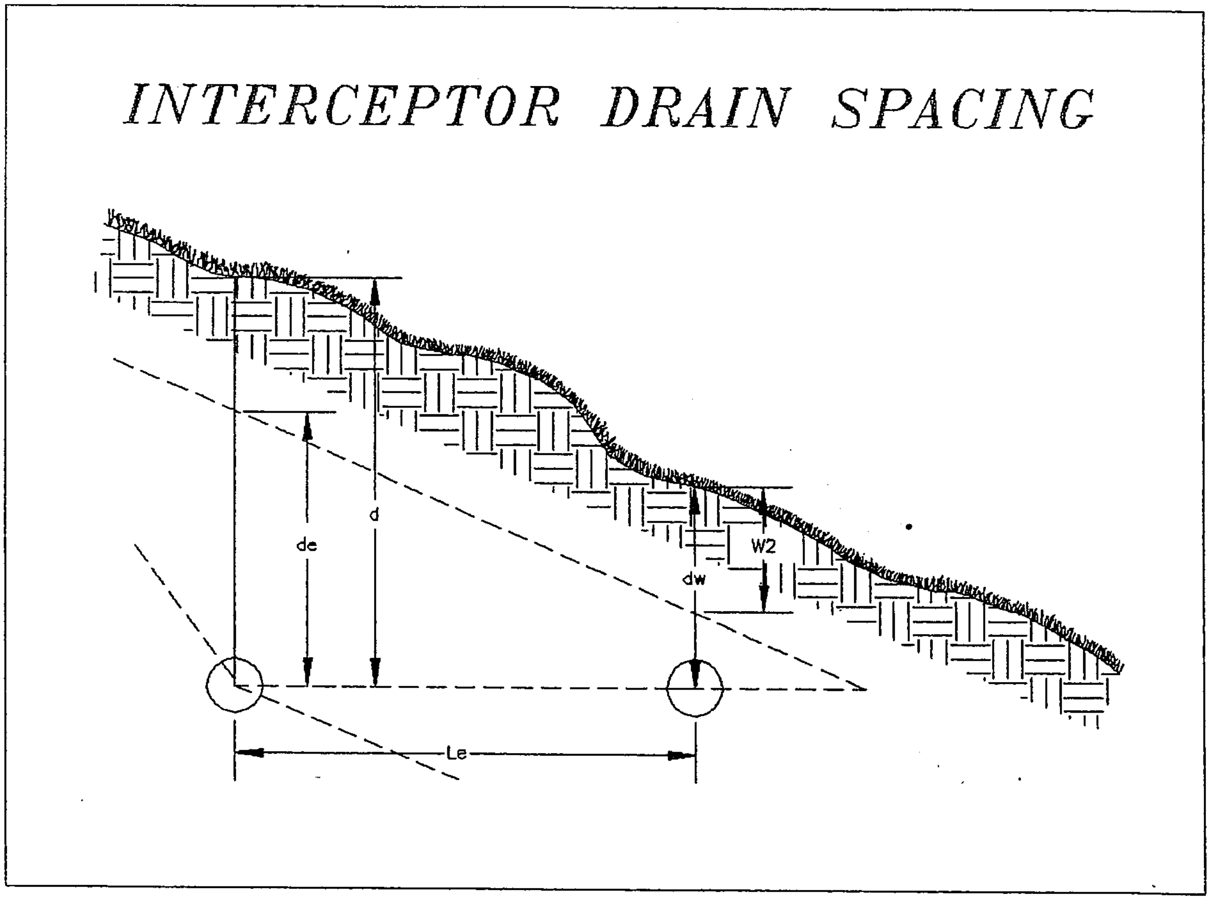
de = the effective depth of the drain, feet.

dw = the desired minimum depth to water table after drainage, feet.

W_2 = the distance from the ground surface to the water table, before drainage, at the distance (Le) downslope from the drain, feet.

Also, see Plate 3.28-9.

Further information on the equation can be obtained from the SCS National Engineering Handbook, Section 16, Drainage of Agricultural Land (66).



Source: USDA-SCS

Plate 3.28-9

STD & SPEC 3.29

SURFACE ROUGHENING

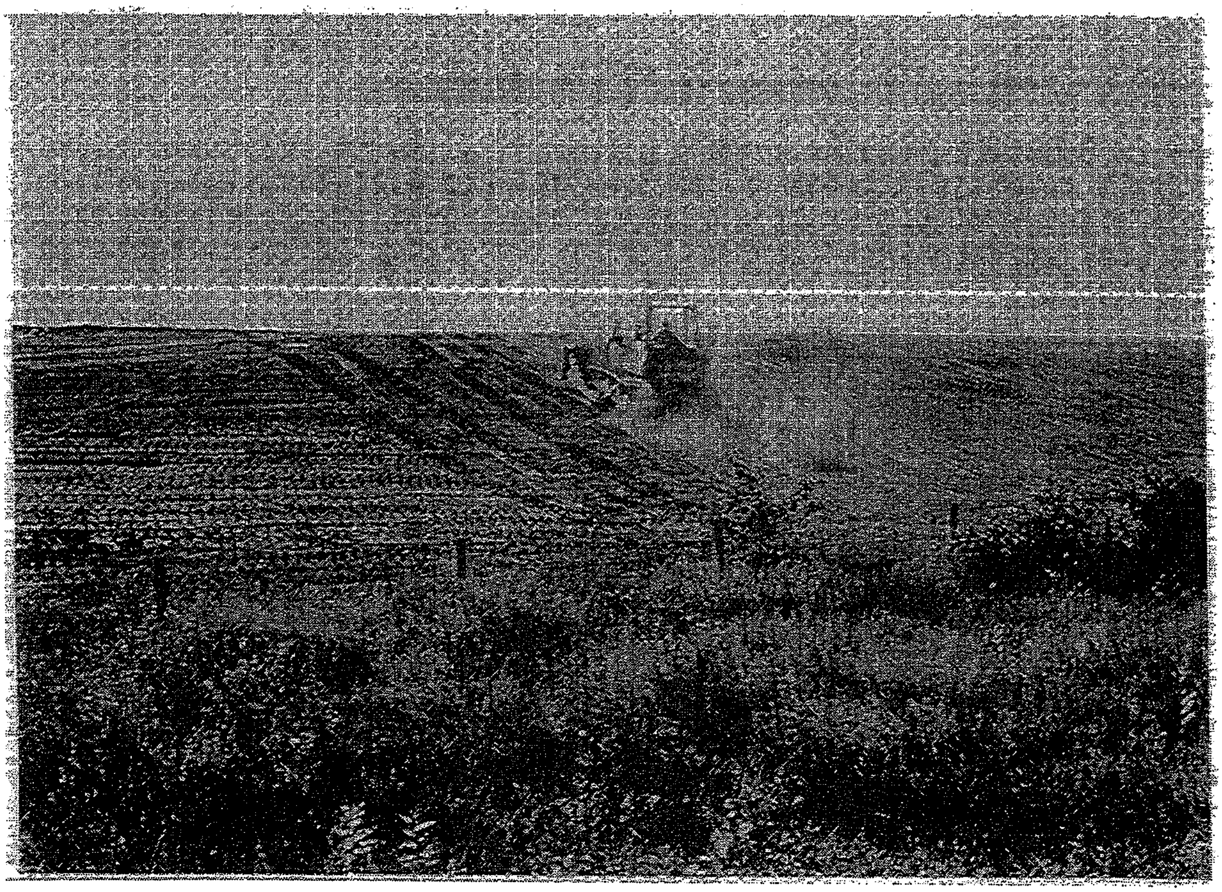
SR

Definition

Providing a rough soil surface with horizontal depressions created by operating a tillage or other suitable implement on the contour, or by leaving slopes in a roughened condition by not fine-grading them.

Purposes

1. To aid in establishment of vegetative cover with seed.
2. To reduce runoff velocity and increase infiltration.
3. To reduce erosion and provide for sediment trapping.



Conditions Where Practice Applies

1. All slopes steeper than 3:1 require surface roughening, either stair-step grading, grooving, furrowing, or tracking if they are to be stabilized with vegetation.

2. Areas with grades less steep than 3:1 should have the soil surface lightly roughened and loose to a depth of 2 to 4 inches prior to seeding.

3. Areas which have been graded and will not be stabilized immediately may be roughened to reduce runoff velocity until seeding takes place.

4. Slopes with a stable rock face do not require roughening or stabilization.

Planning Considerations

Graded areas with smooth, hard surfaces give a false impression of "finished grading" and a job well done. It is difficult to establish vegetation on such surfaces due to reduced water infiltration and the potential for erosion. Rough slope surfaces with uneven soil and rocks left in place may appear unattractive or unfinished at first, but encourage water infiltration, speed the establishment of vegetation, and decrease runoff velocity.

Rough loose soil surfaces give lime, fertilizer and seed some natural coverage. Niches in the surface provide microclimates which generally provide a cooler and more favorable moisture level than hard flat surfaces; this aids seed germination.

There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include stair-step grading, grooving, and tracking. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

1. Disturbed areas which will not require mowing may be stair-step graded, grooved, or left rough after filling.

2. Stair-step grading is particularly appropriate in soils containing large amounts of soft rock. Each "step" catches material which sloughs from above, and provides a level site where vegetation can become established.

3. Areas which will be mowed (these areas should have slopes less steep than 3:1) may have small furrows left by discing, harrowing, raking, or seed-planting machinery operated on the contour.

4. It is important to avoid excessive compacting of the soil surface when scarifying. Tracking with bulldozer treads is preferable to not roughening at all, but is not as

effective as other forms of roughening, as the soil surface is severely compacted and runoff is increased.

Specifications

Cut Slope Applications For Areas Which Will Not Be Mowed

Cut slopes with a gradient steeper than 3:1 shall be stair-step graded or grooved (Plates 3.29-1 and 3.29-2).

1. Stair-step grading may be carried out on any material soft enough to be ripped with a bulldozer. Slopes consisting of soft rock with some subsoil are particularly suited to stair-step grading.

   The ratio of the vertical cut distance to the horizontal distance shall be less than 1:1 and the horizontal portion of the "step" shall slope toward the vertical wall.

   Individual vertical cuts shall not be more than 30 inches on soft soil materials and not more than 40 inches in rocky materials.

2. Grooving consists of using machinery to create a series of ridges and depressions which run perpendicular to the slope (on the contour).

   Grooves may be made with any appropriate implement which can be safely operated on the slope and which will not cause undue compaction. Suggested implements include discs, tillers, spring harrows, and the teeth on a front-end loader bucket. Such grooves shall not be less than 3 inches deep nor further than 15 inches apart.

Fill Slope Applications For Areas Which Will Not Be Mowed

Fill slopes with a gradient steeper than 3:1 shall be grooved or allowed to remain rough as they are constructed. Method (1) or (2) below may be used.

1. Groove according to #2 above.

2. As lifts of the fill are constructed, soil and rock materials may be allowed to fall naturally onto the slope surface (see Plate 3.29-3).

Colluvial materials (soil deposits at the base of slopes or from old stream beds) shall not be used in fills as they flow when saturated.

At no time shall slopes be bladed or scraped to produce a smooth, hard surface.

Cuts, Fills, and Graded Areas Which Will Be Mowed

Mowed slopes should not be steeper than 3:1. Excessive roughness is undesirable where mowing is planned. These areas may be roughened with shallow grooves such as remain after tilling, discing, harrowing, raking, or use of a cultipacker-seeder. The final pass of any such tillage implement shall be on the contour (perpendicular to the slope).

Grooves formed by such implements shall be not less than 1-inch deep and not further than 12-inches apart. Fill slopes which are left rough as constructed may be smoothed with a dragline or pickchain to facilitate mowing.

Roughening With Tracked Machinery (see Plate 3.29-4)

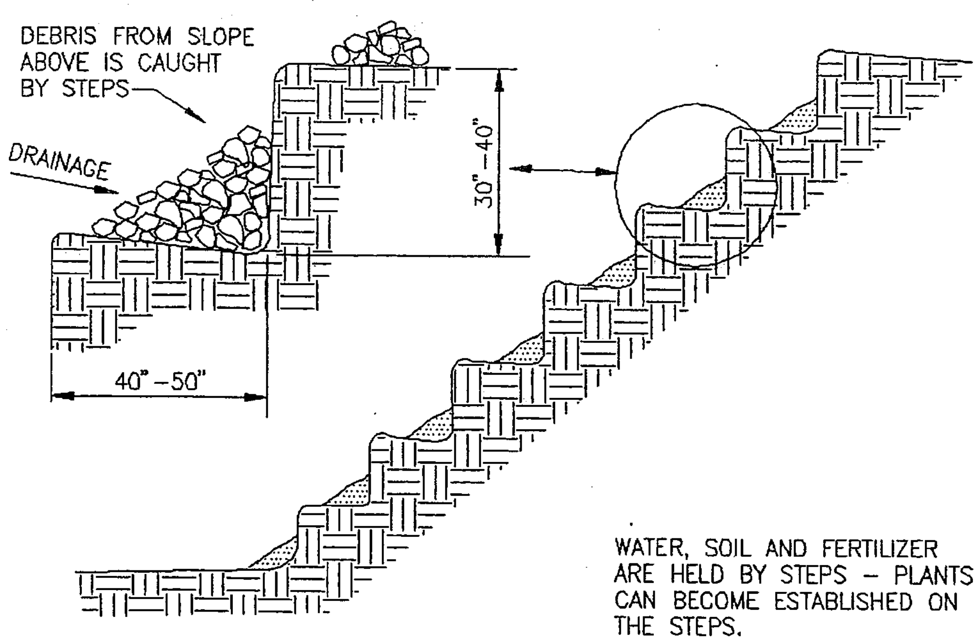
Roughening with tracked machinery on clayey soils is not recommended unless no alternatives are available. Undue compaction of surface soil results from this practice. Sandy soils do not compact severely, and may be tracked. In no case is tracking as effective as the other roughening methods described.

When tracking is the chosen surface roughening technique, it shall be done by operating tracked machinery up and down the slope to leave horizontal depressions in the soil. As few passes of the machinery should be made as possible to minimize compaction.

Seeding

Roughened areas shall be seeded and mulched as soon as possible to obtain optimum seed germination and seedling growth.

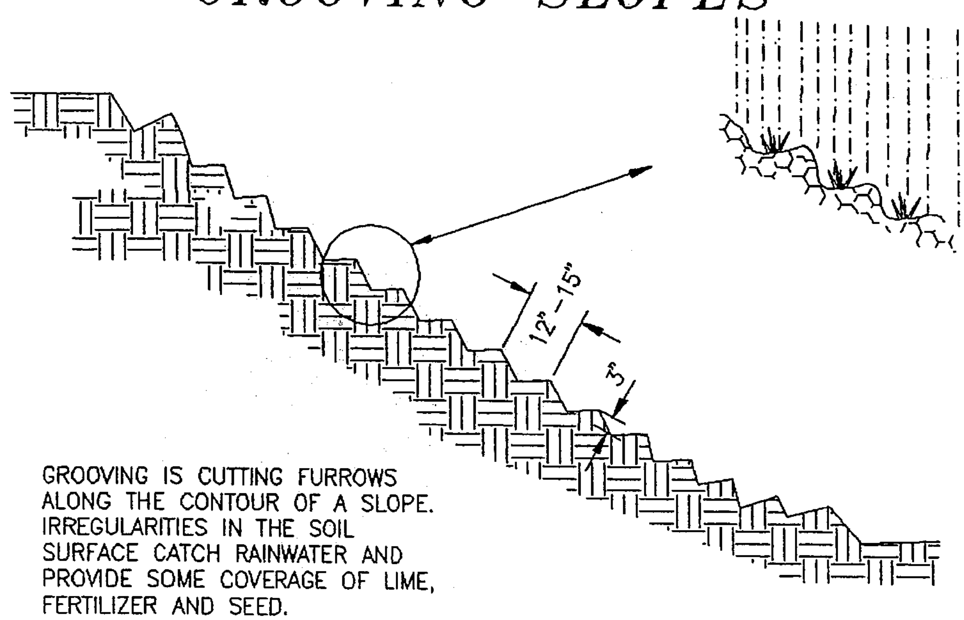
STAIR STEPPING CUT SLOPES



Source: Va. DSWC

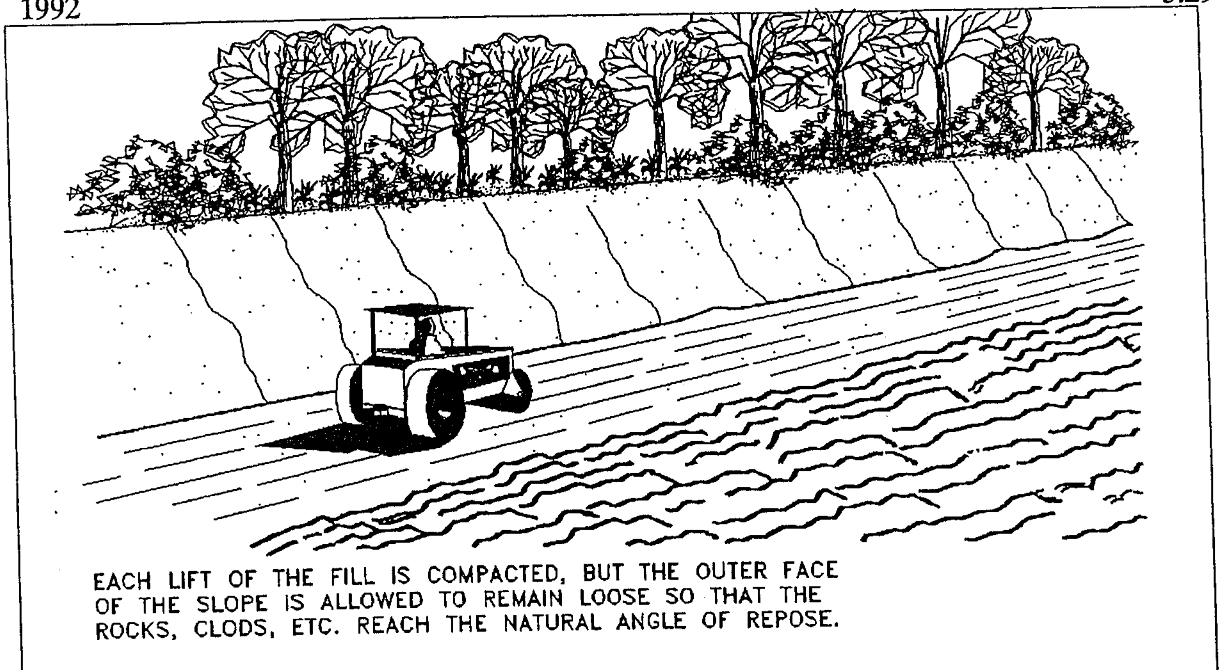
Plate 3.29-1

GROOVING SLOPES



Source: Va. DSWC

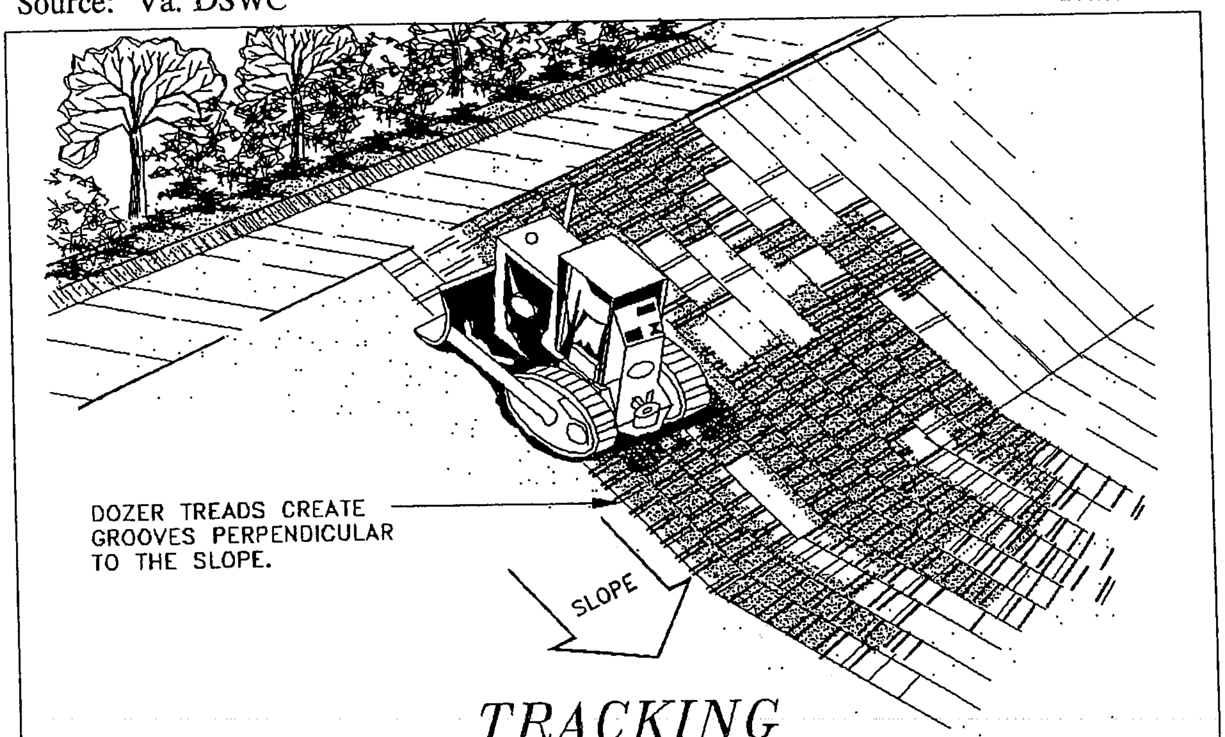
Plate 3.29-2



FILL SLOPE TREATMENT

Source: Va. DSWC

Plate 3.29-3



TRACKING

Source: Michigan Soil Erosion and Sedimentation Guide

Plate 3.29-4

STD & SPEC 3.30

TOPSOILING

Definition

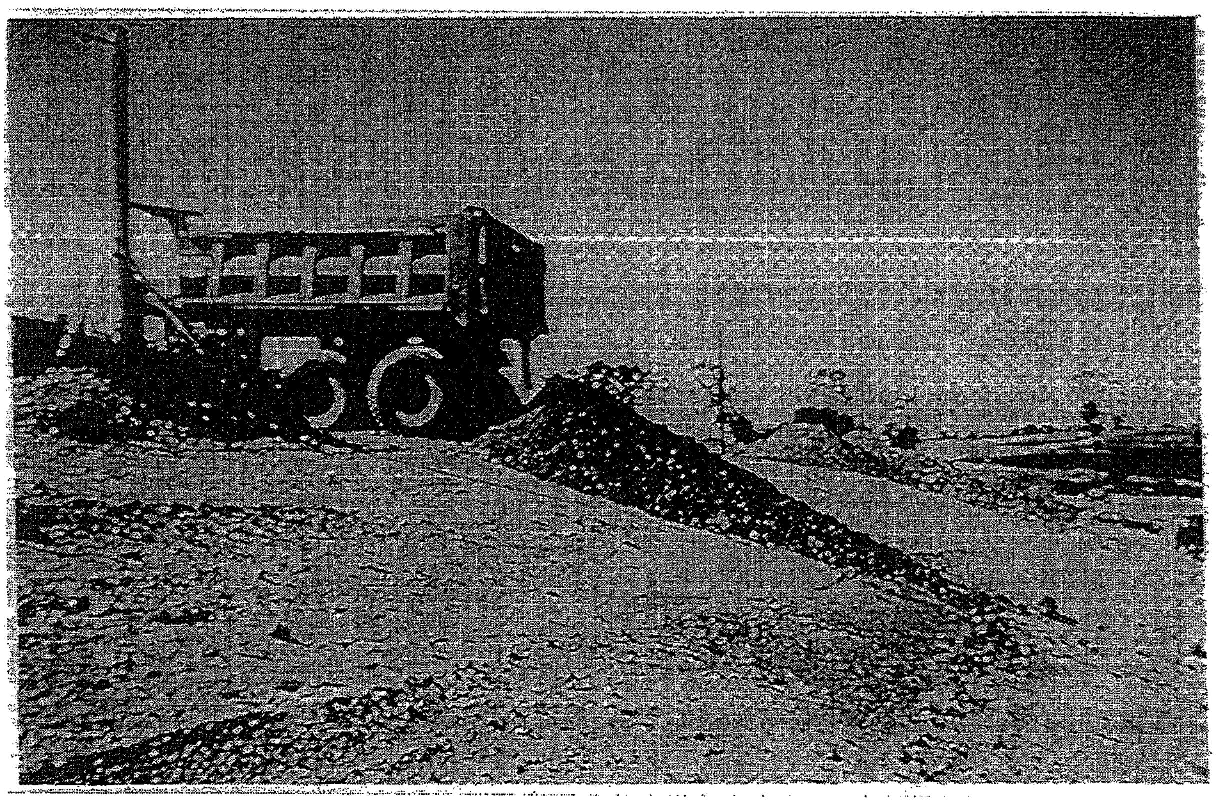
Methods of preserving and using the surface layer of undisturbed soil, often enriched in organic matter, in order to obtain a more desirable planting and growth medium.

Purpose

To provide a suitable growth medium for final site stabilization with vegetation.

Conditions Where Practice Applies

1. Where the preservation or importation of topsoil is determined to be the most effective method of providing a suitable growth medium.



2. Where the subsoil or existing soil presents the following problems:

   a. The texture, pH, or nutrient balance of the available soil cannot be modified by reasonable means to provide an adequate growth medium.

   b. The soil material is too shallow to provide an adequate root zone and to supply necessary moisture and nutrients for plant growth.

   c. The soil contains substances potentially toxic to plant growth.

3. Where high-quality turf is desirable to withstand intense use or meet aesthetic requirements.

4. Where ornamental plants will be established.

5. Only on slopes that are <u>2:1 or flatter</u> unless other measures are taken to prevent erosion and sloughing.

Planning Considerations

Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of organic matter. It is the major zone of root development, carrying much of the nutrients available to plants, and supplying a large share of the water used by plants.

Although topsoil provides an excellent growth medium, there are disadvantages to its use. Stripping, stockpiling, and reapplying topsoil, or importing topsoil, may not always be cost-effective. Topsoiling can delay seeding or sodding operations, increasing the exposure time of denuded areas. Most topsoil contains weed seeds, and weeds may compete with desirable species.

Advantages of topsoil include its high organic matter content and friable consistence, water-holding capacity, and nutrient content.

In site planning, the option of topsoiling should be compared with that of preparing a seedbed in subsoil. The clay content of subsoils does provide high moisture availability and deter leaching of nutrients and, when properly limed and fertilized, subsoils may provide a good growth medium which is generally free of weed seeds. In many cases topsoiling may not be required for the establishment of less demanding, lower maintenance plant material. Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown. Topsoiling is a required procedure when establishing vegetation on shallow soils, soils containing potentially toxic materials, and soils of critically low pH (high acid) levels.

If topsoiling is to be done, the following items should be considered:

1. Whether an adequate volume of topsoil exists on the site. Topsoil will be spread at a compacted depth of 2 to 4 inches (depths closer to 4 inches are preferred).

2. Location of the topsoil stockpile so that it meets specifications and does not interfere with work on the site.

3. Allow sufficient time in scheduling for topsoil to be spread and bonded prior to seeding, sodding, or planting.

4. Care must be taken not to apply topsoil to subsoil if the two soils have contrasting textures. Clayey topsoil over sandy subsoil is a particularly poor combination, as water may creep along the junction between the soil layers, causing the topsoil to slough. Sandy topsoil over a clay subsoil is equally as likely to fail.

5. If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. Topsoiling of steep slopes should be discouraged unless good bonding of soils can be achieved.

Specifications

Materials

Field exploration of the site shall be made to determine if there is sufficient surface soil of good quality to justify stripping. Topsoil shall be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, clay loam). It shall be free of debris, trash, stumps, rocks, roots, and noxious weeds, and shall give evidence of being able to support healthy vegetation. It shall contain no substance that is potentially toxic to plant growth.

All topsoil shall be tested by a recognized laboratory for the following criteria:

Organic matter content shall be not less than 1.5% by weight.

pH range shall be from 6.0-7.5. If pH is less than 6.0, lime shall be added in accordance with soil test results or in accordance with the recommendations of the vegetative establishment practice being used.

Soluble salts shall not exceed 500 ppm.

If additional off-site topsoil is needed, it must meet the standards stated above.

Stripping

Topsoil operations should not be performed when the soil is wet or frozen. Stripping shall be confined to the immediate construction area. A 4-to 6-inch stripping depth is common, but depth may vary depending on the particular soil. All perimeter dikes, basins, and other sediment controls shall be in place prior to stripping.

Stockpiling

Topsoil shall be stockpiled in such a manner that natural drainage is not obstructed and no off-site sediment damage shall result. Stabilize or protect stockpiles in accordance with MS #2.

Side slopes of the stockpile shall not exceed 2:1.

Perimeter controls must be placed around the stockpile immediately; seeding of stockpiles shall be completed within 7 days of the formation of the stockpile, in accordance with Std. & Spec. 3.31, TEMPORARY SEEDING if it is to remain dormant for longer than 30 days (refer to MS #1 and MS #2).

Site Preparation Prior to and Maintenance During Topsoiling

Before topsoiling, establish needed erosion and sediment control practices such as diversions, grade stabilization structures, berms, dikes, level spreaders, waterways, sediment basins, etc. These practices must be maintained during topsoiling.

Grading: Previously established grades on the areas to be topsoiled shall be maintained according to the approved plan.

Liming: Where the pH of the subsoil is 6.0 or less, or the soil is composed of heavy clays, agricultural limestone shall be spread in accordance with the soil test or the vegetative establishment practice being used.

Bonding: After the areas to be topsoiled have been brought to grade, and immediately prior to dumping and spreading the topsoil, the subgrade shall be loosened by discing or scarifying to a depth of at least 2 inches to ensure bonding of the topsoil and subsoil.

Applying Topsoil

Topsoil shall not be placed while in a frozen or muddy condition, when topsoil or subgrade is excessively wet, or in a condition that may otherwise be detrimental to proper grading or proposed sodding or seeding. The topsoil shall be uniformly distributed to a minimum compacted depth of 2 inches on 3:1 or steeper slopes and 4 inches on flatter slopes. (See Table 3.30-A to determine volume of topsoil required for application to various depths). Any irregularities in the surface, resulting from topsoiling or other operations, shall be corrected in order to prevent the formation of depressions or water pockets.

It is necessary to compact the topsoil enough to ensure good contact with the underlying soil and to obtain a level seedbed for the establishment of high maintenance turf. However, undue compaction is to be avoided as it increases runoff velocity and volume, and deters seed germination. Special consideration should be given to the types of equipment used to place topsoil in areas to receive fine turf. Avoid unnecessary compaction by heavy machinery whenever possible. In areas which are not going to be mowed, the surface should be left rough in accordance with SURFACE ROUGHENING (Std. & Spec. 3.29).

Soil Sterilants

No sod or seed shall be placed on soil which has been treated with soil sterilants until sufficient time has elapsed to permit dissipation of toxic materials.

TABLE 3.30-A

CUBIC YARDS OF TOPSOIL REQUIRED FOR APPLICATION TO VARIOUS DEPTHS

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

Source: Va. DSWC

STD & SPEC 3.31

TEMPORARY SEEDING

Definition

The establishment of a temporary vegetative cover on disturbed areas by seeding with appropriate rapidly growing annual plants.

Purposes

1. To reduce erosion and sedimentation by stabilizing disturbed areas that will not be brought to final grade for a period of more than ~~30~~ 14 days. RWE; DEQ-OTS 3-12-14

2. To reduce damage from sediment and runoff to downstream or off-site areas, and to provide protection to bare soils exposed during construction until permanent vegetation or other erosion control measures can be established.

Conditions Where Practice Applies

Where exposed soil surfaces are not to be fine-graded for periods longer than 30 days. Such areas include denuded areas, soil stockpiles, dikes, dams, sides of sediment basins, temporary roadbanks, etc. (see MS #1 and MS #2). A permanent vegetative cover shall be applied to areas that will be left dormant for a period of more than 1 year.

Planning Considerations

Sheet erosion, caused by the impact of rain on bare soil, is the source of most fine particles in sediment. To reduce this sediment load in runoff, the soil surface itself should be protected. The most efficient and economical means of controlling sheet and rill erosion is to establish vegetative cover. Annual plants which sprout rapidly and survive for only one growing season are suitable for establishing temporary vegetative cover. Temporary seeding is encouraged whenever possible to aid in "controlling" construction sites.

Temporary seeding also prevents costly maintenance operations on other erosion control systems. For example, sediment basin clean-outs will be reduced if the drainage area of the basin is seeded where grading and construction are not taking place. Perimeter dikes will be more effective if not choked with sediment.

Temporary seeding is essential to preserve the integrity of earthen structures used to control sediment, such as dikes, diversions, and the banks and dams of sediment basins.

Proper seedbed preparation and the use of quality seed are important in this practice just as in permanent seeding. Failure to carefully follow sound agronomic recommendations will often result in an inadequate stand of vegetation that provides little or no erosion control.

Specifications

Prior to seeding, install necessary erosion control practices such as dikes, waterways, and basins.

Plant Selection

Select plants appropriate to the season and site conditions from Tables 3.31-B and 3.31-C. Note that Table 3.31-B presents plants which can be used without extensive evaluation of site conditions; Table 3.31-C presents more in-depth information on the plant materials.

Seedbed Preparation

To control erosion on bare soil surfaces, plants must be able to germinate and grow. Seedbed preparation is essential.

1. Liming: An evaluation should be conducted to determine if lime is necessary for temporary seeding. In most soils, it takes up to 6 months for a pH adjustment to occur following the application of lime. Therefore, it may be difficult to justify the cost of liming a temporary site, especially when the soil will later be moved and regraded. The following table may be used to determine the actual need along with suggested application rates.

TABLE 3.31-A

LIMING REQUIREMENTS FOR TEMPORARY SITES

pH Test	Recommended Application of Agricultural Limestone
below 4.2	3 tons per acre
4.2 to 5.2	2 tons per acre
5.2 to 6	1 ton per acre

Source: Va. DSWC

2. Fertilizer: Shall be applied as 600 lbs./acre of 10-20-10 (14 lbs./1,000 sq. ft.) or equivalent nutrients. Lime and fertilizer shall be incorporated into the top 2 to 4 inches of the soil if possible.

3. Surface Roughening: If the area has been recently loosened or disturbed, no further roughening is required. When the area is compacted, crusted, or hardened, the soil surface shall be loosened by discing, raking, harrowing, or other acceptable means (see SURFACE ROUGHENING, Std. & Spec. 3.29).

4. Tracking: Tracking with bulldozer cleats is most effective on sandy soils. This practice often causes undue compaction of the soil surface, especially in clayey soils, and does not aid plant growth as effectively as other methods of surface roughening.

Seeding

Seed shall be evenly applied with a broadcast seeder, drill, cultipacker seeder or hydroseeder. Small grains shall be planted no more than 1½ inches deep. Small seeds, such as Kentucky Bluegrass, should be planted no more than 1/4 inch deep. Other Grasses and Legumes should be planted from 1/4 inch to 1/2 inch deep.

Mulching

1. Seedings made in fall for winter cover and during hot and dry summer months shall be mulched according to MULCHING, Std. & Spec. 3.35, except that hydromulches (fiber mulch) will not be considered adequate. Straw mulch should be used during these periods.

2. Temporary seedings made under favorable soil and site conditions during optimum spring and fall seeding dates may not require mulch.

Re-seeding

Areas which fail to establish vegetative cover adequate to prevent rill erosion will be re-seeded as soon as such areas are identified.

TABLE 3.31-B

ACCEPTABLE TEMPORARY SEEDING PLANT MATERIALS

"QUICK REFERENCE FOR ALL REGIONS"

Planting Dates	Species	Rate (lbs./acre)
Sept. 1 - Feb. 15	50/50 Mix of Annual Ryegrass (Lolium multi-florum) & Cereal (Winter) Rye (Secale cereale)	50 - 100
Feb. 16 - Apr. 30	Annual Ryegrass (Lolium multi-florum)	60 - 100
May 1 - Aug 31	German Millet (Setaria italica)	50

Source: Va. DSWC

TABLE 3.31-C

TEMPORARY SEEDING PLANT MATERIALS, SEEDING RATES, AND DATES

SPECIES	SEEDING RATE		NORTH[a]			SOUTH[b]			PLANT CHARACTERISTICS
	Acre	1000 ft²	3/1 to 4/30	5/1 to 8/15	8/15 to 11/1	2/15 to 4/30	5/1 to 9/1	9/1 to 11/15	
OATS (Avena sativa)	3 bu. (up to 100 lbs., not less than 50 lbs.)	2 lbs.	X	-	-	X	-	-	Use spring varieties (e.g., Noble).
RYE[d] (Secale cereale)	2 bu. (up to 110 lbs., not less than 50 lbs.)	2.5 lbs.	X	-	X	X	-	X	Use for late fall seedings, winter cover. Tolerates cold and low moisture.
GERMAN MILLET (Setaria italica)	50 lbs.	approx. 1 lb.	-	X	-	-	X	-	Warm-season annual. Dies at first frost. May be added to summer mixes.
ANNUAL RYEGRASS[c] (Lolium multi-florum)	60 lbs.	1½ lbs.	X	-	X	X	-	X	May be added in mixes. Will mow out of most stands.
WEEPING LOVEGRASS (Eragrostis curvula)	15 lbs.	5½ ozs.	-	X	-	-	X	-	Warm-season perennial. May bunch. Tolerates hot, dry slopes and acid, infertile soils. May be added to mixes.
KOREAN LESPEDEZA[c] (Lespedeza stipulacea)	25 lbs.	approx. 1½ lbs.	X	X	-	X	X	-	Warm season annual legume. Tolerates acid soils. May be added to mixes.

a Northern Piedmont and Mountain region. See Plates 3.22-1 and 3.22-2.
b Southern Piedmont and Coastal Plain.
c May be used as a cover crop with spring seeding.
d May be used as a cover crop with fall seeding.
X May be planted between these dates.
\- May not be planted between these dates.

STD & SPEC 3.32

PERMANENT SEEDING

PS

Definition

The establishment of perennial vegetative cover on disturbed areas by planting seed.

Purposes

1. To reduce erosion and decrease sediment yield from disturbed areas.

2. To permanently stabilize disturbed areas in a manner that is economical, adaptable to site conditions, and allows selection of the most appropriate plant materials.

3. To improve wildlife habitat.

4. To enhance natural beauty.

Conditions Where Practice Applies

1. Disturbed areas where permanent, long-lived vegetative cover is needed to stabilize the soil.

2. Rough-graded areas which will not be brought to final grade for a year or more.

Planning Considerations

Vegetation controls erosion by reducing the velocity and the volume of overland flow and protecting the bare soil surface from raindrop impact.

Areas which must be stabilized after the land has been disturbed require vegetative cover. The most common and economical means of establishing this cover is by seeding grasses and legumes. Permanent vegetative covers must meet the requirements of Minimum Standard #3.

Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.

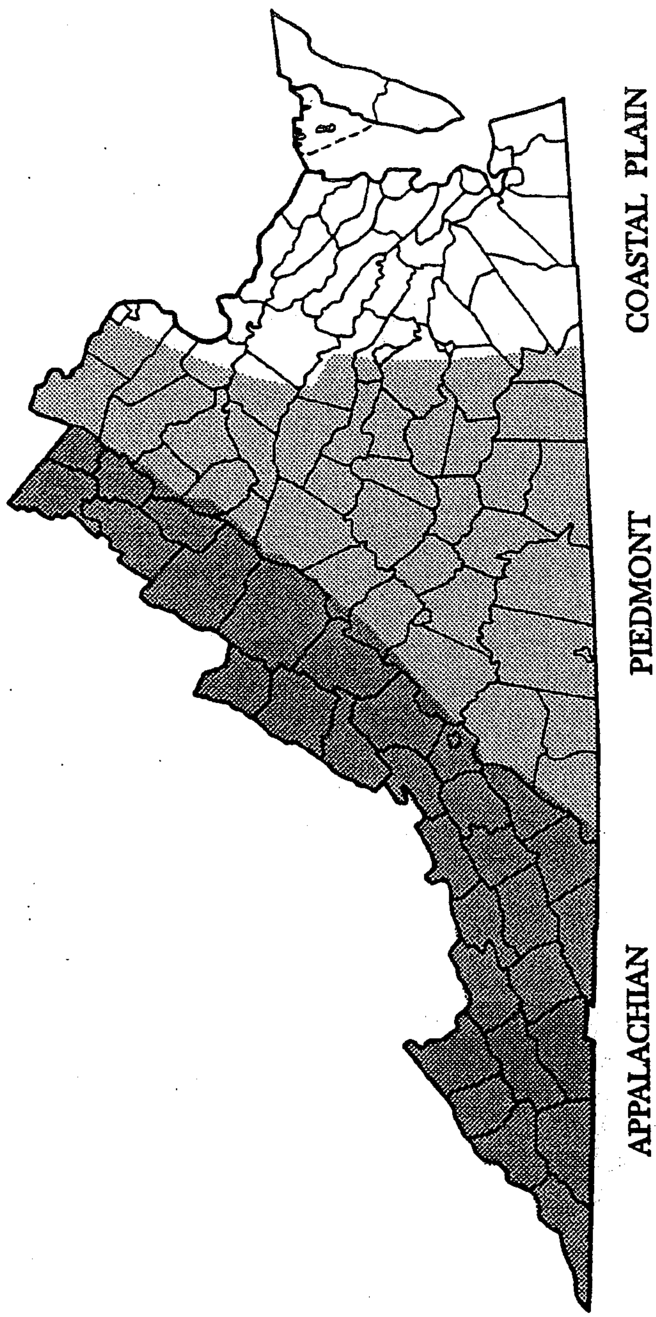
Disadvantages which must be dealt with are the potential for erosion during the establishment stage, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, the potential need for weed control during the establishment phase, and a need for water and appropriate climatic conditions during germination.

There are so many variables in plant growth that an end product cannot be guaranteed. Much can be done in the planning stages to increase the chances for successful seeding. Selection of the right plant materials for the site, good seedbed preparation, and conscientious maintenance are important.

SELECTING PLANT MATERIALS: The factors affecting plant growth are climate, soils, and topography. In Virginia, there are three major physiographic regions that reflect changes in soil and topography. In selecting appropriate plant materials, one should take into account the characteristics of the physiographic region in which the project is located (see Plate 3.32-1).

PHYSIOGRAPHIC REGIONS:

Coastal Plain - Soils on the Coastal Plain are deeply weathered, stratified deposits of sand and clay. They are generally acidic and low in plant nutrients. The sandy soils are hot and droughty in summer. This region receives more rain and is warmer than the other regions of the state. The land is fairly level, and many areas are poorly drained. Warm season grasses traditionally perform well in these areas.



PHYSIOGRAPHIC PROVINCES IN VIRGINIA

Source: Va. DSWC

Plate 3.32-1

Piedmont - Soils on the Piedmont plateau are highly variable. They tend to be shallow, with clayey subsoils. Piedmont soils are low in phosphorus. Soils derived from mica schist are highly erodible. Topography is rolling and hilly. The southern Piedmont has much the same climate as the Coastal Plain. Often referred to as the "transition zone" in planting. Contains areas that will support both warm or cool season grasses.

Appalachian and Blue Ridge Region - This region is divided into plateaus, mountains, and narrow valleys. Soils tend to be shallow and acid, and may erode rapidly on steep slopes. Shaley slopes are often unstable and droughty. This area is colder and drier than the rest of the State. The rugged topography makes plant establishment difficult. Cool season grasses are normally specified in this region.

SOILS: On the whole, soils in Virginia always require some nitrogen (N) fertilization to establish plants. Phosphorus (P) and potassium (K) are usually needed. Except for some small pockets of shallow limestone soils, lime is universally needed.

Soils can be modified with lime and fertilizer, but climate cannot be controlled. For this reason, the State has been divided into two major climatic regions, referred to as the Northern Piedmont and Mountain Region and the Southern Piedmont and Coastal Plain Region, for grass and legume selection (see map, Plate 3.32-2).

Microclimate, or localized climate conditions, can affect plant growth. A south-facing slope is drier and hotter than a north-facing slope, and may require drought-tolerant plants. Shaded areas require shade-tolerant plants; the windward side of a ridge will be drier than the leeward, etc.

LAND USE: A prime consideration in selecting which plants to establish is the intended use of the land. All of these uses - residential, industrial, commercial, recreational - can be separated into two major categories: high-maintenance and low-maintenance.

High-maintenance areas will be mowed frequently, limed and fertilized regularly, and will either receive intense use (e.g., athletics) or require maintaining to an aesthetic standard (home lawns). Grasses used for these situations must be fine-leaved and attractive in appearance, able to form tight sod, and be long-lived perennials. They must be well-adapted to the geographic area where they are planted, because constant mowing puts turf under great stress. Sites where high-maintenance vegetative cover is desirable include homes, industrial parks, schools, churches, athletic playing surfaces as well as some recreational areas.

Low-maintenance areas will be mowed infrequently or not at all; lime and fertilizer may not be applied on a regular basis; the areas will not be subjected to intense use, nor required to have a uniform appearance. These plants must be able to persist with little maintenance over long periods of time. Grass and legume mixtures are favored for these sites because legumes are capable of fixing nitrogen from the air for their own use, and the use of the plants around them. Such mixed stands are better able to withstand adverse conditions.

Sites that would be suitable for low-maintenance vegetation include steep slopes, stream or channel banks, some commercial properties, and "utility turf" areas such as roadbanks.

Seedbed Preparation - The soil on a disturbed site must be modified to provide an optimum environment for seed germination and seedling growth. The surface soil must be loose enough for water infiltration and root penetration. The pH (acidity and alkalinity) of the soil must be such that it is not toxic and nutrients are available, usually between pH 6.0-7.0. Sufficient nutrients (added as fertilizer) must be present. After seed is in place, it must be protected with a mulch to hold moisture and modify temperature extremes, and to prevent erosion while seedlings are growing.

The addition of lime is equally as important as applying fertilizer. Lime is best known as a pH, or acidity, modifier, but it also supplies calcium and magnesium which are plant nutrients. Its effect on pH makes other nutrients more available to the plant. It can also prevent aluminum toxicity by making aluminum less soluble in the soil. Many soils in Virginia are high in aluminum, which stunts the growth of plant roots.

MAINTENANCE: Even with careful, well-planned seeding operations, failures can occur. When it is clear that plants have not germinated on an area or have died, these areas must be reseeded immediately to prevent erosion damage. However, it is extremely important to determine for what reason germination did not take place and make any corrective action necessary prior to reseeding the area. Healthy vegetation is the most effective erosion control available.

Specifications

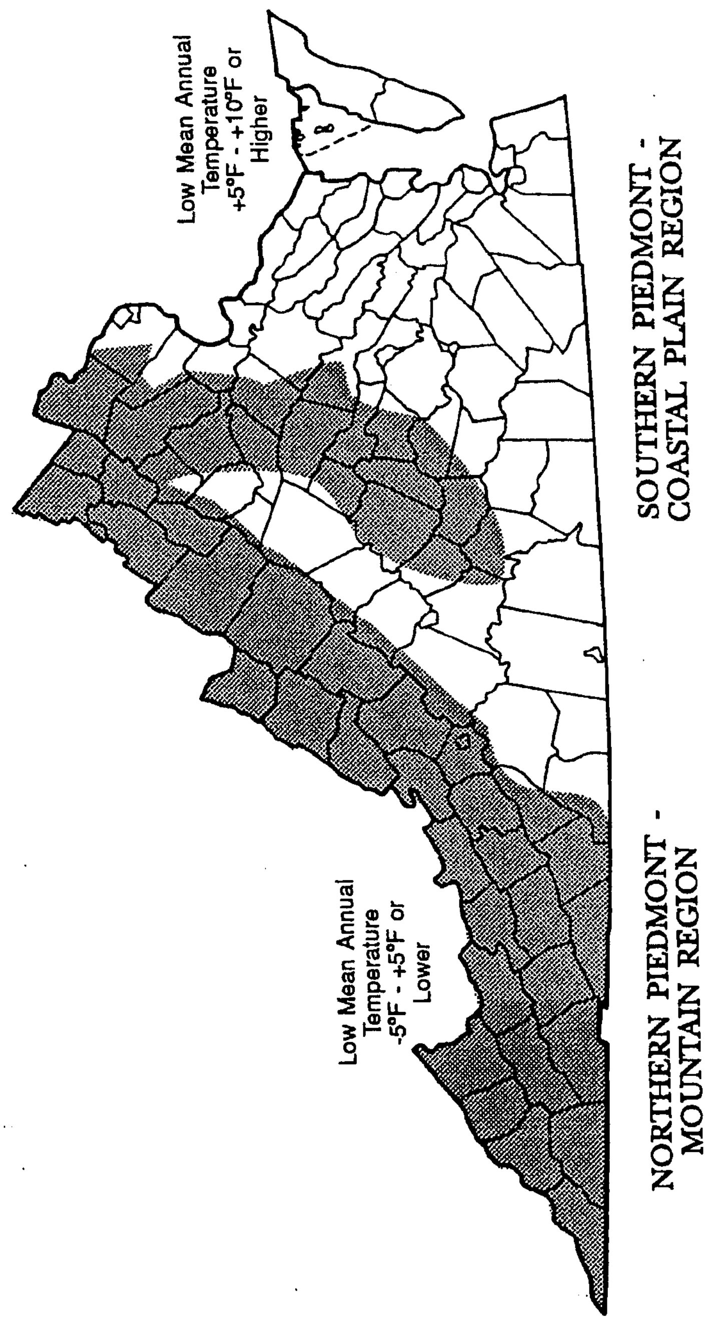
Selection of Plant Materials

1. Selection of plant materials is based on climate, topography, soils, land use, and planting season. To determine which plant materials are best adapted to a specific site, use Tables 3.32-A and 3.22-B which describe plant characteristics and list recommended varieties.

2. Appropriate seeding mixtures for various site conditions in Virginia are given in Tables 3.32-C, 3.32-D and 3.32-E. These mixtures are designed for general use, and are known to perform well on the sites described. Check Tables 3.32-A and 3.32-B for recommended varieties.

3. A more extensive description of plant materials (grasses and legumes), their usage and pictorial representation can be found in Appendix 3.32-c.

4. When using some varieties of turfgrasses, the Virginia Crop Improvement Association (VCIA) recommended turfgrass mixtures may also be used. Consumer protection programs have been devised to identify quality seed of the varieties recommended by the Virginia Cooperative Extension Service. These will bear a label indicating



PLANT HARDINESS ZONES IN VIRGINIA FOR GRASSES AND LEGUMES

Source: Adapted from Virginia Climate Advisory, 1979.

Plate 3.32-2

that they are approved by the Association. Mixtures may be designed for a specific physiographic region or based on intended use. Special consideration is given to plant characteristics, performance, etc.

TABLE 3.32-A
CHARACTERISTICS OF COMMONLY SELECTED GRASSES

COMMON NAME (Botanical Name)	Life Cycle	Season	pH Range	Germination Time In Days	Optimum Germination Temperature (°F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeds Per Pound	MAINTENANCE REQUIREMENTS	REMARKS	Suggested Varieties for Virginia
TALL FESCUE (Festuca arundinacea)	P	C	5.5-6.2	10-14	60-85	F	F	M	SPD	225K	Low when used for erosion control; high when used in lawn	Better suited for erosion control and rough turf application.	Ky 31
TALL FESCUES (Improved)	P	C	5.5-6.2	10-14	60-85	F	G	M	SPD	220K	Responds well to high maintenance.	Excellent for lawn and fine turf.	See current VCIA list.
KENTUCKY BLUEGRASS (Poa pratense)	P	C	6.0-6.5	14	60-75	G	P	M	SPD	2.2m	Needs fertile soil, favorable moisture. Requires several years to become well established.	Excellent for fine turfs-takes traffic, mowing. Poor drought/heat tolerance.	See current VCIA list.
PERENNIAL RYEGRASS (Lolium perenne)	P	C	5.8-6.2	7-10	60-75	F	F	M-H	SPD	227K	Will tolerate traffic.	May be added to mixes. * Improved varieties will perform well all year.	See current VCIA list.

KEY

A = Annual P = Perennial C = Cool Season Plant W = Warm Season Plant G = Good F = Fair P = Poor VP = Very Poor H = High
M = Medium L = Low SPD = Somewhat Poorly Drained MPD = Moderately Poorly Drained PD = Poorly Drained VPD = Very Poorly Drained

TABLE 3.32-A (Continued)
CHARACTERISTICS OF COMMONLY SELECTED GRASSES

COMMON NAME (Botanical Name)		Life Cycle	Season	pH Range	Germination Time, In Days	Optimum Germination Temperature (°F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeds Per Pound	MAINTENANCE REQUIREMENTS	REMARKS	Suggested Varieties for Virginia
FINE FESCUES	HARD FESCUE (Festuca Longifolia)	P	C	5.0-6.2	10-14	60-80	VG	G	L	MWD	400K	Grows well in sun or shade and will tolerate infertile soils; improved disease resistance.	Exceeds all fine fescues in most tests. Excellent for low-maintenance situations.	Reliant, Spartan, Aurora
	CHEWINGS FESCUE	P	C	5.0-6.2	10-14	60-80	VG	G	L	MWD	400K	Tolerates shade, dry infertile soils.	Poor traffic tolerance, less thatch than other fine fescues.	Flyer
	RED FESCUE (Festuca Rubra)	P	C	5.0-6.2	10-14	60-80	VG	G	L	MWD	400K	Low to medium fertility requirements. Requires well-drained soil.	Spreads by rhizomes, tillers and stolons. Will not take traffic - very shade tolerant.	Long-fellow, Victory
REED CANARYGRASS (Phalaris arundinacea)		P	C	5.8-6.2	21	70-85	G	G	M-H	VPD	530K	Do not mow closely or often.	Conservation cover in wet areas.	No named varieties

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TABLE 3.32-A (Continued)
CHARACTERISTICS OF COMMONLY SELECTED GRASSES

COMMON NAME (Botanical Name)	Life Cycle	Season	pH Range	Germination Time, In Days	Optimum Germination Temperature (°F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeds Per Pound	MAINTENANCE REQUIREMENTS	REMARKS	Suggested Varieties for Virginia
REDTOP (Agrostis alba)	P	C	5.8-6.2	10	65-85	G	F	L	PD	5m	Will tolerate poor, infertile soils; deep rooted.	Does well in erosion control mixes - not for lawns.	No named varieties.
WEEPING LOVEGRASS (Evagrostis curvula)	P	W	4.5-6.2	14	65-85	F-P	G	L-M	SPD	1.5m	Low-fertility requirements; excellent drought tolerance.	Fast-growing, warm-season bunch grass. Excellent cover for erosion control.	No named varieties.
BERMUDAGRASS (Cynodon dactylon)	P	W	5.8-6.2	21	70-95	P	G	M-H	SPD	1.8m hulled	High nitrogen utilization, excellent drought tolerance. Some varieties adapted to western VA.	Common varieties used for erosion control. Hybrids used for fine turf.	See current VCIA list.
ORCHARDGRASS (Dactylis glomerata)	P	C	5.8-6.2	18	60-75	F	F	M	SPD	625K	Does best on well-drained, loamy soil.	Good pasture selection - may be grazed.	Virginia origin or Potomac

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TABLE 3.32-A (Continued)
CHARACTERISTICS OF COMMONLY SELECTED GRASSES

COMMON NAME (Botanical Name)	Life Cycle	Season	pH Range	Germination Time In Days	Optimum Germination Temperature (°F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeds Per Pound	MAINTENANCE REQUIREMENTS	REMARKS	Suggested Varieties for Virginia
ANNUAL RYEGRASS (Lolium multiflorum)	A	C	5.8-6.2	7	60-70	G	P	M-H	SPD	227K	Will grow on most Virginia Soils. Do not use in fine-turf areas.	May be added into mixes or established alone as temporary cover in spring and fall.	No named varieties.
RYE (Secale cereale)	A	C	5.8-6.2	7	55-70	VG	G	L-M	SPD	18K	Will establish in most all Virginia soils. Do not use in fine-turf areas.	May be added into mixes or established alone for late fall/winter cover.	Abruzzi, Balboa
FOXTAIL MILLET (Setaria italica)	A	W	5.8-6.2	10	65-85	VP	G	M	MWD	220K	Establishes well during summer. Very low moisture requirements.	May be added to erosion-control mixes or established alone.	Common, German

KEY

A = Annual   P = Perennial   C = Cool Season Plant   W = Warm Season Plant   G = Good   F = Fair   P = Poor   VP = Very Poor   H = High
M = Medium   L = Low   SPD = Somewhat Poorly Drained   MPD = Moderately Poorly Drained   PD = Poorly Drained   VPD = Very Poorly Drained

TABLE 3.32-B
CHARACTERISTICS OF LEGUMES APPROPRIATE FOR EROSION CONTROL

COMMON NAME (Botanical Name)	Life Cycle	Season	pH Range	Germination Time In Days	Optimum Germination Temperature (°F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeds Per Pound	MAINTENANCE REQUIREMENTS	REMARKS	Suggested Varieties for Virginia
CROWNVETCH (Coronilla varia)	P	C	6.0-6.5	14-21	70	G	VG	M	MWD	110K	Does best on well-drained soils. Minimum maintenance when established. May need phosphorus. Inoculation is essential.	Excellent for steep, rocky slopes. Produces colorful blooms in May/June. Slow to establish. Does best when seeded in spring.	Penngift Chemung Emerald
SERICEA LESPEDEZA (Lespedeza cuneata)	P	W	5.8-6.2	21-28	70-85	F	VG	L	MWD	335K	Grows in most well-drained soils. Low fertility requirements. Inoculation is essential.	Use hulled seed in spring; unhulled in fall. Very deep-rooted legume. Excellent choice for eastern Va.	Serecia Interstate
FLATPEA (Lathyrus silvestrus)	P	C	5.0-7.0	14-28	65-75	G	G	L	PD	15K	Needs lime and high phosphorus. Good shade tolerance.	Tolerates acidic and wetter soils better than other legumes.	Lathco
BIRDSFOOT TREFOIL (Lotus corniculatus)	P	C	6.0-6.5	7	65-70	G	F	M	SPD	375K	Inoculation is essential. Grows in medium-fertile, slightly acid soils.	Grows better on poorly drained soils than most legumes. Poor drought/heat tolerance.	No named varieties.

KEY

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TABLE 3.32-B (Continued)
CHARACTERISTICS OF LEGUMES APPROPRIATE FOR EROSION CONTROL

COMMON NAME (Botanical Name)	Life Cycle	Season	pH Range	Germination Time In Days	Optimum Germination Temperature (°F)	Winter Hardiness	Drought Tolerance	Fertility	Soil Drainage Tolerance	Seeds Per Pound	MAINTENANCE REQUIREMENTS	REMARKS	Suggested Varieties for Virginia
ANNUAL LESPEDEZAS (Lespedeza striata, L. stipulacea)	A	W	5.8-6.2	14	70-85	F	VG	L	MWD	200K	Will grow on almost any well-drained soil.	Choose Kobe for southeastern Va.; needs almost no nitrogen to survive.	Kobe, Korean
RED CLOVER (Trifolium pratense)	P	C	6.0-6.5	7-14	70	G	F	M	SPD	275K	Needs high levels of phosphorus and potassium.	Acts as a biennial. Can be added to low-maintenance mixes.	Kenstar, Kenland
WHITE CLOVER (Trifolium repens)	P	C	6.0-6.5	10	70	G	P	M	PD	700K	Requires favorable moisture, fertile soils, high pH.	Spreads by soil surface stolons, white flowers.	Common, White Dutch

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TABLE 3.32-C
SITE SPECIFIC SEEDING MIXTURES
FOR APPALACHIAN/MOUNTAIN AREA

	Total Lbs. Per Acre
Minimum Care Lawn	
- Commercial or Residential	200-250 lbs.
- Kentucky 31 or Turf-Type Tall Fescue	90-100%
- Improved Perennial Ryegrass *	0-10%
- Kentucky Bluegrass	0-10%
High-Maintenance Lawn	
Minimum of three (3) up to five (5) varieties of bluegrass from approved list for use in Virginia.	125 lbs.
General Slope (3:1 or less)	
- Kentucky 31 Fescue	128 lbs.
- Red Top Grass	2 lbs.
- Seasonal Nurse Crop **	20 lbs.
	150 lbs.
Low-Maintenance Slope (Steeper than 3:1)	
- Kentucky 31 Fescue	108 lbs.
- Red Top Grass	2 lbs.
- Seasonal Nurse Crop **	20 lbs.
- Crownvetch ***	20 lbs.
	150 lbs.

* Perennial Ryegrass will germinate faster and at lower soil temperatures than fescue, thereby providing cover and erosion resistance for seedbed.

** Use seasonal nurse crop in accordance with seeding dates as stated below:

March, April through May 15th	Annual Rye
May 16th through August 15th	Foxtail Millet
August 16th through September, October	Annual Rye
November through February	Winter Rye

*** If Flatpea is used, increase to 30 lbs./acre. All legume seed must be properly inoculated. Weeping Lovegrass may also be included in any slope or low-maintenance mixture during warmer seeding periods; add 10-20 lbs/acre in mixes.

TABLE 3.32-D
SITE SPECIFIC SEEDING MIXTURES FOR PIEDMONT AREA

	Total Lbs. Per Acre
Minimum Care Lawn	
- Commercial or Residential	175-200 lbs.
- Kentucky 31 or Turf-Type Tall Fescue	95-100%
- Improved Perennial Ryegrass	0-5%
- Kentucky Bluegrass	0-5%
High-Maintenance Lawn	200-250 lbs.
- Kentucky 31 or Turf-Type Tall Fescue	100%
General Slope (3:1 or less)	
- Kentucky 31 Fescue	128 lbs.
- Red Top Grass	2 lbs.
- Seasonal Nurse Crop *	20 lbs.
	150 lbs.
Low-Maintenance Slope (Steeper than 3:1)	
- Kentucky 31 Fescue	108 lbs.
- Red Top Grass	2 lbs.
- Seasonal Nurse Crop *	20 lbs.
- Crownvetch **	20 lbs.
	150 lbs.

* Use seasonal nurse crop in accordance with seeding dates as stated below:

February 16th through April	Annual Rye
May 1st through August 15th	Foxtail Millet
August 16th through October	Annual Rye
November through February 15th	Winter Rye

** Substitute Sericea lespedeza for Crownvetch east of Farmville, Va. (May through September use hulled Sericea, all other periods, use unhulled Sericea). If Flatpea is used in lieu of Crownvetch, increase rate to 30 lbs./acre. All legume seed must be properly inoculated. Weeping Lovegrass may be added to any slope or low-maintenance mix during warmer seeding periods; add 10-20 lbs./acre in mixes.

TABLE 3.32-D

SITE SPECIFIC SEEDING MIXTURES FOR COASTAL PLAIN AREA

	Total Lbs. Per Acre
Minimum Care Lawn	
- Commercial or Residential	
- Kentucky 31 or Turf-Type Tall Fescue	175-200 lbs.
or	
- Common Bermudagrass **	75 lbs.
High-Maintenance Lawn	
- Kentucky 31 or Turf-Type Tall Fescue	200-250 lbs.
or	
- Hybrid Bermudagrass (seed) **	40 lbs. (unhulled)
or	30 lbs. (hulled)
- Hybrid Bermudagrass (by other vegetative establishment method, see Std. & Spec. 3.34)	
General Slope (3:1 or less)	
- Kentucky 31 Fescue	128 lbs.
- Red Top Grass	2 lbs.
- Seasonal Nurse Crop *	20 lbs.
	150 lbs.
Low Maintenance Slope (Steeper than 3:1)	
- Kentucky 31 Tall Fescue	93-108 lbs.
- Common Bermudagrass **	0-15 lbs.
- Red Top Grass	2 lbs.
- Seasonal Nurse Crop *	20 lbs.
- Sericea Lespedeza **	20 lbs.
	150 lbs.

* Use seasonal nurse crop in accordance with seeding dates as stated below:

February, March through April . . . . Annual Rye
May 1st through August . . . . Foxtail Millet
September, October through November 15th . . . . . Annual Rye
November 16th through January . . . . Winter Rye

** May through October, use hulled seed. All other seeding periods, use unhulled seed. Weeping Lovegrass may be added to any slope or low-maintenance mix during warmer seeding periods; add 10-20 lbs./acre in mixes.

Seedbed Requirements

Vegetation should not be established on slopes that are unsuitable due to inappropriate soil texture, poor internal structure or internal drainage, volume of overland flow, or excessive steepness, until measures have been taken to correct these problems.

To maintain a good stand of vegetation, the soil must meet certain minimum requirements as a growth medium. The existing soil must have these characteristics:

1. Enough fine-grained material to maintain adequate moisture and nutrient supply.

2. Sufficient pore space to permit root penetration. A bulk density of 1.2 to 1.5 indicates that sufficient pore space is present. A fine granular or crumb-like structure is also favorable.

3. Sufficient depth of soil to provide an adequate root zone. The depth to rock or impermeable layers such as hardpans shall be 12 inches or more, except on slopes steeper than 2:1 where the addition of soil is not feasible.

4. A favorable pH range for plant growth. If the soil is so acidic that a pH range of 6.0-7.0 cannot be attained by addition of pH-modifying materials, then the soil is considered an unsuitable environment for plant roots and further soil modification would be required.

5. Freedom from toxic amounts of materials harmful to plant growth.

6. Freedom from excessive quantities of roots, branches, large stones, large clods of earth, or trash of any kind. Clods and stones may be left on slopes steeper than 3:1 if they do not significantly impede good seed soil contact.

If any of the above criteria cannot be met, i.e., if the existing soil is too coarse, dense, shallow, acidic, or contaminated to foster vegetation, then topsoil shall be applied in accordance with TOPSOILING, Std. & Spec. 3.30.

Necessary structural erosion and sediment control practices will be installed prior to seeding. Grading will be carried out according to the approved plan.

Surfaces will be roughened in accordance with SURFACE ROUGHENING, Std. & Spec. 3.29.

Soil Conditioners

In order to modify the texture, structure, or drainage characteristics of a soil, the following materials may be added to the soil:

1. Peat is a very costly conditioner, but works well. If added, it shall be sphagnum moss peat, hypnum moss peat, reed-sedge peat or peat humus, from fresh-water sources. Peat shall be shredded and conditioned in storage piles for at least six months after excavation.

2. Sand shall be clean and free of toxic materials. Sand modification is ineffective unless you are adding 80 to 90% sand on a volume basis. This is extremely difficult to do on-site. If this practice is considered, consult a professional authority to ensure that it is done properly.

3. Vermiculite shall be horticultural grade and free of toxic substances. It is an impractical modifier for larger acreage due to expense.

4. Raw manure is more commonly used in agricultural applications. However, when stored properly and allowed to compost, it will stabilize nitrogen and other nutrients. Manure, in its composted form, is a viable soil conditioner; however, its use should be based on site-specific recommendations offered by a professional in this field.

5. Thoroughly rotted sawdust shall have 6 pounds of nitrogen added to each cubic yard and shall be free of stones, sticks, and toxic substances.

6. The use of treated sewage sludge has benefitted from continuing advancements in its applications in the agricultural community. When composted, it offers an alternative soil amendment. Limitations include a potentially undesirable pH (because of lime added during the treatment process) and the possible presence of heavy metals. This practice should be thoroughly evaluated by a professional and be used in accordance with any local, state, and federal regulations.

Lime and Fertilizer

Lime and fertilizer needs should be determined by soil tests. Soil tests may be performed by the Cooperative Extension Service Soil Testing Laboratory at VPI&SU, or by a reputable commercial laboratory. Information concerning the State Soil Testing Laboratory is available from county extension agents. Reference Appendix 3.32-d for liming applications (in lbs.) needed to correct undesirable pH for various soil types.

Under unusual conditions where it is not possible to obtain a soil test, the following soil amendments will be applied:

Lime

Coastal Plain: 2 tons/acre pulverized agricultural grade limestone (90 lbs./1000 ft.^{2}).

Piedmont and Appalachian Region: 2 tons/acre pulverized agricultural grade limestone (90 lbs./1000 ft.^{2}).

Note: An agricultural grade of limestone should always be used.

Fertilizer

Mixed grasses and legumes: 1000 lbs./acre 10-20-10 or equivalent nutrients (23 lbs./1000 ft.^{2}).

Legume stands only: 1000 lbs./acre 5-20-10 (23 lbs./ 1000 ft.^{2}) is preferred; however, 1000 lbs./acre of 10-20-10 or equivalent may be used.

Grass stands only: 1000 lbs./acre 10-20-10 or equivalent nutrients, (23 lbs./1000 ft.^{2}).

Other fertilizer formulations, including slow-release sources of nitrogen (preferred from a water quality standpoint), may be used provided they can supply the same amounts and proportions of plant nutrients.

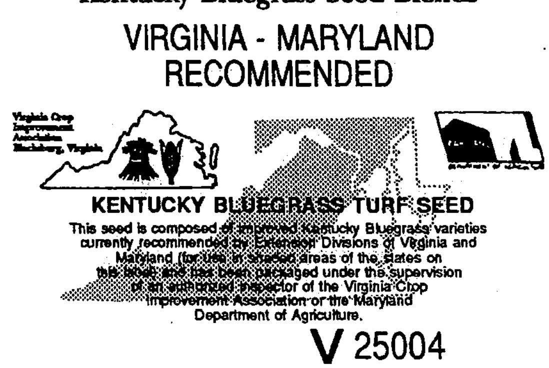
Incorporation - Lime and fertilizer shall be incorporated into the top 4-6 inches of the soil by discing or other means whenever possible. For erosion control, when applying lime and fertilizer with a hydroseeder, apply to a rough, loose surface.

Seeding

1. Certified seed will be used for all permanent seeding whenever possible. Certified seed is inspected by the Virginia Crop Improvement Association or the certifying agency in other states. The seed must meet published state standards and bear an official "Certified Seed" label (see Appendix 3.32-a).

Kentucky Bluegrass Seed Mixtures

Kentucky Bluegrass Seed Blends



2. Legume seed should be inoculated with the inoculant appropriate to the species. Seed of the Lespedezas, the Clovers and Crownvetch should be scarified to promote uniform germination.

3. Apply seed uniformly with a broadcast seeder, drill, culti-packer seeder, or hydroseeder on a firm, friable seedbed. Seeding depth should be 1/4 to 1/2 inch.

4. To avoid poor germination rates as a result of seed damage during hydroseeding, it is recommended that if a machinery breakdown of 30 minutes to 2 hours occurs, 50% more seed be added to the tank, based on the proportion of the slurry remaining in the tank. Beyond 2 hours, a full rate of new seed may be necessary.

   Often hydroseeding contractors prefer not to apply lime in their rigs as it is abrasive. In inaccessible areas, lime may have to be applied separately in pelletized or liquid form. Surface roughening is particularly important when hydroseeding, as a roughened slope will provide some natural coverage of lime, fertilizer and seed.

   Legume inoculants should be applied at five times the recommended rate when inoculant is included in the hydroseeder slurry.

Mulching

All permanent seeding must be mulched immediately upon completion of seed application. Refer to MULCHING, Std. & Spec. 3.35.

Maintenance of New Seedings

In general, a stand of vegetation cannot be determined to be fully established until it has been maintained for one full year after planting.

Irrigation: New seedings should be supplied with adequate moisture. Supply water as needed, especially late in the season, in abnormally hot or dry weather, or on adverse sites. Water application rates should be controlled to prevent excessive runoff. Inadequate amounts of water may be more harmful than no water.

Re-seeding: Inspect seeded areas for failure and make necessary repairs and re-seedings within the same season, if possible.

a. If vegetative cover is inadequate to prevent rill erosion, over-seed and fertilize in accordance with soil test results.

b. If a stand has less than 40% cover, re-evaluate choice of plant materials and quantities of lime and fertilizer. The soil must be tested to determine if acidity or nutrient imbalances are responsible. Re-establish the stand following seedbed preparation and seeding recommendations.

Fertilization: Cool season grasses should begin to be fertilized 90 days after planting to ensure proper stand and density. Warm season fertilization should begin at 30 days after planting.

Apply maintenance levels of fertilizer as determined by soil test. In the absence of a soil test, fertilization should be as follows:

Cool Season Grasses

4 lbs. nitrogen (N)

1 lb. phosphorus (P) Per 1000 ft.^{2} per year

2 lbs. potash (K)

Seventy-five percent of the total requirements should be applied between September 1 and December 31st. The balance should be applied during the remainder of the year. **More than 1 lb. of soluble nitrogen per 1000 ft.^{2} should not be applied at any one time.**

Warm Season Grasses

Apply 4-5 lbs. nitrogen (N) between May 1 and August 15th per 1000 ft.^{2} per year.

Phosphorus (P) and Potash (K) should only be applied according to soil test.

Note: The use of slow-release fertilizer formulations for maintenance of turf is encouraged to reduce the number of applications and the impact on groundwater.

Additional Information on the Successful Establishment of Grasses and Legumes

See Appendix 3.32-b for "helpful hints" in achieving high success rates in grass or legume plantings.

APPENDIX 3.32-a

SEED QUALITY CRITERIA

Where certified seed is not available, the minimum requirements for grass and legume seed used in vegetative establishment are as follows:

a. All tags on containers of seed shall be labeled to meet the requirements of the State Seed Law.

b. All seed shall be subject to re-testing by a recognized seed laboratory that employs a registered seed technologist or by a state seed lab.

c. All seed used shall have been tested within twelve (12) months.

d. Inoculant - the inoculant added to legume seed in the seed mixtures shall be a pure culture of nitrogen-fixing bacteria prepared for the species. Inoculants shall not be used later than the date indicated on the container. Twice the supplier's recommended rate of inoculant will be used on dry seedings; five times the recommended rate if hydroseeded.

e. The quality of the seed used shall be shown on the bag tags to conform to the guidelines in Table 3.32-E.

TABLE 3.32-E

QUALITY OF SEED*

	Minimum Seed Purity (%)	Minimum Germination (%)
Legumes		
Crownvetch	98	65**
Lespedeza, Korean	97	85**
Lespedeza, Sericea	98	85**
Grasses		
Bluegrass, Kentucky	97	85
Fescue, Tall (Improved, Turf-Type Cultivars)	98	85
Fescue, Tall (Ky-31)	97	85
Fescue, Red	98	85
Redtop	94	80
Reed Canarygrass	98	80
Perennial Ryegrass	98	90
Weeping Lovegrass	98	87
Annuals		
Annual Ryegrass	97	90
German Millet	98	85
Oats	98	80
Cereal Rye	98	85

* Seed containing prohibited or restricted noxious weeds should not be accepted. Seed should not contain in excess of 0.5% weed seed. To calculate percent pure, live seed, multiply germination times purity and divide by 100.

Example: Ky-31 Tall Fescue with a germination of 85 percent and a purity of 97 percent.

97 x 85 = 8245. 8245 ÷ 100 = 82.45 percent pure live seed.

** Includes "hard seed"

APPENDIX 3.32-b

KEYS TO SUCCESSFUL ESTABLISHMENT OF GRASSES AND LEGUMES

Planning

Where feasible, grading operations should be planned around optimal seeding dates for the particular region. The most effective times for establishing perennial grass in Virginia generally extend from March through May and from August through October. Outside these dates, the probability of failure is much higher. If the time of year is not suitable for seeding a permanent cover (perennial species), a temporary cover crop should be planted. Temporary seeding of annual species (small grains, ryegrasses or millets) often succeeds during periods of the year that are unsuitable for seeding permanent (perennial) species.

Variations in weather and local site conditions can modify the effects of regional climate on seeding success. For this reason, mixtures including both cool and warm season species are preferred for low-maintenance cover, particularly in the Coastal Plain. Such mixtures promote cover which can adapt to a range of conditions. Many of these mixtures are not desirable, however, for high quality lawns, where variation in texture of the turf is inappropriate. It is important to note that in Virginia the establishment of 100% warm season grasses in a high quality lawn is limited to the extreme eastern portions of the Coastal Plain.

Selection

Species selection should be considered early in the process of preparing an erosion and sediment control plan. A variety of vegetation can be established in Virginia due to the diversity in both soils and climate. However, for practical, economical stabilization and long-term protection of disturbed sites, species selection should be made judiciously.

Seasonality must be considered when selecting species. Grasses and legumes are usually classified as warm or cool season in reference to their season of growth. Cool season plants realize most of their growth during the spring and fall and are relatively inactive or dormant during the hot summer months. Therefore, fall is the most favorable time to plant them. Warm season plants "green-up" late in the spring, grow most actively during the summer, and go dormant at the time of the first frost in fall. Spring and early summer are preferred planting times for warm season plants.

Seed Mixtures

As previously noted, the establishment of high quality turf frequently involves planting one single species. However, in seedings for erosion control purposes, the inclusion of more than one species should always be considered. Mixtures need not be excessive in poundage or seed count. The addition of a quick-growing annual provides early protection and facilitates establishment of one or two perennials in a mix. More complex mixtures might include a quick-growing annual, one or two legumes and more than one perennial grass.

The addition of a "nurse" crop (quick-growing annuals added to permanent mixtures) is a sound practice for soil stabilization, particularly on difficult sites - those with steep slopes; poor, rocky, erosive soils; those seeded out the optimum seeding periods; or in any situation where the development of permanent cover is likely to be slow. The nurse crop germinates and grows rapidly, holding the soil until the slower-growing perennial seedlings become established.

APPENDIX 3.32-c

PLANT INFORMATION SHEETS

Contents:

Annual Grasses and Grains

Oats
Rye
Foxtail Millet
Annual Ryegrass

Annual Legumes

Annual Lespedeza

Perennials

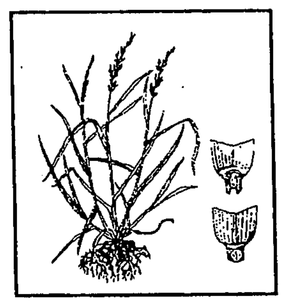
Tall Fescue
Kentucky Bluegrass
Perennial Ryegrass
Fine Fescues
Bermudagrass
Reed Canarygrass

Miscellaneous Erosion Control Grasses

Weeping Lovegrass
Redtop

Legumes

Crownvetch
Flatpea
Sericea Lespedeza
White Clover

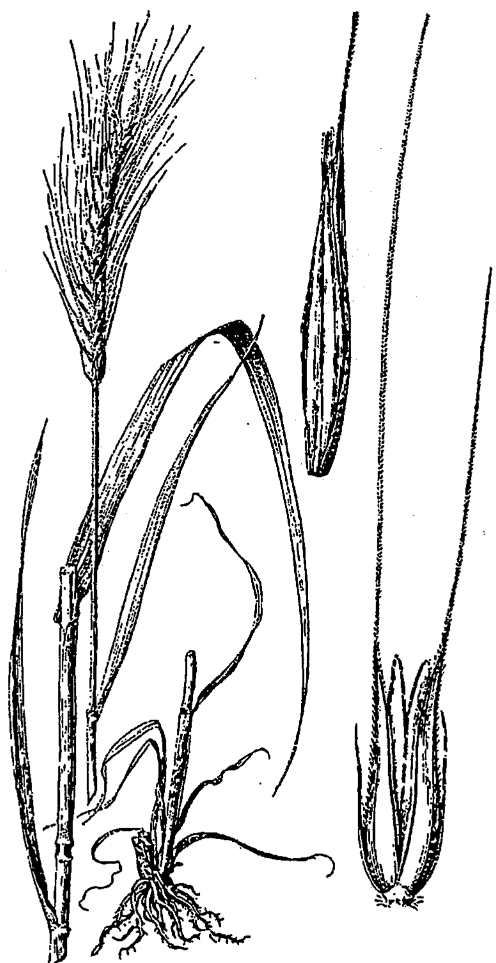


ANNUAL GRASSES AND GRAINS

Small grains are cool season annual grasses primarily grown for animal feed and human consumption. In Virginia, the grains used for soil stabilization are primarily Rye and Oats. Foxtail Millet, which is sometimes considered a small grain, is becoming a very popular and successful planting for soil stabilization.

1. Oats (Avenasativa): A cool season annual grass primarily grown for animal feed and human consumption, but also used for soil stabilization. Oats are seeded in early spring in the western part of the state (winter oats may be sown in the Coastal Plain). Seeding rates are 3 bushels (100 lbs.) per acre bare ground or 2-1/2 lbs. per 1000 square feet.

2. Rye (Secale cereale): Often referred to as Winter Rye because of its winter hardiness, Rye is the most common small grain used for soil stabilization. It is also the most productive grain on dry, infertile, acid or sandy soils. It may be seeded in the fall for winter ground cover. By maturing early, it offers less competition during the late spring period, a critical time in the establishment of perennial species. Rye grain germinates quickly and is tolerant of poor soils. Including Rye grain in fall-seeded mixtures is almost always advantageous, but it is particularly helpful on difficult and erodible soils, erodible slopes or when seeding is late. Rates up to 100 lbs. for bare ground. Overly thick stands of Rye grain will suppress the growth of perennial seedlings. Approximately 50 lbs. per acre is the maximum for this purpose and, where lush growth is



Rye (Secale cereale)

expected, that rate should either be cut in half, or Rye grain should be totally eliminated from the mixture.

3. Foxtail Millet (Setaria italica): A warm season annual grass which may be used for temporary cover. German Millet (variety commonly used in Virginia) germinates quickly and goes to seed quickly. These features make it an excellent companion grass for summer seedlings. It dies at first frost. Seeding rates are up to 50 lbs. per acre for temporary cover. Use 10 to 20 lbs. per acre in mixes.

4. Annual Rye (Lolium multiflorum): A cool season annual grass used for temporary cover or as a nurse grass to allow for germination of permanent stands. Most commonly used in mixes for erosion control. Performs well throughout the state in neutral to slightly acid soils. Rates up to 100 lbs. per acre for temporary cover. Use 10 to 20 lbs. per acre in mixes.

Foxtail Millet (Setaria italica)

Annual Rye (Lolium multiflorum)

ANNUAL LEGUMES

1. Annual Lespedezas (Lespedeza striata)

Uses: Pasture, hay, erosion control, soil improvement, wildlife food.

Description: Annual warm season legumes. Korean Lespedeza is larger and coarser than Common Lespedeza and grows to about 12 inches. Seed of Korean is shiny and black, while seed of Common is stippled. Kobe is the most desirable variety of Common Lespedeza.

Adaptation: Throughout Virginia. Optimum pH range is 6.0 to 6.5; will grow from 5.5 to 7.0. Will grow in soil textures ranging from sands to clays and through a wide range of fertility conditions.

Establishment: Seed should always be inoculated. May be seeded alone or mixed with grasses or small grains. Requires a firm seedbed; may be broadcast or drilled. Should be seeded in early spring at 25 to 40 lbs. per acre or one-half to 1 lb. per 1000 square feet, depending on use. (Use lower figure as half the seeding rate of any spring seeding with grass or grain.) Should not be mowed at less than three inches. Lespedeza will not make a large contribution in sod grasses like Bluegrass; they do best in open sod grasses like tall fescue.

Sources: Seed of common variety (Kobe) and Korean varieties (Climax, Harbin and Rowan) are commercially available.

Annual Lespedezas (Lespedeza striata)

PERENNIALS

1. Tall Fescue (Festuca arundinacea)

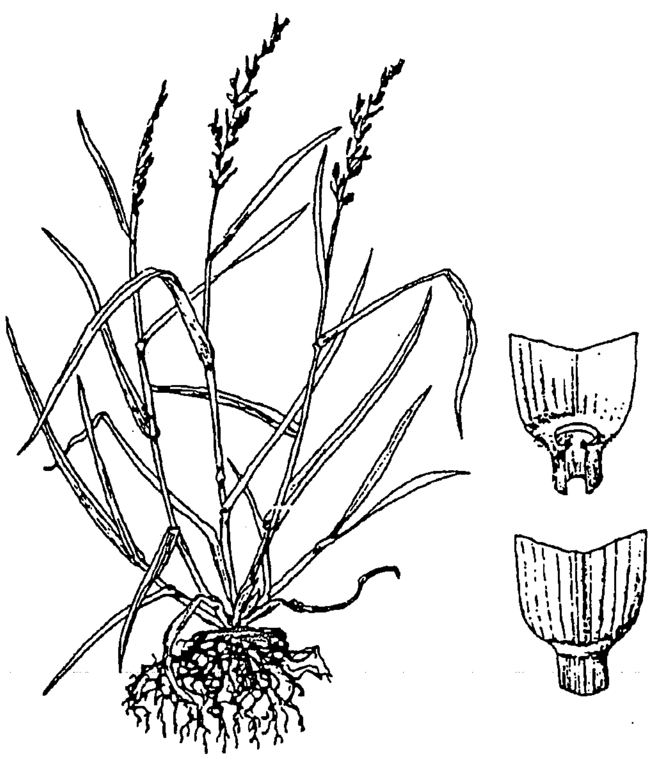
Uses: Pasture, hay, recreation areas, lawns and stabilization of waterways, banks, slopes, cuts, fills, and spoils. It is the most widely used grass at this time for stabilizing large disturbed areas.

Description: A robust, cool season, long-lived, deep-rooted bunchy grass which may have short rhizomes (underground stems). Kentucky 31 is the best-known variety. A number of new varieties of Tall Fescue are becoming available for lawn and other fine-turf uses, and several offer definite improvements. However, their higher cost over the old standby, KY 31, is seldom justified when used for purposes of stabilization and erosion control. Tall Fescue tolerates a wide range of seeding dates; however, with the possible exception of high mountain elevation, it is most dependable when planted in fall.

Adaptation: Adapts well to both high and low maintenance uses throughout Virginia. Adapted to a wide range of climatic conditions. Optimum pH range is 6.0 to 7.0; will tolerate from 3.0 to 8.0. Will grow on shallow and claypan soils if they are moist. Growth is limited more by moisture than by temperature extremes, but it will tolerate drought, infertile soils and moderate shade.

Establishment: Requires a firm seedbed. Hydroseeding is successful. Seeding rates vary from 100 lbs. per acre for erosion control to 250 lbs. per acre for lawns. Plant in early spring or from the middle of August through September. Legumes may not thrive in fescue stands due to the aggressive growth habits of this grass. Mowing is desirable on critical areas at least once every two years; lack of periodic mowing will encourage clumpiness.

Sources: Readily available as seed and sod.



Tall Fescue (Festuca arundinacea)

2. Kentucky Bluegrass (Poa pratense)

Uses: Pasture, turf for lawns, athletic fields, golf courses, and playgrounds. Also used to stabilize waterways, slopes, cuts and fills. Choice food for grouse, turkeys, deer and rabbits.

Description: Long-lived, cool season perennial grass which forms a dense sod. Becomes dormant in the heat of summer since its growing season is spring and fall.

Adaptation: Best adapted to well-drained, fertile soils of limestone origin and the climate of northern and western Virginia. Optimum pH range is 6.0 to 7.0. Bluegrasses are better suited to high maintenance situations in the transition zone. Essentially dormant during dry or hot weather; however, it will normally survive severe drought.

Establishment: Requires a firm, weed-free seedbed and adequate fertilization (liberal phosphorus) and lime are important. Can be used with Tall Fescues at low rates. Minimum mowing height is 1-1/2 inches. Critical erosion areas may be mowed only once per year, if desired. This grass is usually seeded with a mixture of other grasses or legumes; several varieties of Bluegrass should be used together to ensure good stand survival. Bare ground rates are 120 lbs. per acre. Overseed 1 to 1-1/2 per 1000 square feet.

Sources: Readily available as seed and sod.

Kentucky Bluegrass (Poa pratense)

3. Perennial Ryegrass (Lolium perrenne)

Uses: Erosion control, soil improvement, lawns, pasture, and hay; newer varieties are excellent for high-traffic areas.

Description: Perennial Ryegrasses are an excellent selection where rapid establishment is desired. Cool season. Ryegrasses cross-pollinate freely so "Common Ryegrass" may be a mixture of annual and perennial species. Certified seed of Perennial Ryegrass varieties is produced: Blaser, Palmer, Goalie, Fiesta II, Ranger, Regal and Pennfine may be used in Virginia.

Perennial Ryegrass (Lolium perrenne)

Adaptation: Throughout Virginia. Grows best on dark, rich soils in mild climates. Newer varieties have good drought tolerance but may require irrigation if under drought stress or heavy traffic. Will tolerate wet soils with good surface drainage.

Establishment: A firm, mellow surface over compact subsoils gives good results. Seed in fall or spring. Perennial Ryegrass may also be seeded in mid-August to early September. For turf, use a rate of 5 to 8 lbs. per 1000 square feet, if seeded alone; lesser amounts are suitable in mixtures, depending on the characteristics of the companion species. Generally not seeded alone except on athletic fields with intensive use. Perennial Ryegrass does best when used with bluegrass as 20 percent or less of the mixture. Ryegrasses germinate rapidly which makes them particularly suited to disturbed-area stabilization and temporary seeding. They will, however, tend to dominate stands in mixtures if percentage is too high.

Sources: Readily available commercially. Care should be taken to buy seed appropriate to the needs of the project.

4. Fine Fescues

- Red Fescue
- Hard Fescue
- Chewings Fescue

Uses: Excellent for shady, low maintenance areas and north-facing slopes. May be used to stabilize waterways, slopes, banks, cuts, fills, and as a cover crop in orchards.

Description: Red Fescue is a cool season perennial that occurs in two forms: bunch-type and creeping. Creeping Red Fescue forms a tight sod. The leaves of Red Fescue are narrow and wiry. Hard Fescues are slow-growing with excellent shade tolerance.

Adaptation: Shade tolerant and somewhat drought-resistant once established. Grows well in sandy and acidic soils. Optimum pH range is 4.5 to 6.0. Prefers well-drained soils but requires adequate moisture for establishment. In areas of high temperature and humidity (such as southeastern Virginia), some Fine Fescues may turn brown or deteriorate during the summer. Newer varieties of Hard Fescue are more drought tolerant.

Establishment: Rarely seeded in pure stands. Seedbed preparation and fertility adjustments are usually dictated by the other grasses in the mixture. Red Fescues may comprise 25 to 60% by weight of a seeding mixture. In shaded areas red fescue may be the key grass in the mixture. Mowing consistently below 1-1/2 is not recommended.

Sources: Readily available commercially. New Hard Fescues may be in short supply.

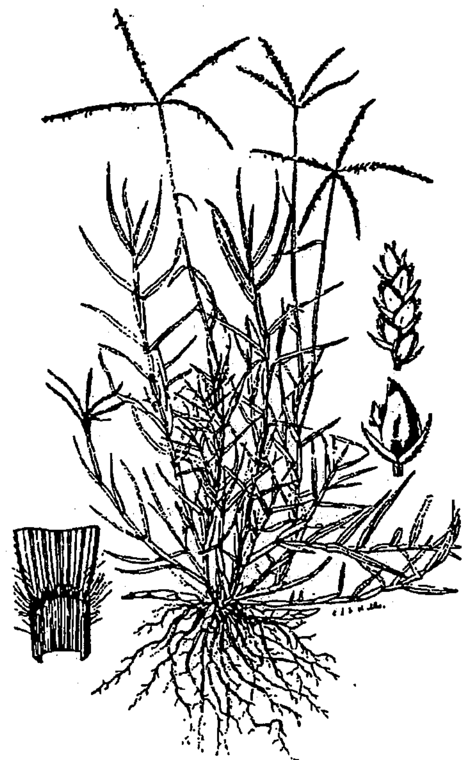
Red Fescue (Festuca rubra)

5. Bermudagrass (Cynodon dactylion)

Uses: Soil and water conservation, pasture, hay, silage, lawns, both high maintenance and general purpose turf, and stabilization of grassed waterways.

Description: A long-lived, warm season perennial that spreads by stolons and rhizomes (runners and underground stems). Height of stems of Common Bermudagrass may be 12 inches. The stems are short-jointed and the leaves flat and spreading. Common Bermudagrass may be established vegetatively with sprigs (sections of stems) or from seeds; however, it has the potential to develop into a weed problem because it spreads vigorously. Cold-tolerant hybrids are usually specified. These are traditionally established from sprigs or sod, but seed is now available.

Adaptation: Southern Piedmont and Coastal Plain in Virginia and some southern appalachian ridges and valleys. Check Std. & Spec. 3.34 for regional adaptations of varieties. Makes its best growth when average daily temperatures are above 75 degrees. Grows on a wide range of soils from heavy clays to deep sands. Optimum pH is 6.0 to 6.5. It is drought-resistant and salt-tolerant. Tolerates floods of short duration but will not thrive on waterlogged soils; does not persist under heavy shade. For rough areas, the varieties Midland (a forage hybrid) and Coastal are recommended. For fine-turf areas, Tufcote (a fine-leaved turf hybrid), Midiron, Tifway, and Vamont are used in Virginia.



Bermudagrass (Cynodon dactylion)

Establishment: By sodding or planting sprigs. Sprigs should be planted (by hand or machine) when soil is warm in a well-prepared, moist seedbed. One end of the sprig should extend above ground, and the other should be covered by firmly packed soil.

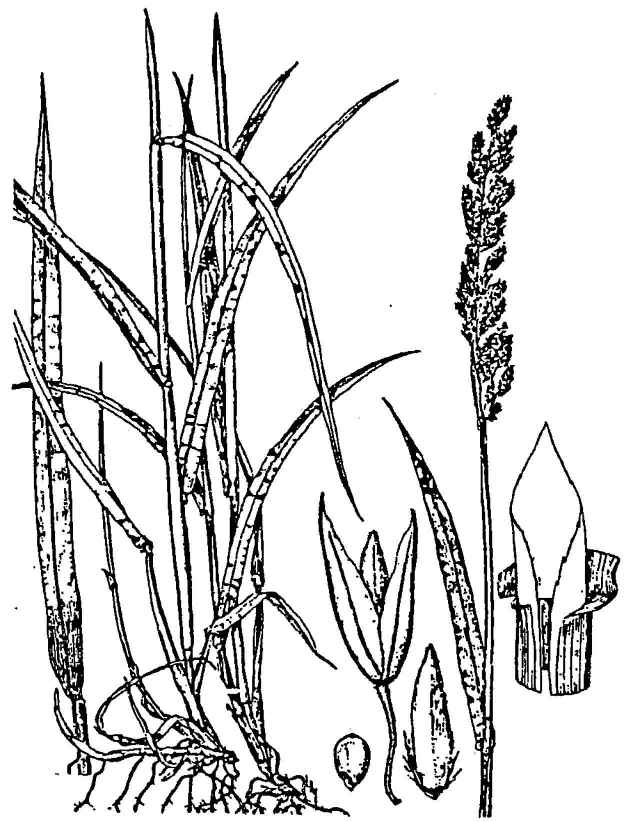
Sources: Readily available as seed, sprigs, and sod.

6. Reed Canarygrass (Phalaris arundinacea)

Uses: Pasture, hay silage, and erosion control. An excellent grass for stabilizing waterways, healing and controlling gullies, and protecting shorelines of ponds and reservoirs from wave action. Also provides good cover for shooting preserves. Can be used in deep gullies and drainage ditches where streamflow is rapid. Vigorous growth may impede flow in small, low velocity channels.

Description: A long-lived, cool season, clumpy perennial with coarse rhizomes (underground stems). Grows 4 to 7 feet tall. Most widely used variety is Ioreed.

Adaptation: Throughout Virginia. Does best in a cool, moist climate. Makes best growth on fertile, moist, medium to fine soils; but will grow in a wide range of soil moisture conditions. Will also grow well on swampy or floodplain soils consisting of peat, muck or sand. Will withstand flooding, yet is quite drought-tolerant when mature. Optimum pH range 5.0 to 7.5.



Reed Canarygrass (Phalaris arundinacea)

Establishment: Requires a well-prepared seedbed that is firm and weed free. Seed in spring or late summer; drill seed alone or with a legume. Seed must be fresh - it should be labeled as having at least 70% germination tested within the last 6 months. Normally, pure stands should be established because this grass is not very compatible with other plants. Mowing should not occur more than twice a year on stabilized critical erosion areas or waterway as this will result in reduced stands.

Sources: Available commercially.

MISCELLANEOUS EROSION CONTROL GRASSES

1. Weeping Lovegrass (Eragrostis curvula)

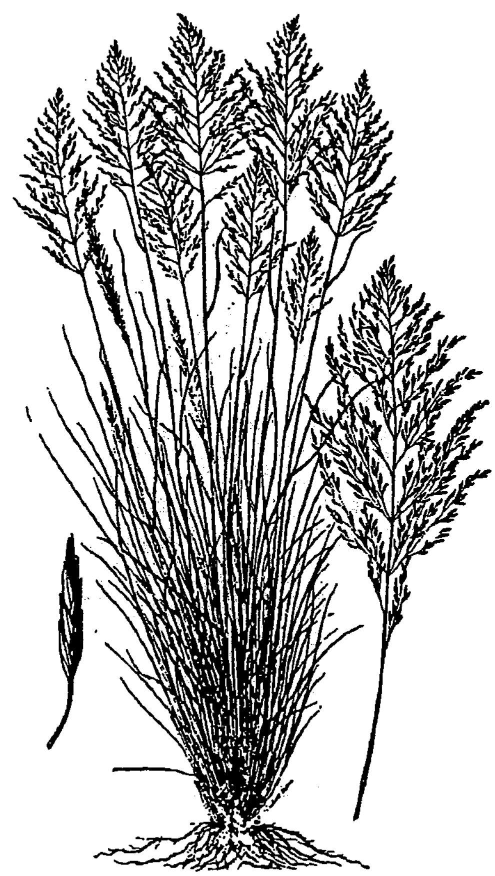
Uses: Fast-growing cover for erosion control. In the northeast, weeping lovegrass acts as a summer annual. The normal life of 3 to 5 years may be foreshortened by low winter temperatures. May provide permanent cover on southern exposure.

Description: A rapid-growing, warm season bunch grass introduced from East Africa. The long, narrow leaves are numerous, very fine, and droop over to the ground, hence the name. Leaf height is rarely above 12 inches.

Adaptation: Prefers light-textured, well-drained soil; will thrive on soil of low fertility. Low winter temperatures may deplete stand.

Establishment: Easy to establish by seed; germinates rapidly and grows quickly. Lime and fertilizer needs are similar to those of Tall Fescue and Ryegrass. Requires pH of 5.5 or higher. May be planted any time after danger of frost and throughout the summer. Very fine seed, commonly added to erosion control seed mixtures. Use of hydroseeders is successful if the seeding rate is increased to compensate for the lack of a firm seedbed. Normal seeding rates are 5 to 20 lbs. per acre in mixes.

Sources: Readily available from large seed companies.



Weeping Lovegrass (Eragrostis curvula)

2. Redtop (Agrostis alba)

Uses: Erosion control, pasture, companion grass in turf seedings and stabilizing ditch and channel banks, grassed waterways, and other disturbed areas.

Description: A coarse, cool-season perennial grass with rhizomes (underground stems). Grows to 30 to 40 inches.

Adaptation: Throughout Virginia; does better in the cool, humid areas. Will grow under a wide variety of soil and moisture conditions. Grows on very acid soils (pH 4.0 to 7.5) and poor, clay soils of low fertility. While drought-resistant, it is also a useful wetland grass.

Establishment: Has very small seed and requires a compact seedbed. May be sown in early spring or late summer. Seldom seeded alone except as temporary turf. Adequate fertilization is essential on critical areas to obtain good cover rapidly. Most commonly added to mixes, usually 2 to 3 lbs. per acre. Redtop will disappear from a stand under frequent low mowing.

Sources: Available from commercial sources.

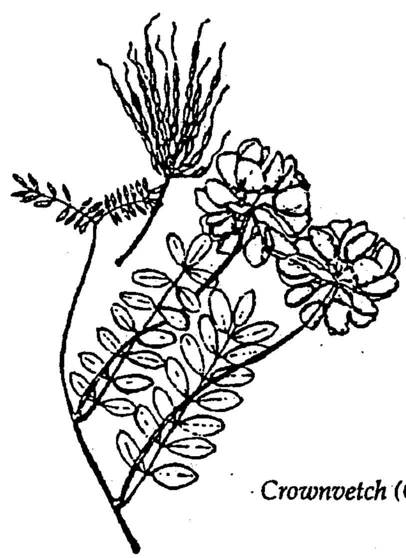
Redtop (Agrostis alba)

LEGUMES

1. Crownvetch (Coronilla varia)

Uses: For erosion control of critical areas such as steep roadbanks, surface mine spoil and industrial waste areas. It is also useful as a residential ground cover. It provides high-quality forage for ruminant animals and serves as a wildlife food and cover plant.

Description: A deep-rooted, cool season, perennial, herbaceous legume with a semi-reclining growth habit. It reaches 2 to 3 feet in height, and does not climb or twine. It fixes nitrogen in the soil and makes a dense mat of vegetative cover.



Crownvetch (Coronilla varia)

Adaptation: Best adapted to the northern Piedmont and Mountain regions of Virginia. It grows best on well-drained soils with a pH range of 5.5 to 8.3. It will persist on more acid soils for a prolonged period once established. It is not adapted to soils with poor drainage. Crownvetch is winter-hardy and drought-tolerant. Varieties commonly used are Chemung, Penngift and Emerald.

Establishment: Only inoculated seed should be used. Requires at least 500 lbs. per acre of 5-10-10 fertilizer (or the area should be fertilized according to soil test results). Soil acidity must be raised above a pH of 5.5. Crownvetch requires mulch and can be hydroseeded successfully. Seeding in the spring is most successful. Frost-seeding may be used on steep or stony sites (seed in late winter, and allow frost action to work the seed into soil). Crownvetch often takes 2 to 3 years to establish a dense stand. A companion grass such as Perennial Ryegrass or Redtop needs to be mixed into the initial planting, but the Crownvetch will eventually crowd out the companion plants. It will not persist under frequent mowing.

Sources: Available commercially.

2. Flatpea (Lathyrus sylvestris)

Uses: Flatpea is an erosion control plant that provides a thick mat of vegetative cover, fixes nitrogen in the soil, and can be maintained with a minimum of management. It is useful on roadbanks, dams, borrow area, gravel pits, surface mine spoil, and industrial waste areas. It is an ideal plant for stabilizing logging roads and utility right-of-ways since it will restrict the invasion of many woody species. It also provides good wildlife cover and food.

Description: A cool season perennial legume. It will climb to a height of 6 to 7 feet if support is available, but the normal height is 2 to 3 feet.

Flatpea (Lathyrus sylvestris)

Adaptation: Flatpea is adaptable to a wide variety of soil conditions. It is drought-tolerant, cold-hardy, and does well on low-fertility sites such as sands, gravels, and soils from acid sandstones. It is not adapted to wet sites, but it will grow on somewhat poorly drained soils. It will tolerate minor shade and a minor degree of flooding. The optimum pH range is from 6.0 to 6.5. The only available variety is Lathco, developed by the USDA-Soil Conservation Service.

Establishment: Use only inoculated seed. The seedbed should be scarified, if possible. The seed is normally drilled or band seeded, but on rough sites or steep slopes, it can be broadcast and then worked into the soil by light dragging. Where possible, a light application of mulch, properly anchored, will assure a good stand. Lime is essential if the soil is below a pH of 5.0. Fertilize according to a soil test or apply 400 lbs. per acre of 10-20-10. Work lime and fertilizer into soil when preparing the seedbed. For a primary stand, use a seeding rate of 30 to 40 lbs. in a mixture with 8 to 10 lbs. of Perennial Ryegrass or 10 to 15 lbs. of Tall Fescue. Flatpea is slow to germinate, so grasses are needed to provide quick cover. Early spring seedings in April or May are best; June seedings are less desirable. Grass seedings may be overseeded with Flatpea from November through March. Flatpea is usually not winter-hardy if seeded in mid or late summer; therefore, dormant seedings are recommended. Mulch with straw at a minimum rate of 1-1/2 tons per acre on all critical sites, and anchor. Little management is required. Remove woody vegetation if the site is invaded. Mowing is acceptable once the stand is established. Mow after full bloom at a 6-inch minimum height.

Sources: Lathco is commercially available.

3. Sericea Lespedeza (Lespedeza cuneata)

Uses: Hay, pasture, erosion control, cover crop, wildlife food.

Description: Warm season perennial legume with upright woody stems 12 to 18 inches tall. Roots widely branched penetrating soil 3 feet or more.

Adaptation: Well adapted to all parts of Virginia. Best on well-drained, deep soils of medium texture. Will also grow on sandy, rather acidic, infertile soils. Most often the legume of choice for eastern Virginia. Optimum pH range is 6.0 to 6.5, but will tolerate a range of 5.0 to 7.0. It is drought-tolerant. Common varieties in Virginia are Serala and Interstate.

Sericea Lespedeza (Lespedeza cuneata)

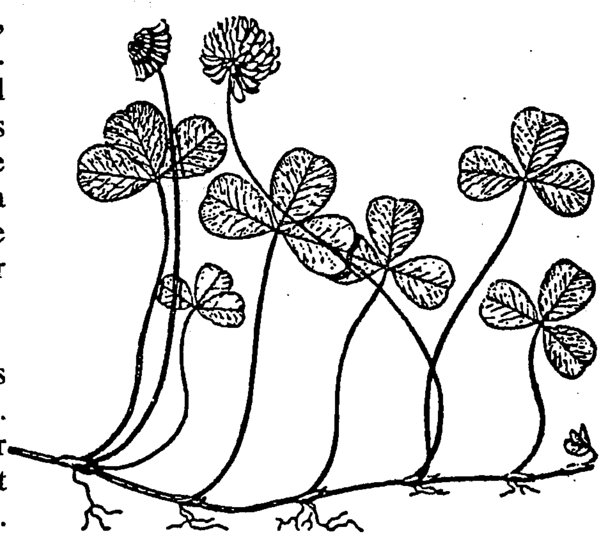
Establishment: Seed from April to June. Requires a firm seedbed. Use only inoculated seed. Rates vary from 20 to 30 lbs. of unhulled seed per acre. Requires phosphate and potash. Will not persist under frequent mowing (once a year recommended).

Sources: Seed of common varieties is commercially available.

4. White Clover (Trifolium repens)

Uses: Common White Clover is used mostly for pastures. Ladino clover, a giant white clover, is also used for hay and silage in mixtures with a grass. The thick-growing, spreading characteristics of the common type make it ideal for erosion control.

Description: A cool season perennial legume. The common type has a prostrate type of growth, while the Ladino is more upright. Both spread by stolons (horizontal branches along ground) and by roots at the nodes. Representative common varieties used in Virginia are Tillman, Common and White Dutch. Ladino is the only cultivar for the large type.



White Clover (Trifolium repens)

Adaptation: Thrives in cool climates and on moist, rich soils with full sun. Will not tolerate extremes of cold or drought. Where soil moisture is not adequate, Ladino is short-lived. Optimum soil pH is 6.5, but it will grow in a range of 5.0 to 7.5. Common White Clover volunteers readily in Bluegrass mixtures where moderate to high fertility is maintained. Stands are persistent.

Establishment: Ladino Clover requires inoculation, fertilizing, and liming for successful growth. Phosphorus and potash are the key fertilizer elements required. Ladino makes a good companion crop with grasses such as Orchardgrass, Bromegrass, Tall Fescue and Timothy. These grasses will normally crowd out the Ladino after 2 to 3 years. Seed should be planted (drilled or broadcast) at shallow depths, and a firm seedbed is desirable.

Sources: Available commercially.

APPENDIX 3.32-d

TABLE 3.32-F

LBS. OF GROUND AGRICULTURAL LIMESTONE*
PER THOUSAND SQUARE FEET NEEDED
TO CORRECT pH LEVEL OF ACID SOILS TO 6.5

Existing pH	Soil Texture		
	Sandy Loam	Loam	Clay Loam
6.2	20	35	40
6.0	40	55	70
5.8	55	65	85
5.6	70	80	105
5.4	90	100	125
5.2	105	120	140
5.0	120	140	160
4.8	125	180	205
4.6	155	210	230
4.0	200	250	300

* Lime should always be applied in accordance with the results of a soil test, such as may be obtained through the soil testing laboratory at VPI&SU or through a reputable commercial laboratory.

Source: DSWC's Basic Urban E&S in Virginia

STD & SPEC 3.33

SODDING

SO

Definition

Stabilizing fine-graded disturbed areas by establishing permanent grass stands with sod.

Purposes

1. To establish permanent turf immediately.

2. To prevent erosion and damage from sediment and runoff by stabilizing the soil surface.

3. To reduce the production of dust and mud associated with bare soil surfaces.

4. To stabilize drainageways where concentrated overland flow will occur.

5. For use as a filtering device for sediments in areas prior to achieving permanent stabilization.

Conditions Where Practice Applies

1. Disturbed areas which require immediate vegetative covers, or where sodding is preferred to other means of grass establishment.

2. Locations particularly suited to stabilization with sod are:

   - waterways carrying intermittent flow
   - area around drop inlets or in grassed swales
   - residential or commercial lawns where quick use or aesthetics are factors.

Planning Considerations

The successful establishment of quality turfgrass is difficult in Virginia. Extremes in temperature and moisture availability create severe stresses on both cool and warm season grasses. The selection of appropriate turf-establishment methods requires a great deal of forethought.

A quality turf containing the recommended mixtures and species can be established with either seed or sod. Soil preparation for the two methods is the same.

The advantages of properly installed sod include:

1. Immediate erosion control.
2. An instant green surface with no dust or mud.
3. Nearly year-round establishment capability.
4. Less chance of failure than seed.
5. Freedom from weeds.
6. Quick use of the sodded surface.
7. The option of buying a quality-controlled product with predictable results.

It is initially more costly to install sod than to seed. However, this cost is justified in places where sod can perform better than seed in controlling erosion.

In swales and waterways where concentrated flow will occur, properly pegged sod is preferable to seed because there is no lag time between installation and the time when the channel is protected by vegetation.

Drop inlets which will be placed in grassed areas can be kept free of sediments, and the grade immediately around the inlet can be maintained, by framing the inlet with sod strips.

Sod can be laid during times of the year when seeded grass may fail, so long as there is adequate water available for irrigation in the early weeks.

Ground preparation and proper maintenance are as important with sod as with seed. Sod is composed of living plants and those plants must receive adequate care in order to provide vegetative stabilization on a disturbed area.

Specifications

Soil Preparation

1. Prior to soil preparation, areas to be sodded shall be brought to final grade in accordance with the approved plan.

2. Soil tests should be made to determine the exact requirements for lime and fertilizer. Soil tests may be conducted by the State Laboratory at VPI & SU or a reputable commercial laboratory. Information on state soil tests is available from county or city agricultural extension agents.

   Under difficult circumstances where it is not possible to obtain a soil test, the following soil amendments shall be made:

   > Pulverized agricultural limestone at 90 lbs./1000 sq. ft. (2 tons/acre).
   >
   > Fertilizer at 25 lbs./1000 sq. ft. (1000 lbs./acre) of 10-10-10 in fall, or 25 lbs./1000 sq. ft. of 5-10-10 in spring.

   Note: Equivalent nutrients may be applied with other fertilizer formulations.

   These amendments shall be spread evenly over the area to be sodded, and incorporated (if possible) into the top 3 to 6 inches of the soil by discing, harrowing or other acceptable means.

3. Prior to laying sod, the soil surface shall be clear of trash, debris, large roots, branches, stones and clods in excess of 1 inch in length or diameter. Sod shall not be applied to gravel or other non-soil surfaces.

4. Any irregularities in the soil surface resulting from top-soiling or other operations shall be filled or leveled in order to prevent the formation of depressions or water pockets.

5. Areas to be topsoiled and topsoil used shall fulfill the requirements of TOPSOILING, Std. & Spec. 3.30. No sod shall be spread on soil which has been treated with soil sterilants or any other toxic herbicides until enough time has elapsed to permit dissipation of toxic materials.

Quality of Sod

1. Sod used shall be state-certified. Certified turfgrass sod is grown from Certified seed, inspected and certified by the Virginia Crop Improvement Association (VCIA) or the certifying agency in other states. This ensures genetic purity, high quality, freedom from noxious weeds and excessive insect or disease problems. The sod must meet published state standards and bear an official blue "Certified Turf" label on the bill of lading.

VIRGINIA CROP IMPROVEMENT ASSOCIATION
BLACKSBURG, VIRGINIA

VIRGINIA CROP IMPROVEMENT ASSOCIATION
GROWN IN VIRGINIA

Certified Turf

The turf accompanying this invoice is represented by the producer to be a part of the lot that has been officially field inspected and has met the requirements for "Certified Turf" under the rules and regulations of the Virginia Crop Improvement Association.

No. 255

2. High-quality sod is also available outside of the VCIA certified sod program. When purchasing this sod, the consumer is encouraged to be aware of factors which are important in determining sod quality. High-quality sod will contain the best varieties and be free of serious disease, insect, or weed problems. It will be dense, have good color, and hold together well.

3. Sod shall be machine cut at a uniform soil thickness of 3/4 inch (± 1/4 inch) at the time of cutting. This thickness shall exclude shoot growth and thatch.

4. Pieces of sod shall be cut to the supplier's standard width and length, with a maximum allowable deviation in any dimension of 5%. Torn or uneven pads will not be acceptable.

5. Standard size sections of sod shall be strong enough to support their own weight and retain their size and shape when suspended from a firm grasp on one end of the section.

6. Sod shall not be cut or laid in excessively wet or dry weather.

7. Sod shall be harvested, delivered, and installed within a period of 36 hours.

Choosing Appropriate Types of Sod

The type of sod used must be composed of plants adapted to the locality. Use Table 3.33-A to select the type of sod best suited to your area.

Sod Installation (See Plate 3.33-1)

1. Sod should not be laid on soil surfaces that are frozen.

2. During periods of high temperature, the soil shall be lightly irrigated immediately prior to laying the sod, to cool the soil and reduce root burning and dieback.

3. The first row of sod shall be laid in a straight line with subsequent rows placed parallel to and butting tightly against each other. Lateral joints shall be staggered to promote more uniform growth and strength. Care shall be exercised to ensure that sod is not stretched or overlapped and that all joints are butted tight in order to prevent voids which would cause drying of the roots.

4. On slopes 3:1 or greater, or wherever erosion may be a problem, sod shall be laid with staggered joints and secured by stapling or other approved methods. Sod shall be installed with the length perpendicular to the slope (on the contour).

5. As sodding of clearly defined areas is completed, sod shall be rolled or tamped to provide firm contact between roots and soil.

6. After rolling, sod shall be irrigated to a depth sufficient that the underside of the sod pad and the soil 4 inches below the sod is thoroughly wet.

7. Until such time a good root system becomes developed, in the absence of adequate rainfall, watering shall be performed as often as necessary to maintain moist soil to a depth of at least 4 inches.

8. The first mowing shall not be attempted until the sod is firmly rooted, usually 2-3 weeks. Not more than one third of the grass leaf shall be removed at any one cutting.

TABLE 3.33-A

TYPE OF SOD AVAILABLE IN VIRGINIA AND RECOMMENDED USES

Kentucky Bluegrass: Adapted to the Northern Piedmont and Mountain Regions. Individual varieties selected must make up not less than 10%, nor more than 35% of the total mixture on a weight basis. All varieties must be certified. Selections can be made from Category I alone or various combinations of Categories I, II and III, as noted.

Category I - Recommended Kentucky Bluegrass Varieties

65% - 100% A-34, Abbey, Aspen, Asset, Baron, Blacksburg, Bristol, Cheri, Chateau, Classic, Coventry, Georgetown, Glade, Haga, Julia, Liberty, Loft's 1757, Merit, Midnight, Monopoly, Plush, Princeton 104, Rugby, Suffolk, Victa

Category II - Special use varieties. If used, must contain at least 65% Category I varieties

Shade Tolerant

10-35% Bristol, Columbia, Georgetown, Glade, Midnight

Low-Maintenance Tolerant

10-35% Columbia, Georgetown, Monopoly, Ram I, Touchdown, Victa

Category III - Promising Kentucky Bluegrass - Limited performance data or seed availability

10-35% Dawn, Estate, Freedom, Kelly

(continued)

TABLE 3.33-A (CONTINUED)

TYPE OF SOD AVAILABLE IN VIRGINIA AND RECOMMENDED USES

Tall Fescue: Adapted to the entire state.

Recommended Tall Fescue Varieties:

90-100%	Amigo, Apache, Bonanza, Chieftain, Finelawn 5GL, Mesa, Rebel II, Shenandoah, Tribute

Promising Tall Fescues

Certified Arriba, Austin, Avanti, Aztec, Cochise, Crossfire, Eldorado, Hubbard 87, Jaguar II, Maverick II, Monarch, Olympic II, Phoenix, Safari, Shortstop, Sundance, Taurus, Thoroughbred, Titan, Tradition, Vegas, Winchester, Wrangler

0-10%	Kentucky bluegrass: Baron, Cheri, Columbia, Monopoly, Nassau, Ram I, Victa

Bermudagrass: Tufcote is adapted to the Richmond-Danville-Newport News triangle. Midiron may be used east of Roanoke and south of Charlottesville. Tifgreen and Tifway may be used to the east and south of Richmond. Vamont may be used east of Roanoke and at lower elevations in southwestern Virginia.

Certified Midiron, Tifgreen#, Tifway, Tifway II, Tufcote and Vamont

Zoysiagrass: This sod performs best in southeastern Virginia.

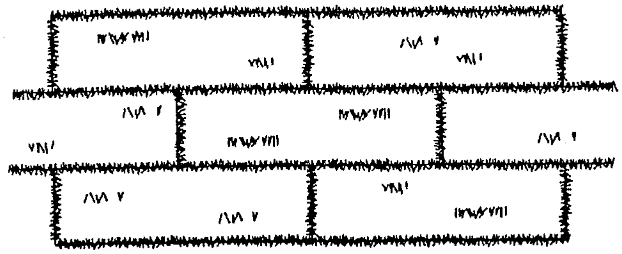
Meyer, Emerald#

Note: Common Bermudagrass is not recommended for sod production.

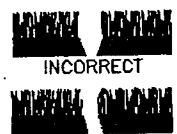
Only recommended in southeastern Virginia.

Source: 1991 Virginia Turfgrass Variety Recommendations, Virginia Crop Improvement Association

SODDING

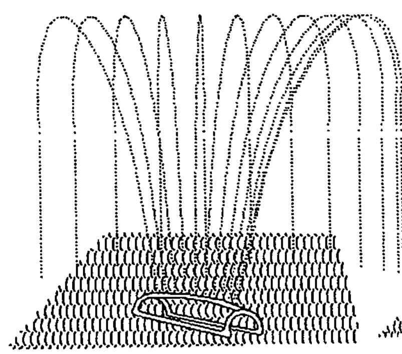


LAY SOD IN A STAGGERED PATTERN. BUTT THE STRIPS TIGHTLY AGAINST EACH OTHER. DO NOT LEAVE SPACES AND DO NOT OVERLAP. A SHARPENED MASON'S TROWEL IS A HANDY TOOL FOR TUCKING DOWN THE ENDS AND TRIMMING PIECES.

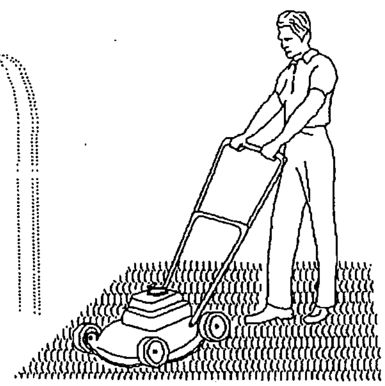


BUTTING – ANGLED ENDS CAUSED BY THE AUTOMATIC SOD CUTTER MUST BE MATCHED CORRECTLY.

ROLL SOD IMMEDIATELY TO ACHIEVE FIRM CONTACT WITH THE SOIL.

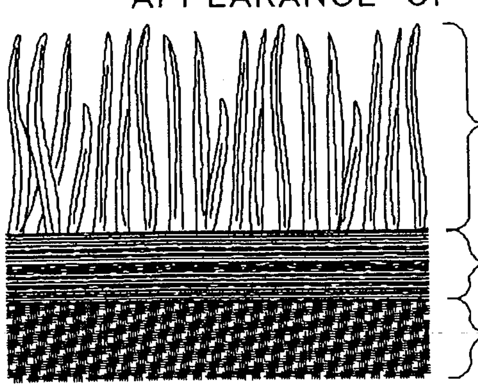


WATER TO A DEPTH OF 4" AS NEEDED. WATER WELL AS SOON AS THE SOD IS LAID.



MOW WHEN THE SOD IS ESTABLISHED – IN 2–3 WEEKS. SET THE MOWER HIGH (2"–3").

APPEARANCE OF GOOD SOD



SHOOTS OR GRASS BLADES. GRASS SHOULD BE GREEN AND HEALTHY, MOWED AT A 2"–3" CUTTING HEIGHT.

THATCH – GRASS CLIPPINGS AND DEAD LEAVES, UP TO 1/2" THICK.

ROOT ZONE – SOIL AND ROOTS. SHOULD BE 1/2"–3/4" THICK, WITH DENSE ROOT MAT FOR STRENGTH.

Source: Va. DSWC

Plate 3.33-1

Sodded Waterways

1. Care should be taken to prepare the soil adequately in accordance with this specification. The sod type shall consist of plant materials able to withstand the designed velocity (see STORMWATER CONVEYANCE CHANNELS, Std. & Spec. 3.17).

2. Sod strips in waterways shall be laid perpendicular to the direction of flow. Care should be taken to butt ends of strips tightly.

3. After rolling or tamping, sod shall be pegged or stapled to resist washout during the establishment period. Jute mesh or other netting may be pegged over the sod for extra protection in critical areas.

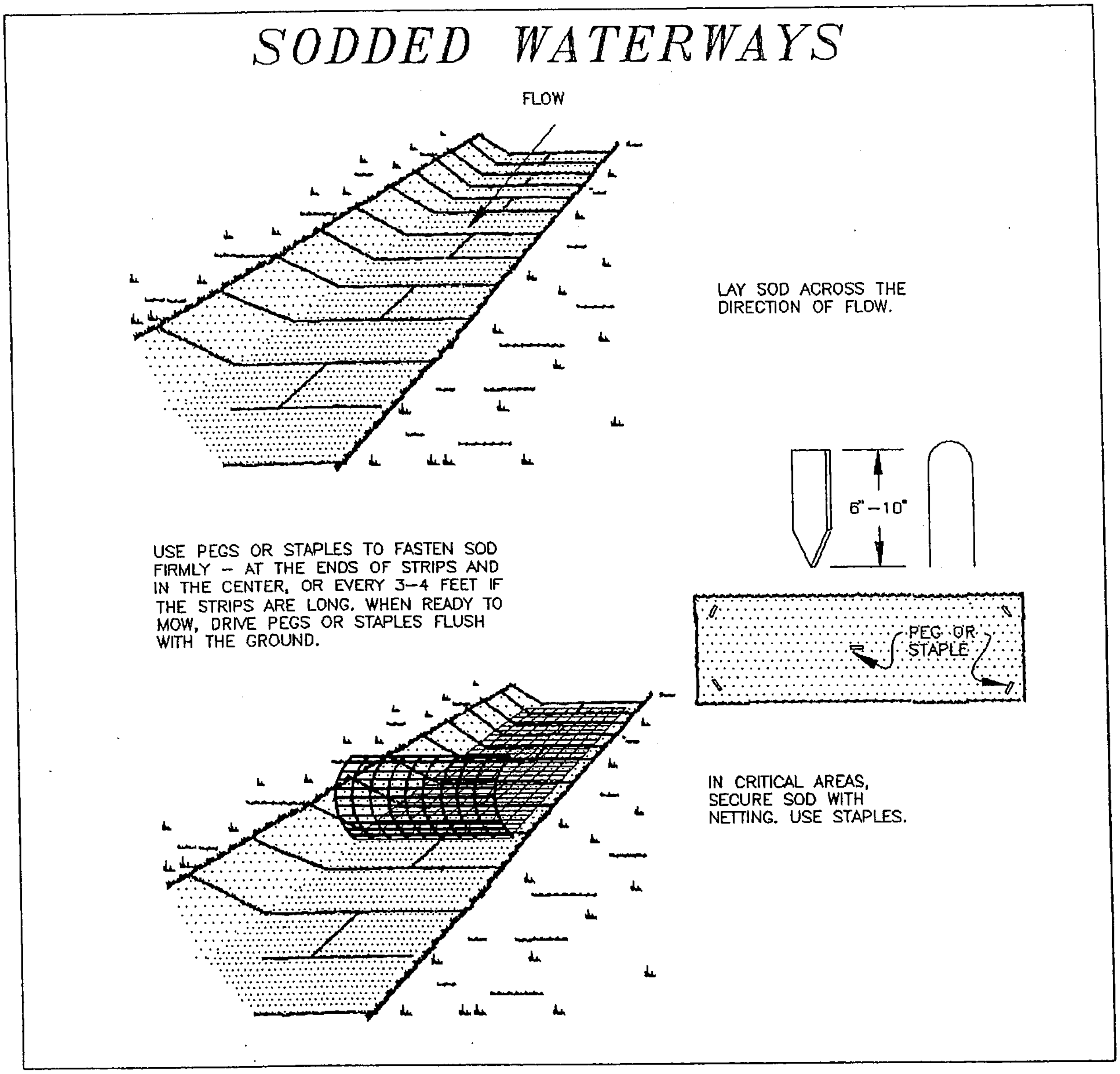
4. All other specifications for this practice shall be adhered to when sodding a waterway.

Maintenance of Established Sod

1. During the 2 to 3 week establishment stage, sod shall be watered as necessary to maintain adequate moisture in the root zone and prevent dormancy of sod.

2. No more than one third of the shoot (grass leaf) should be removed in any mowing. Grass height should be maintained between 2 and 3 inches unless otherwise specified.

3. After the first growing season, established sod will require fertilization and may require lime. Follow soil test recommendations when possible, or apply maintenance levels as outlined in Table 3.33-B.



Source: Va. DSWC

Plate 3.33-2

TABLE 3.33-B

MAINTENANCE FERTILIZATION OF ESTABLISHED SOD

Cool Season Grasses

4 lbs. nitrogen (N) per 1000 sq. ft./year
1 lb. phosphorus (P) per 1000 sq. ft./year
2 lbs. Potash (K) per 1000 sq. ft./year

75% of the total requirements should be applied between September 1 and December 31st. The balance should be applied during the remainder of the year.

Warm Season Grasses

Apply 4-5 lbs. nitrogen (N) per 1000 sq. ft. per year (between May 1st and August 15th).

Phosphorus (P) and Potash (K) should only be applied according to soil tests.

Maintenance fertilizations should utilize slow release fertilizers which reduce the number of applications per year and subsequently reduce the adverse impacts on groundwater.

Source: Va. DSWC

STD & SPEC 3.34

BERMUDAGRASS & ZOYSIAGRASS ESTABLISHMENT

BE or ZE

Definition

The establishment of vegetative cover with hybrid Bermudagrass or Zoysiagrass by planting sprigs, stolons, or plugs.

Purposes

1. To reduce erosion and decrease sediment yield from disturbed areas.

2. To stabilize disturbed areas with a specific plant material suited to the site at a cost of less than would be incurred by installing sod.

3. To establish vegetative cover more rapidly than would be possible using seed.

Conditions Where Practice Applies

1. In areas where hybrid Bermudagrass or Zoysiagrass is the desired plant material, and establishment with sod is not preferred.

2. Bermudagrass and Zoysiagrass are particularly suited to droughty, sandy sites or situations where high salt content is a problem. They should not be used in shaded areas or on poorly drained sites.

3. Where irrigation can be made available during the establishment phase.

Planning Considerations

Bermuda and Zoysia are warm season, permanent grasses which are well-suited to erosion control, as they have vigorous rhizomes and stolons (runners). There are two types of Bermudagrass grown in Virginia, common and hybrid.

Common Bermudagrass produces seed and may be established with seed. However, it has the potential to become a weed problem because it spreads vigorously; it is also coarse and not suitable for fine turf. Common Bermuda has little cold tolerance and winterkills frequently.

Hybrid Bermudagrasses and Zoysiagrass are established mainly by sodding, sprigging, or plugging. There are recent developments in the turf industry that have allowed hybrid Bermuda stands to be established from seed; however, the technology is relatively new. These grasses produce a fine, tight turf, do not spread as vigorously as common Bermudagrass, exhibit good cold tolerance, and can withstand many adverse conditions. For these reasons, hybrid Bermudagrass and Zoysiagrass are the warm season permanent turf grasses of choice for Virginia.

> Sprigging: A sprig is a small section of rhizome (underground stem) 3 to 5 inches long, with at least one node or joint. Leaves should be present at the nodes. Stolons (runners) are above-ground stems that spread by creeping on the soil surface. A mixture of sprigs and stolons is usually used in "sprigging". Sprigs may be planted by machine or hand.
>
> Plugging: Plugs are small sections of sod which are pressed into precut holes in the soil so that topgrowth is flush to the surface and leaves are exposed. Plugs are usually planted by hand; however, plugging machines are also available.

Notably, where speed is essential and cost is not an overriding constraint, sod should be used (see SODDING, Std. & Spec. 3.33).

Both Zoysia and Bermuda are particularly suited to use in grasslined waterways. Depending upon the soil type, an established stand of can tolerate intermittent concentrated flows of water on slopes up to 10%. It is important to divert runoff from the waterway during the first three weeks of establishment to permit the grass to take root. If this cannot be done, the center of the waterway should be sodded to prevent washout.

Bermudagrass is drought-tolerant, salt-tolerant, and tolerates floods of short duration. It prefers a pH range from 6.0-7.0 with high nitrogen fertilization during the growing season. Most Bermudagrasses are adapted to the warmer climates in Southeastern Virginia; however, turf research has developed several varieties that continue to perform very well in the western part of the state. Currently, varieties of all Bermudagrass will be dormant in winter and will turn brown at that time.

The Bermudagrass hybrids most frequently used in Virginia differ in appearance, cold tolerance, and suitability for turf use. The following varieties are suggested for rough and fine-turf areas:

For Rough Areas

Midland: A cold-hardy variety adapted in all areas of the state at medium to low elevations. Adapted for forage production, this is a tall-growing Bermuda (12-18 inches) and should be used in low-maintenance areas.

Coastal: Also a forage type, for low-maintenance areas. Can be used as far west and north as Chatham, Charlotte Courthouse, and Warsaw but will winterkill during severe winters at these locations.

For Fine-Turf Areas

Midiron: A fine-turf type. Has a good chance of surviving most winters as far west and north as Blacksburg and Charlottesville.

Vamont: Similar cold tolerance and texture to Midiron but far more aggressive.

Tufcote: A fine-turf type. Less cold-hardy than Midiron.

Tifway: A fine-textured turf type. Good survival east and south of Richmond in most years. Not as cold-hardy as Tufcote.

Research continues on the ways to successfully establish Zoysiagrass in Virginia. It has been determined that Zoysia has limited potential for use in athletic field development due to recovery problems and slow establishment. Establishment is commonly achieved by sprigs or plugs and seeds pre-treated with potassium hydroxide. The following varieties are presently listed on the VCIA recommended list:

Meyer: A broad blade is prevalent. This variety is considered more winter-hardy than others.

Emerald: A fine-turf type. A much finer blade than that found on Meyer. This variety is also much less winter-hardy.

Specifications

Soil Preparation

Procedures for preparing the soil are the same for sprigging and plugging.

1. Bermuda and Zoysia require soil which is well drained, loose enough for root penetration, has a pH range between 6.0-7.0, and is free of toxic amounts of materials harmful to plant growth. If any of these criteria cannot be met, topsoil shall be applied in accordance with TOPSOILING, Std. & Spec. 1.61.

2. Necessary erosion and sediment control practices will be installed prior to establishment of Bermudagrass. Final grading will be carried out according to the approved plan.

3. Surfaces will be roughened in accordance with SURFACE ROUGHENING, Std. & Spec. 3.29.

4. The soil shall be free of debris, trash, large roots, and weeds.

Lime and Fertilizer

Soil tests should be made to determine the exact requirements for lime and fertilizer. Soil tests may be conducted by the State Laboratory at VPI&SU or a reputable commercial laboratory. Information on state soil tests is available from county or city agricultural extension agents.

Under difficult circumstances where it is not possible to obtain a soil test, the following soil amendments shall be made:

> Pulverized agricultural limestone: 90 lbs./1,000 sq. ft.
> (2 tons/acre). An agricultural grade of limestone should be used.
>
> Fertilizer: Apply 1000 lbs. 10-10-10/acre and follow with additional nitrogen application as indicated by soil test conducted 30-60 days later.
>
> Note: Equivalent nutrients may be applied with other fertilizer formulations.

These amendments shall be spread evenly over the area to be sprigged, and incorporated into the top 3-6 inches of the soil by discing, harrowing or other acceptable means.

Any irregularities in the soil surface resulting from topsoiling or other operations shall be filled or leveled in order to prevent the formation of water pockets.

Soil preparation, liming, and fertilizing should be completed before delivery of sprigs or sod is requested. This material is perishable and should not remain on a pallet or in crates longer than 36 hours from the time of digging. The presence of mildew or distinct yellowing of the leaves is usually a good indication of damage to turf.

Sprigging and Plugging

Sources

Sprigs can be purchased as sod and then shredded or can often be purchased by the bushel. For turf-type Bermudagrasses, Certified or Approved sod sources (bearing the label of the VCIA) should be used. Plugs may be cut from sod as needed or purchased pre-cut. Coastal and Midland Bermudagrasses may be available through agricultural sources. Interested persons should contact the county or city agricultural extension agent or the USDA-SCS district office for information on where these materials may be obtained. Sprigs shall be 3 to 5 inches long, having several nodes (joints). Plugs shall have a minimum diameter of 2 inches.

Quantities of Material Needed

Sprigging: 8-12 bushels/1,000 sq. ft. or 350-500 bushels/acre. One bushel of sprigs is approximately equal to 1 sq. yd. of sod (with soil removed).

Plugging: About 12 sq. yds. of sod for 1,000 sq. ft., or 530 sq. yds. of sod for one acre.

When to Plant

To establish quickly, many feel Bermudagrass should not be in a dormant state (leaves should be green). However there is research that shows some success with dormant installations. Nonetheless, in order that plants may develop adequate root structure before cold weather begins, plantings should be made no later than midsummer. May 1 through July 15 is the optimum season for Bermudagrass establishment. Some cultivars may be established as late as mid-August in the southeastern part of the state.

How to Plant

Sprigging: Sprigs may be broadcast over the surface by hand, planted in rows by machine, or applied with a hydrosprigger. Machines are available which will insert sprigs properly and firm the soil over them. When sprigs are broadcast or hydrosprigged, they should be partially covered with soil by light discing or topdressing with good soil. Ideally, half of the sprig should be covered with soil, and half (including some leaves) should be exposed. Soil should be firmed over the sprigs by using a cultipacker, or by rolling or tamping. When planted in rows, sprigs should be placed no more than 12 inches apart in rows which are 12 to 18 inches apart. Closer spacing is recommended for slopes, waterways, and highly erodible soils.

Plugging: Plugs should be inserted in the soil surface so that leaf tips are above the surrounding soil, and tamped firmly in place. Plugs should be placed in a grid pattern on 12- to 18-inch centers. Closer spacing is recommended on critical areas. Plugs are usually placed by hand, but machines are available which can plug automatically.

Helpful Hints

The following are essential for good Bermudagrass or Zoysiagrass growth:

1. Adequate moisture - water immediately after planting, and water enough to keep soil moist to a depth of 4 inches during the first 4 weeks and as needed thereafter to sustain growth.

2. Sunlight - do not permit mulches, other plantings, etc. to shade new Bermudagrass stands.

3. Freedom from erosive forces - keep concentrated flows of water off of new plantings for 2 weeks to one month.

Weed Control

In order to become effectively established, Bermudagrass must not have to compete with weeds for sunlight, water, or space. Cultivating is impractical as growing stolons may be injured.

Oxadiazon or equivalent, applied immediately following sprigging at a rate of 100-150 lbs./acre (depending on time of year), gives excellent control of most broadleaf and grassy weeds; use 2-3 lbs. of active ingredient/acre. For control of broadleaf weeds only, apply Dicamba (1/4 to 1/2 lb. active ingredient/acre) and 2,4-D (1 lb. active ingredient/acre). Use these herbicides when weeds are 2- to 3-inches tall, but not before grass is well-rooted.

Maintenance

Bermudagrass and Zoysiagrass sprigs and plugs can be expected to root in 5 to 10 days under optimum conditions. Full coverage of the soil by spreading plants can be obtained in 8-12 weeks with good growing conditions and proper maintenance.

Stands may be mowed when growth requires it. Coastal and Midland growths may be left unmowed except for once-a-year trimming to 6 inches. Turf-type Bermudagrasses may be cut at 1 to 1½ inches.

For maintenance purposes, apply 1 lb. actual nitrogen/1000 sq. ft. at 30-45 day intervals after initial installation until August 15th. Fertilizer must be of a type in which 50% or more of the nitrogen is water-insoluble.

STD & SPEC 3.35

MULCHING

MU

Definition

Application of plant residues or other suitable materials to the soil surface.

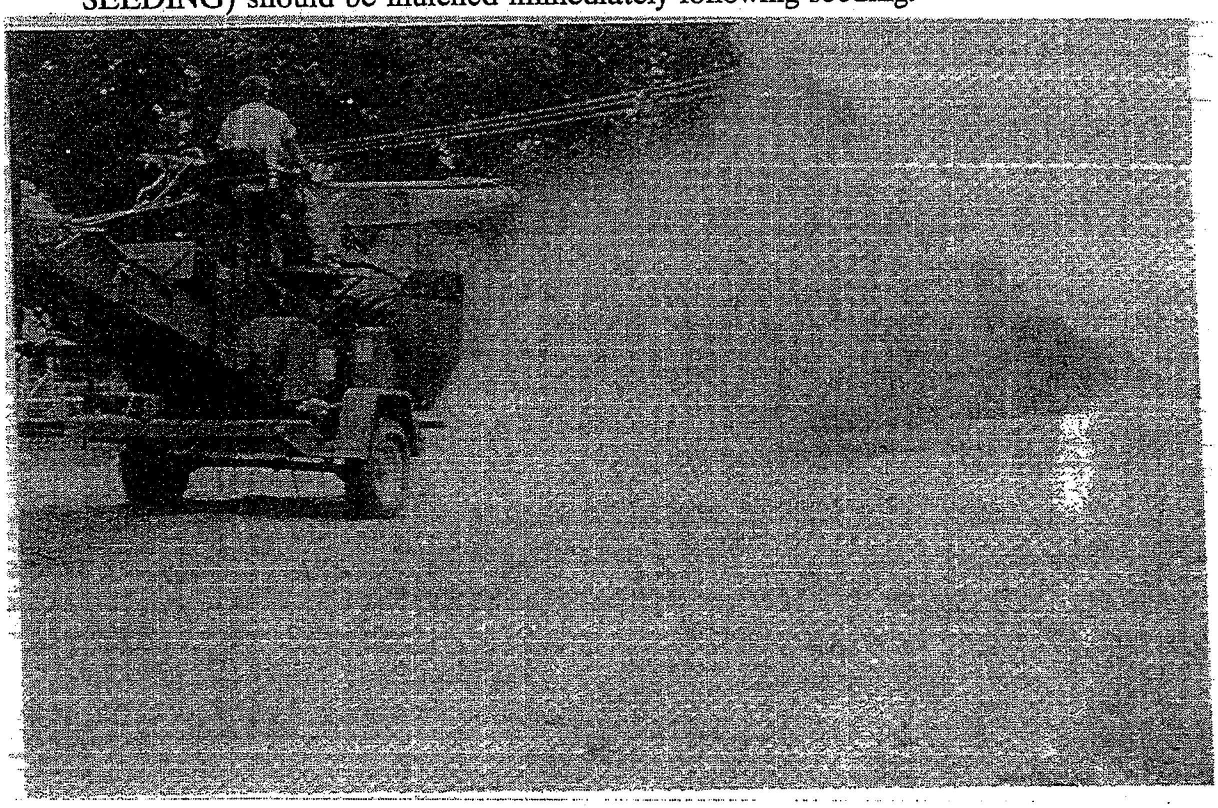
Purposes

1. To prevent erosion by protecting the soil surface from raindrop impact and reducing the velocity of overland flow.

2. To foster the growth of vegetation by increasing available moisture and providing insulation against extreme heat and cold.

Conditions Where Practice Applies

1. Areas which have been permanently seeded (see Std. & Spec. 3.32, PERMANENT SEEDING) should be mulched immediately following seeding.



2. Areas which cannot be seeded because of the season should be mulched to provide some protection to the soil surface. An organic mulch should be used, and the area then seeded as soon weather or seasonal conditions permit. It is not recommended that fiber mulch be used alone for this practice; at normal application rates it just simply does not provide the protection that is achieved using other types of mulch.

3. Mulch may be used together with plantings of trees, shrubs, or certain ground covers which do not provide adequate soil stabilization by themselves.

4. Mulch shall be used in conjunction with temporary seeding operations as specified in TEMPORARY SEEDING, Std. & Spec. 3.31.

Planning Considerations

Mulches are applied to the soil surface to conserve a desirable soil property or to promote plant growth. A surface mulch is one of the most effective means of controlling runoff and erosion on disturbed land.

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination.

Organic mulch materials, such as straw, wood chips, bark, and fiber mulch have been found to be the most effective.

Chemical soil stabilizers or soil binders should not be used alone for mulch. These materials are useful to bind organic mulches together to prevent displacement.

A variety of manufactured SOIL STABILIZATION BLANKETS AND MATTING (see Std. & Spec. 3.36) have been developed for erosion control in recent years. Some of these products can be used as mulches, particularly in critical areas such as waterways. They also may be used to hold other mulches to the soil surface.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season and economics. It is especially important to mulch liberally in mid-summer and prior to winter, and on cut slopes and southern slope exposures.

Organic Mulches

Straw - The mulch most commonly used in conjunction with seeding. The straw should come from wheat or oats (free of troublesome weed seeds) and may be spread by hand or machine. Straw can be windblown and must be anchored down by an acceptable method.

Hay - May be used in lieu of straw where volunteers will not present a problem, and may be spread by hand or machine. Hay can be windblown and must also be anchored or tacked down.

Corn Stalks - These should be shredded into 4- to 6-inch lengths. Stalks decompose slowly and are resistant to displacement.

Wood Chips - Suitable for areas that will not be closely mowed, and around ornamental plantings. Chips decompose slowly and do not require tacking. They must be treated with 12 pounds of nitrogen per ton to prevent nutrient deficiency in plants; however, can be a very inexpensive mulch if chips are obtained from trees cleared on the site.

Bark Chips, Shredded Bark - These are by-products of timber processing which are used in landscaped plantings. Bark is also a suitable mulch for areas planted to grasses and not closely mowed. It may be applied by hand or mechanically and is not usually toxic to grasses or legumes; additional nitrogen fertilizer is not required.

Fiber Mulch - Used in hydroseeding operations and applied as part of the slurry. It creates the best seed-soil contact when applied over top of (as a separate operation) newly seeded areas. These fibers do not require tacking, although tacking agents or binders are sometimes used in conjunction with the application of fiber mulch. This form of mulch does not provide sufficient protection to highly erodible soils. Additionally, fiber mulch will not be considered adequate mulch when used during the dry summer months or when used for late fall mulch cover. Use straw mulch during these periods. Fiber mulch may be used to tack (anchor) straw mulch. This treatment is well suited for steep slopes, critical areas, and areas susceptible to displacement.

There are other organic materials which make excellent mulches but are only available locally or seasonally. Creative use of these materials can reduce costs.

Chemical Mulches and Soil Binders

A wide range of synthetic, spray-on materials are marketed to stabilize and protect the soil surface. These are emulsions or dispersions of vinyl compounds, rubber or other substances which are mixed with water and applied to the soil. They may be used alone in some cases as temporary stabilizers, or in conjunction with fiber mulches or straw.

When used alone, chemical mulches do not have the capability to insulate the soil or retain soil moisture that organic mulches have. This soil protection is also easily damaged by traffic. Application of these mulches is usually more expensive than organic mulching, and the mulches decompose in 60-90 days.

Blankets and Matting

Field experience has shown that plastic netting, when used alone, does not retain soil moisture or modify soil temperature. In some cases it may stabilize the soil surface while grasses are being established, but is primarily used in grassed waterways and on slopes to hold straw or similar mulch in place.

Jute mesh and other soil stabilization blankets are good choices for mulching on difficult slopes and in minor drainage swales. Most of the soil stabilization mattings (used to create a permanent matrix for root growth within the soil) must receive mulching in order to properly stabilize an area. Notably, some manufacturers have recently developed permanent mattings which include self-contained, temporary mulching materials; however, these measures will have to meet the requirements noted in Std. & Spec. 3.36, SOIL STABILIZATION BLANKETS AND MATTING, before they can be recommended for use on steep slopes and in channel flow situations.

The most critical aspect of installing blankets and mats is obtaining firm, continuous contact between the material and the soil. Without such contact, the material may fail and thereby allow erosion to occur. It is important to use an adequate number of staples and make sure the material is installed properly in order to maximize soil protection. These products are discussed in more detail in Std. & Spec. 3.36, SOIL STABILIZATION BLANKETS & MATTING.

Specifications

Organic Mulches

Organic mulches may be used in any area where mulch is required, subject to the restrictions noted in Table 3.35-A.

Materials: Select mulch material based on site requirements, availability of materials, and availability of labor and equipment. Table 3.35-A lists the most commonly used organic mulches. Other materials, such as peanut hulls and cotton burs, may be used with the permission of the local Plan-Approving Authority.

Prior to mulching: Complete the required grading and install needed sediment control practices.

Lime and fertilizer should be incorporated and surface roughening accomplished as needed. Seed should be applied prior to mulching except in the following cases:

a. Where seed is to be applied as part of a hydroseeder slurry containing fiber mulch.

b. Where seed is to be applied following a straw mulch spread during winter months.

TABLE 3.35-A

ORGANIC MULCH MATERIALS AND APPLICATION RATES

MULCHES:	RATES:		NOTES:
	Per Acre	Per 1000 sq. ft.	
Straw or Hay	1½ - 2 tons (Minimum 2 tons for winter cover)	70 - 90 lbs.	Free from weeds and coarse matter. Must be anchored. Spread with mulch blower or by hand.
Fiber Mulch	Minimum 1500 lbs.	35 lbs.	Do not use as mulch for winter cover or during hot, dry periods.* Apply as slurry.
Corn Stalks	4 - 6 tons	185 - 275 lbs.	Cut or shredded in 4-6" lengths. Air-dried. Do not use in fine turf areas. Apply with mulch blower or by hand.
Wood Chips	4 - 6 tons	185 - 275 lbs.	Free of coarse matter. Air-dried. Treat with 12 lbs nitrogen per ton. Do not use in fine turf areas. Apply with mulch blower, chip handler, or by hand.
Bark Chips or Shredded Bark	50 - 70 cu. yds.	1-2 cu. yds.	Free of coarse matter. Air-dried. Do not use in fine turf areas. Apply with mulch blower, chip handler, or by hand.

* When fiber mulch is the only available mulch during periods when straw should be used, apply at a minimum rate of 2000 lbs./ac. or 45 lbs./1000 sq. ft.

Source: Va. DSWC

Application: Mulch materials shall be spread uniformly, by hand or machine.

When spreading straw mulch by hand, divide the area to be mulched into approximately 1,000 sq. ft. sections and place 70-90 lbs. (1½ to 2 bales) of straw in each section to facilitate uniform distribution.

Mulch Anchoring: Straw mulch must be anchored immediately after spreading to prevent displacement. Other organic mulches listed in Table 3.35-A do not require anchoring. The following methods of anchoring straw may be used:

1. Mulch anchoring tool (often referred to as a Krimper or Krimper Tool): This is a tractor-drawn implement designed to punch mulch into the soil surface. This method provides good erosion control with straw. It is limited to use on slopes no steeper than 3:1, where equipment can operate safely. Machinery shall be operated on the contour.

2. Fiber Mulch: A very common practice with widespread use today. Apply fiber mulch by means of a hydroseeder at a rate of 500-750 lbs./acre over top of straw mulch or hay. It has an added benefit of providing additional mulch to the newly seeded area.

3. Liquid mulch binders: Application of liquid mulch binders and tackifiers should be heaviest at edges of areas and at crests of ridges and banks, to prevent displacement. The remainder of the area should have binder applied uniformly. Binders may be applied after mulch is spread or may be sprayed into the mulch as it is being blown onto the soil.

   The following types of binders may be used:

   a. Synthetic binders - Formulated binders or organically formulated products may be used as recommended by the manufacturer to anchor mulch.

   * b. Asphalt - Any type of asphalt thin enough to be blown from spray equipment is satisfactory. Recommended for use are rapid curing (RC-70, RC-250, RC-800), medium curing (MC-250, MC-800) and emulsified asphalt (SS-1, CSS-1, CMS-2, MS-2, RS-1, RS-2, CRS-1, and CRS-2).

      Apply asphalt at 0.10 gallon per square yard (10 gal./1000 sq. ft. or 430 gal./acre). Do not use heavier applications as it may cause the straw to "perch" over rills. All asphalt designations are from the Asphalt Institute Specifications.

* Note: This particular method is not used as commonly today as it once was in the past. The development of hydraulic seeding equipment promoted the industry

to turn to synthetic or organically based binders and tackifiers. When this method is used, environmental concerns should be addressed to ensure that petroleum-based products do not enter valuable water supplies. Avoid applications into waterways or channels.

4. Mulch nettings: Lightweight plastic, cotton, or paper nets may be stapled over the mulch according to manufacturer's recommendations.

5. Peg and twine: Because it is labor-intensive, this method is feasible only in small areas where other methods cannot be used. Drive 8- to 10-inch wooden pegs to within 3 inches of the soil surface, every 4 feet in all directions. Stakes may be driven before or after straw is spread. Secure mulch by stretching twine between pegs in a criss-cross-within-a square pattern. Turn twine 2 or more times around each peg.

Chemical Mulches

Chemical mulches* may be used alone only in the following situations:

a. Where no other mulching material is available.

b. In conjunction with temporary seeding during the times when mulch is not required for that practice.

c. From March 15 to May 1 and August 15 to September 30, provided that they are used on areas with slopes no steeper than 4:1, which have been roughened in accordance with SURFACE ROUGHENING, Std. & Spec. 3.29. If rill erosion occurs, another mulch material shall be applied immediately.

* Note: Chemical mulches may be used to bind other mulches or with fiber mulch in a hydroseeded slurry at any time. Manufacturer's recommendations for application of chemical mulches shall be followed.

Maintenance

All mulches and soil coverings should be inspected periodically (particularly after rainstorms) to check for erosion. Where erosion is observed in mulched areas, additional mulch should be applied. Nets and mats should be inspected after rainstorms for dislocation or failure. If washouts or breakage occur, re-install netting or matting as necessary after repairing damage to the slope or ditch. Inspections should take place up until grasses are firmly established. Where mulch is used in conjunction with ornamental plantings, inspect periodically throughout the year to determine if mulch is maintaining coverage of the soil surface; repair as needed.

STD & SPEC 3.36

Treat. - 1

or

Treat. - 2

SOIL STABILIZATION BLANKETS & MATTING

B/M

Definition

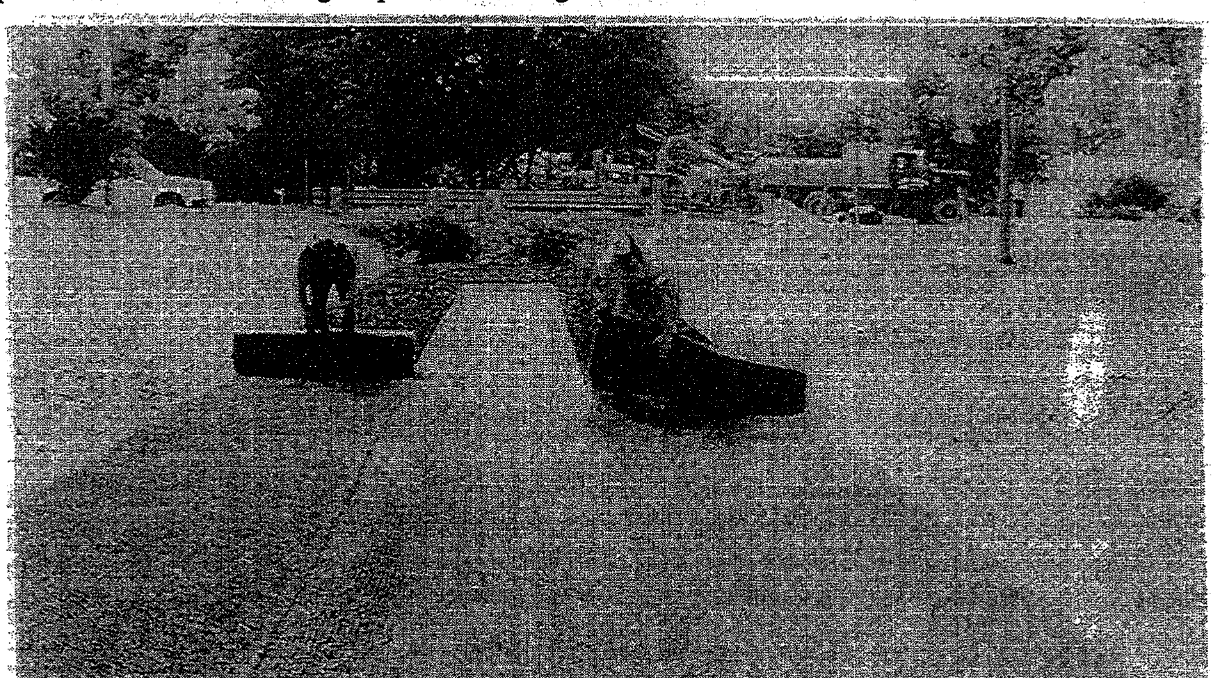
The installation of a protective covering (blanket) or a soil stabilization mat on a prepared planting area of a steep slope, channel or shoreline.

Purpose

To aid in controlling erosion on critical areas by providing a microclimate which protects young vegetation and promotes its establishment. In addition, some types of soil stabilization mats are also used to raise the maximum permissible velocity of turf grass stands in channelized areas by "reinforcing the turf" to resist the forces of erosion during storm events.

Conditions Where Practice Applies

On short, steep slopes where erosion hazard is high and planting is likely to be too slow in providing adequate protective cover; in vegetated channels where the velocity of design flow exceeds "allowable" velocity; on streambanks or tidal shorelines where moving water is likely to wash out new plantings; or in areas where the forces of wind prevent standard mulching practices from remaining in place until vegetation becomes established.



Planning Considerations

Soil stabilization blankets and mats can be applied to problem areas to supplement nature's erosion control system (vegetation) in its initial establishment and in providing a safe and "natural" conveyance for high velocity stormwater runoff. They are being used today in many applications were previously a structural lining would have been required. Care must be taken to choose the type of blanket or matting which is most appropriate for the specific needs of a project. Two general types of blankets and mats are discussed within this specification. However, with the abundance of soil stabilization products available today, it is impossible to cover all the advantages, disadvantages and specifications of all manufactured blankets and mats. Therefore, as with many erosion control-type products, there is no substitute for a thorough understanding of the manufacturer's instructions and recommendations and a site visit by a designer or plan reviewer to verify a product's appropriateness.

Treatment-1 is a degradable soil stabilization blanket which includes "combination" blankets consisting of a plastic netting which covers and is intertwined with a natural organic or man-made mulch; or, a jute mesh which is typically homogeneous in design and can act alone as a soil stabilization blanket.

It should be used to help establish vegetation on previously disturbed slopes - normally problem slopes of 3:1 or greater. Since the materials which compose the soil stabilization blankets will deteriorate over time, they should be used in permanent conveyance channels with the realization that the system's resistance to erosion is based on the type of vegetation planted and the existing soil characteristics. During the establishment of vegetation, **Treatment-1** should not be subjected to shallow or deep concentrated flows moving at greater than 4 feet/second.

Treatment-1 provides the following benefits in the achievement of vegetative stabilization when properly applied over seed and required amendments:

1. Protection of the seed and soil from raindrop impact and subsequent displacement.

2. Thermal consistency and moisture retention for seedbed area.

3. Stronger and faster germination of grasses and legumes.

4. Planing off excess stormwater runoff.

5. Prevention of sloughing of topsoil added to steeper slopes.

Treatment-2 is a soil stabilization matting which consists of a non-degradable, 3-dimensional plastic structure which can be filled with soil prior to planting. This configuration provides a matrix for root growth where the matting becomes entangled and penetrated by roots, forming continuous anchorage for surface growth and promoting enhanced energy dissipation. **Treatment-2** can be used on problem slopes (normally 3:1 or greater), and in stormwater conveyance channels.

In addition to those benefits noted for **Treatment-1, Treatment-2** provides the following benefits in the achievement of vegetative stabilization and in the replacement of more traditional channel linings such as concrete and riprap:

1. Causes soil to drop out of stormwater and fill matrix with fine soils which become the growth medium for the development of roots.

2. When embedded in the soil within stormwater channels, it acts with the vegetative root system to form an erosion resistant cover which resists hydraulic lift and shear forces.

Since **Treatment-2** is non-degradable, it can be used in permanent conveyance channels and can withstand higher velocities of flow than the vegetation and soil would normally allow. However, a <u>10 feet/second velocity of flow</u> should be the maximum allowed in a conveyance system which utilizes **Treatment-2.**

<u>VDOT Nomenclature and Product Information</u>

The Virginia Department of Transportation has its own nomenclature for many of the standards and specifications found in this handbook; this is true in the case of soil stabilization blankets and matting. The following relationship exists between the two methods of naming the practice:

<u>Va. E&S-C Handbook</u>		<u>VDOT Specifications</u>
Treatment-1	(is equivalent to)	EC-2
Treatment-2	(is equivalent to)	EC-3

It is recommended that most current VDOT "Approved Products List" for these products be consulted prior to installation of a particular blanket or mat. Importantly, the list names those products approved for a certain <u>range of flow velocities</u> when **Treatment-2** (VDOT's EC-3) installation is contemplated.

<u>TREATMENT-1</u>: SOIL STABILIZATION BLANKET

(Allowable Velocity Range During Vegetation Establishment: 0 - 4 f.p.s.)

<u>Materials</u>

1. <u>Combination Blankets</u> - They shall consist of a photo-degradable plastic netting which covers and is entwined in a natural organic or man-made mulching material.

The mulching material shall consist of wood fibers, wood excelsior, straw, coconut fiber, or man-made fibers, or a combination of the same. The blanket shall be of consistent thickness with the mulching material/fibers evenly distributed over its entire length. The mulching material/fibers must interlock or entwine to form a dense layer which not only resists raindrop impact, but will allow vegetation to penetrate the blanket.

The blanket shall be nontoxic to vegetation and to the germination of seed and shall not be injurious to the unprotected skin of humans. At a minimum, the plastic netting must cover the top side of the blanket and possess a high web strength. The netting shall be entwined with the mulching material/fiber to maximize strength and provide for ease of handling.

2. <u>Jute Mesh</u> - It shall be of a uniform, open, plain weave, of undyed and unbleached single jute yarn. The yarn shall be of loosely twisted construction and shall not vary in thickness by more than one half of its normal diameter. Jute mesh shall be new and shall conform to the following:

   a. Length of jute mesh shall be marked on each roll.

   b. There shall be 0.60-inch openings (± 25%) between strands, lengthwise.

   c. There shall be 0.90-inch openings (± 25%) between strands, lengthwise.

   d. Weight shall average 0.90 lbs./square yard with a tolerance of 5%.

   As previously noted, jute mesh provides such good coverage (large surface area of strands) and contains such small openings that it can be used alone as a blanket.

3. <u>Other **Treatment-1** Products</u> - These shall conform to manufacturer's specifications and be approved by the Plan-Approving Authority prior to being specified for a particular application. These products should be installed in accordance with manufacturer's recommendations, <u>provided those recommendations are at least as stringent as this specification</u>. Again, it is recommended that VDOT's "Approved Products List" be consulted. In no case shall these products cover less than 30% of the soil surface.

4. <u>Staples</u> - Staples for anchoring Treatment-1 shall be No. 11-gauge wire or heavier. Their length shall be a minimum of 6 inches. A larger staple with a length of up to 12 inches should be used on loose, sandy, or unstable soils.

Installation Requirements

Site Preparation - After site has been shaped and graded to approved design, prepare a friable seedbed relatively free from clods and rocks more than 1½ inches in diameter and any foreign material that will prevent uniform contact of the protective covering with the soil surface.

Planting - Lime, fertilize, and seed in accordance with seeding or other type of planting plan. When using jute mesh on a seeded area, apply approximately one-half the seed after laying the mat. The protective covering can be laid over sprigged areas where small grass plants have been inserted into the soil. Where ground covers are to be planted, lay the protective covering first and then plant through the material as per planting design.

When open-weave nets are used, lime, fertilizer, seed and mulch should be applied before laying the net. When a combination blanket (such as an "excelsior" blanket) is used, seed and soil amendments must also be applied before the blanket is laid.

Orientation - See Plate 3.36-1 for orientation of **Treatment-1** for different topographic conditions.

Laying and Stapling (see Plate 3.36-2) - If instructions have been followed, all needed check slots will have been installed, and the protective covering will be laid on a friable seedbed free from clods, rocks, roots, etc. that might impede good contact.

1. Start laying the protective covering from the top of the channel or top of slope and unroll down-grade.

2. Allow to lay loosely on soil - do not stretch.

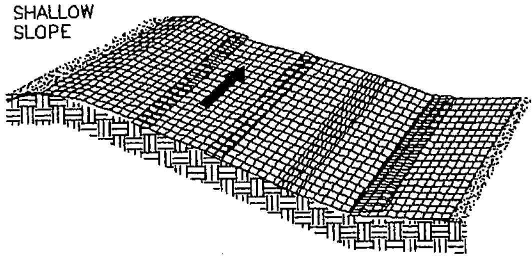
3. Upslope ends of the protective covering should be buried in a anchor slot no less than 6-inches deep. Tamp earth firmly over the material. Staple the material at a minimum of every 12 inches across the top end.

4. Edges of the material shall be stapled every 3 feet. Where multiple widths are laid side by side, the adjacent edges shall be overlapped a minimum of 2 inches and stapled together.

5. Staples shall be placed down the center, staggered with the edges at 3 foot intervals.

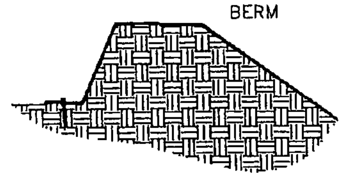
Check slots - On highly erodible soils and on slopes steeper than 4:1, erosion check slots should be made every 50 feet (see Plate 3.36-2). Insert a fold of the material (separate piece) into a 6-inch trench and tamp firmly. Staple fold to "main" blanket at minimum 12-inch intervals across the upstream and downstream portion of the blanket.

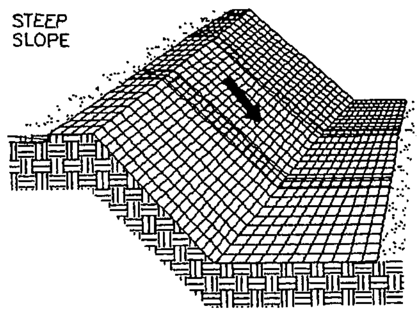
TYPICAL ORIENTATION OF TREATMENT – 1 (SOIL STABILIZATION BLANKET)



ON SHALLOW SLOPES, STRIPS OF NETTING PROTECTIVE COVERINGS MAY BE APPLIED ACROSS THE SLOPE.

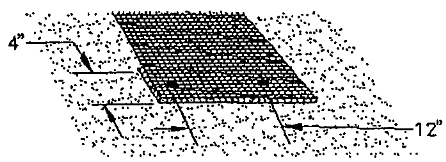
WHERE THERE IS A BERM AT THE TOP OF THE SLOPE, BRING THE MATERIAL OVER THE BERM AND ANCHOR IT BEHIND THE BERM.

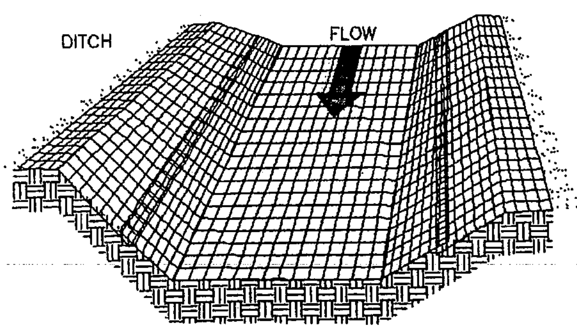




ON STEEP SLOPES, APPLY PROTECTIVE COVERING PARALLEL TO THE DIRECTION OF FLOW AND ANCHOR SECURELY.

BRING MATERIAL DOWN TO A LEVEL AREA BEFORE TERMINATING THE INSTALLATION. TURN THE END UNDER 4" AND STAPLE AT 12" INTERVALS.



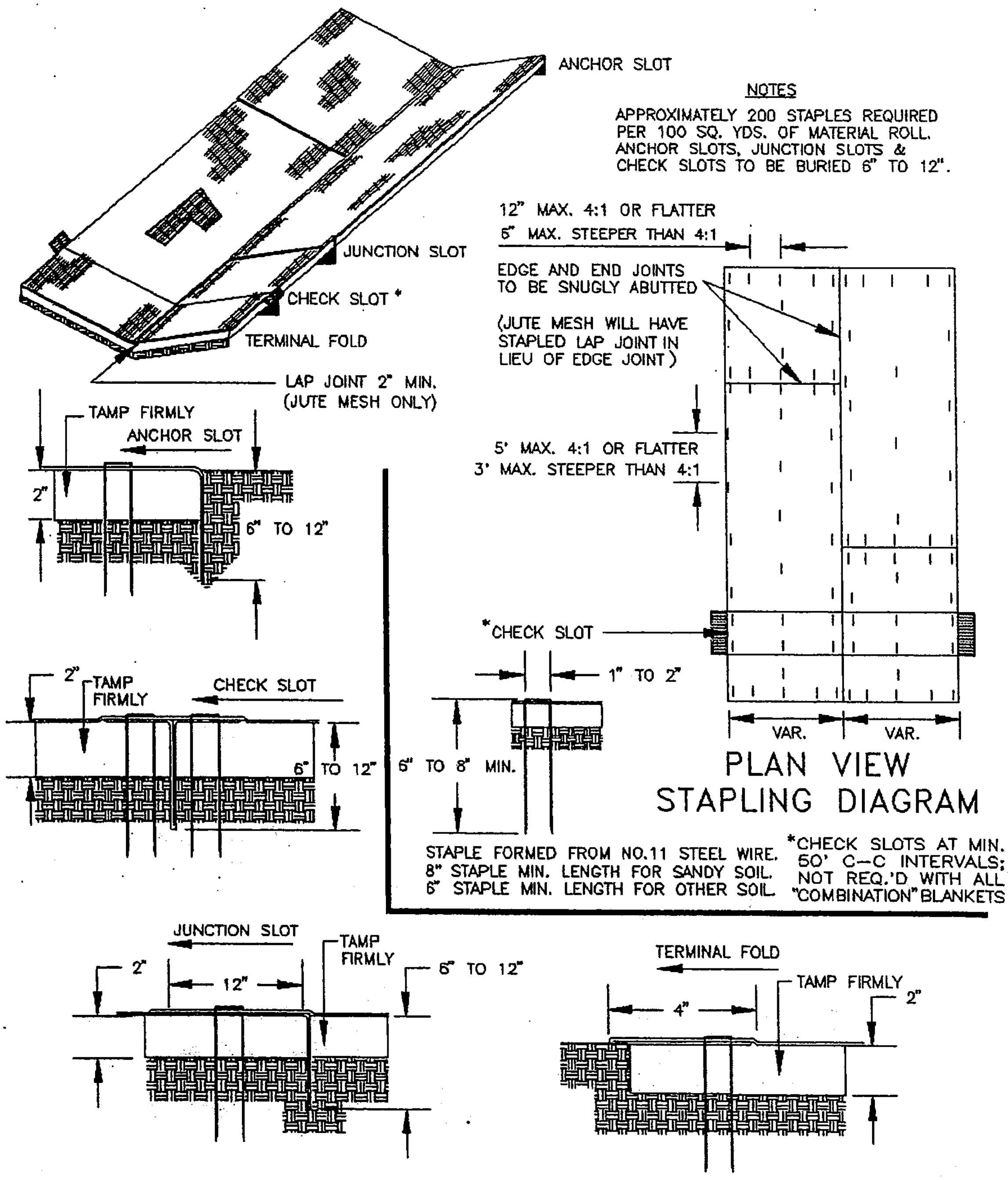


IN DITCHES, APPLY PROTECTIVE COVERING PARALLEL TO THE DIRECTION OF FLOW. USE CHECK SLOTS AS REQUIRED. AVOID JOINING MATERIAL IN THE CENTER OF THE DITCH IF AT ALL POSSIBLE.

Source: Adapted from Ludlow Products Brochure

Plate 3.36-1

TYPICAL TREATMENT – 1 (SOIL STABILIZATION BLANKET) INSTALLATION CRITERIA



Source: VDOT Road and Bridge Standards

Plate 3.36-2

Note: Many combination blankets are designed and manufactured to resist movement and uplift to a point which check slots may not be required. Plan designers and review authorities are urged to study manufacturers' recommendations and site conditions.

Joining Protective Coverings - Insert a new roll of material into an anchor slot, as with upslope ends. Overlap the end of the previous roll a minimum of 12 inches, and staple across the end of the roll just below the anchor slot and across the material every 12 inches.

Terminal End - At the point at which the material is discontinued, or at which time the protective covering meets a structure of some type, fold 4 inches of the material underneath and staple every 12 inches (minimum).

At bottom of slopes - Lead net out onto a level area before anchoring. Turn ends under 4 inches, and staple across end every 12 inches.

Final Check - These installation techniques must be adhered to:

1. Protective blanket is in uniform contact with the soil.
2. All lap joints are secure.
3. All staples are driven flush with the ground.
4. All disturbed areas have been seeded.

TREATMENT-2: SOIL STABILIZATION MATTING

(Allowable velocity range after vegetative establishment: 0 - 10 f.p.s.)

Materials

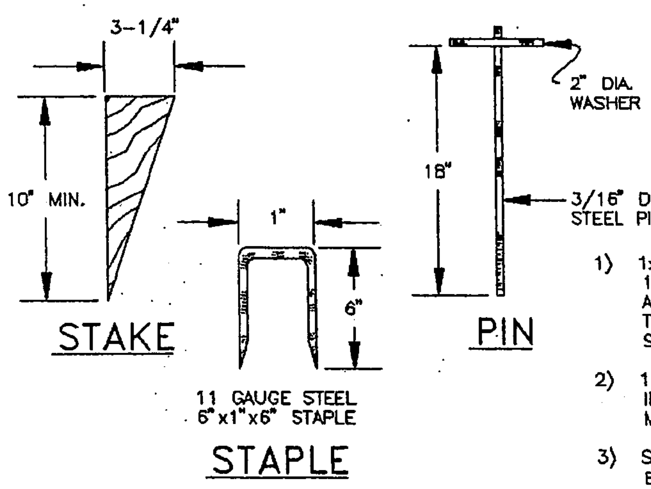
Matting - The majority of these products provide a three dimensional geomatrix of nylon, polyethylene, or randomly oriented monofilaments, forming a mat. These products contain ultra violet (UV) inhibiting stabilizers, added to the compounds to ensure endurance and provide "permanent root reinforcement."

The three dimensional feature creates an open space which is allowed to fill with soil. The roots of the grass plant become established within the mat itself, forming a synergistic root and mat system. As the grass becomes established, the two actually "reinforce" each other, preventing movement or damage to the soil. Allowable velocities are increased considerably over natural turf stands.

Selection of the appropriate matting materials along with proper installation become critical factors in the success of this practice. VDOT's "Approved Products List" can be a real asset in the selection process. Consultation with the supplier or the manufacturer and thorough evaluation of performance data to ensure proper selection of a soil stabilization matting are also essential. Although many manufacturers claim their products may inhibit erosion associated with channel velocities of up to 20 ft./sec., it is recommended that any velocities that exceed 10 ft./sec. be properly protected with some form of structural lining (see Std. & Spec. 3.17, STORMWATER CONVEYANCE CHANNEL).

Staples - Staples or anchoring methods and recommendations vary by manufacturers. The expectation of high velocities should dictate the use of more substantial anchoring. Some of the typically recommended stakes, staples and pins are depicted in Plate 3.36-3

STAKES, STAPLES, & PINS
FOR
INSTALLATION OF
TREATMENT - 2
SOIL STABILIZATION MATTING



1) 1x4 TRIANGULAR SURVEY STAKE – MINIMUM 10" IN LENGTH. PLACEMENT OF THE STAKE ACROSS THE FLOW OF THE WATER IS THOUGHT TO PROVIDE A "PINBALL EFFECT" TO HELP SLOW THE VELOCITY.
2) 11 GAUGE STEEL – MINIMUM 1" WIDE BY 6" IN LENGTH STEEL STAPLE – 2"x8" STAPLE MAY BE REQUIRED IN CERTAIN SOIL CONDITIONS.
3) STEEL PINS – 3/16 DIAMETER STEEL PIN BY 18" IN LENGTH WITH A 2" DIAMETER WASHER ON TOP. (SEE ILLUSTRATION)

Source: Product literature from Greenstreak, Inc. Plate 3.36-3

Installation Requirements

Site Preparation - After site has been shaped and graded to approved design, prepare a friable seedbed relatively free from clods and rocks more than 1 inch in diameter, and any foreign material that will prevent contact of the soil stabilization mat with the soil surface. If necessary, redirect any runoff away from the ditch or slope during installation.

Planting - Lime, fertilize and seed in accordance with MS #1 and the approved plan, paying special attention to the plant selection that may have been chosen for the matted area. If the area has been seeded prior to installing the mat, make sure and reseed all areas disturbed during installation.

Mulching - Mulch (normally straw) should be applied following installation of **Treatment-2** at rates noted in Std. & Spec. 3.35, MULCHING.

Laying and Securing - See Plates 3.36-4, 3.36-5 and 3.36-6. Similar to installing **Treatment-1**, but Plan Approving Authority's requirements or manufacturer's recommendations must be followed as detailed. The key to achieving desired performance is dependent upon proper installation.

Check Slots - See Plate 3.36-4. Matting manufacturers vary significantly in their check slot requirements. Similar to the installation of **Treatment-1**, a check slot may be required when laying **Treatment-2** to "correct" the flow of water if it has the potential to undermine the matting. Most authorities (including VDOT) require that the sides of the matting also be entrenched, creating a slope shelf for the material to rest on, preventing water from entering under the mat on the sides.

Securing the Material and Joining Mats - Again, product specifications vary - upstream and downstream terminal slots, new roll overlaps and multiple width installations differ by various products and manufacturers.

Final Check - These installation techniques must be adhered to:

1. Soil stabilization mat is in uniform contact with the soil.

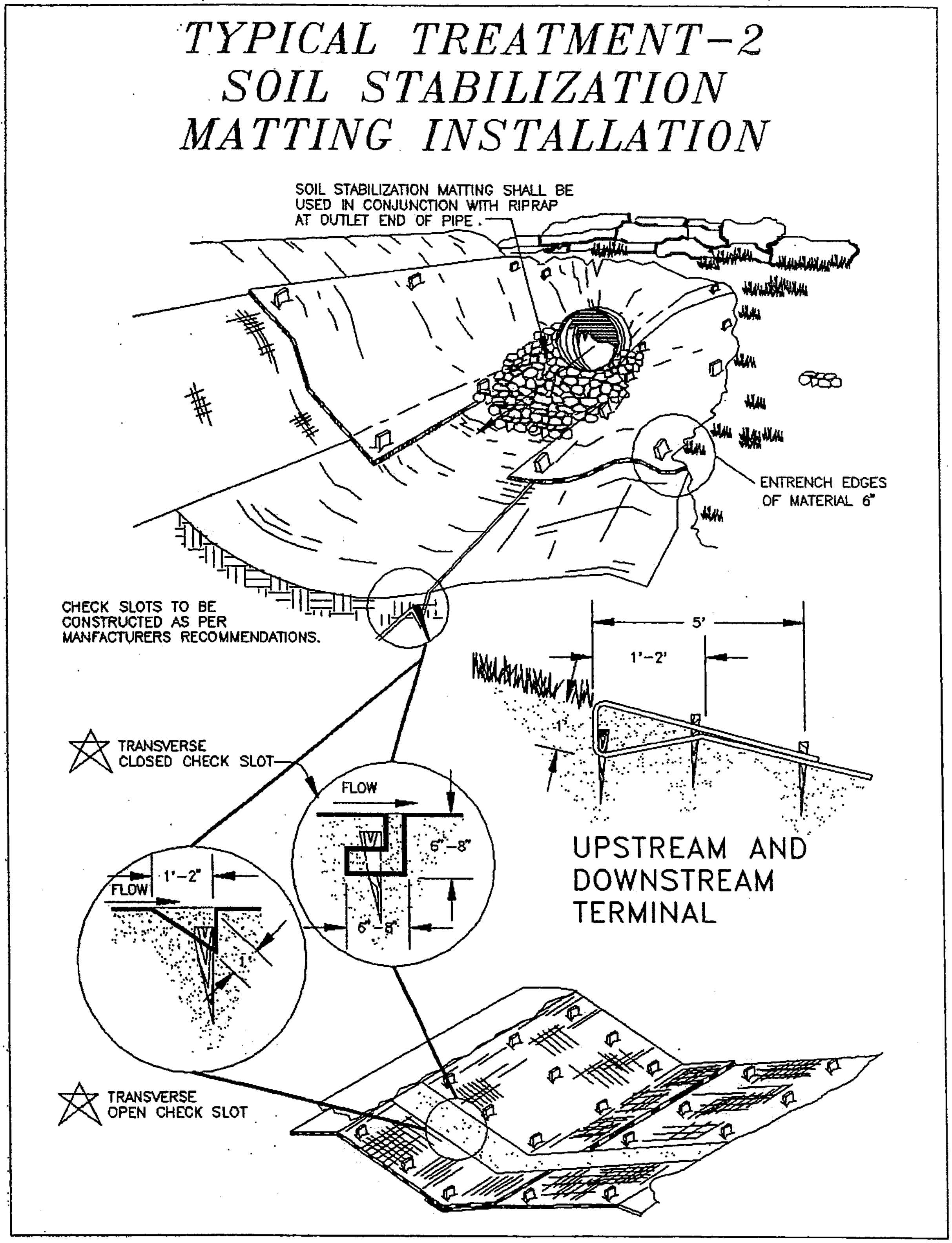
2. All required slots and lapped joints are in place.

3. The material is properly anchored.

4. All disturbed areas are seeded.

Maintenance

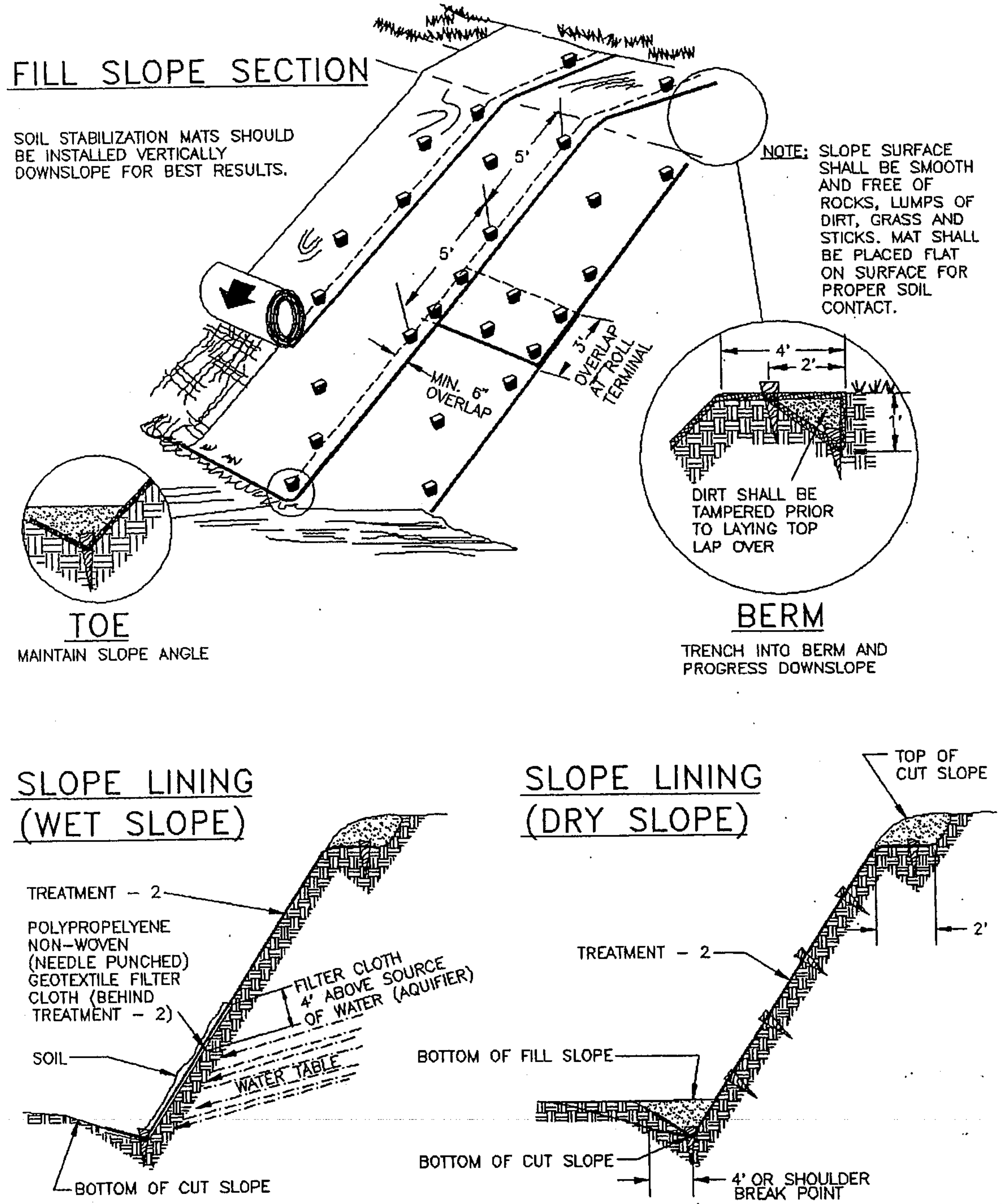
All soil stabilization blankets and matting should be inspected periodically following installation, particularly after rainstorms to check for erosion and undermining. Any dislocation or failure should be repaired immediately. If washouts or breakage occurs, re-install the material after repairing damage to the slope or ditch. Continue to monitor these areas until which time they become permanently stabilized; at that time an annual inspection should be adequate.



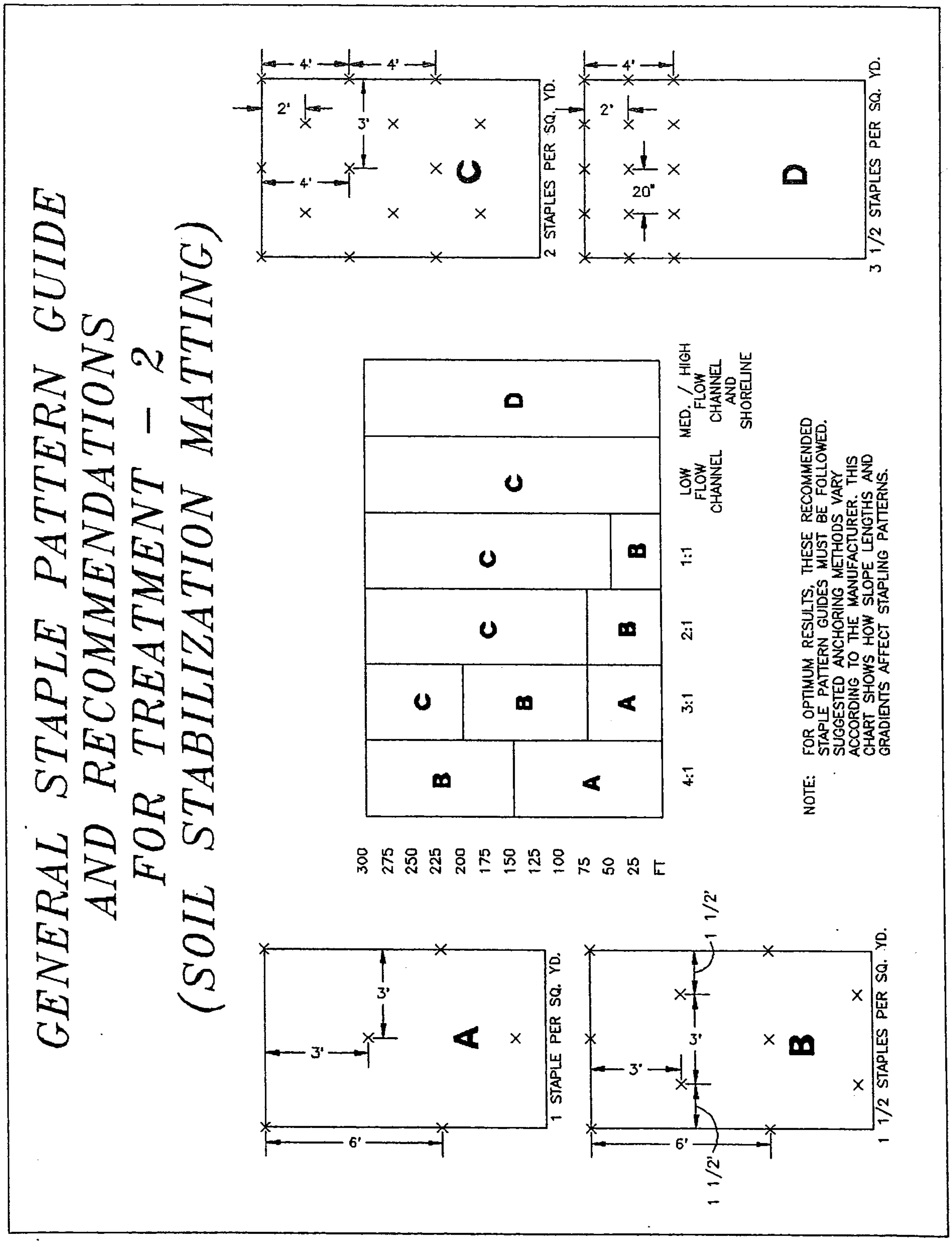
Source: VDOT Road and Bridge Standards

Plate 3.36-4

TYPICAL TREATMENT – 2
SOIL STABILIZATION MATTING
SLOPE INSTALLATION



Source: VDOT Road and Bridge Standards Plate 3.36-5

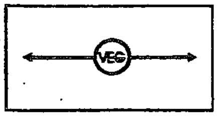


Source: Product literature from North American Green

Plate 3.36-6

STD & SPEC 3.37

TREES, SHRUBS, VINES & GROUND COVERS



VEG

Definition

Stabilizing disturbed areas by establishing vegetative cover with trees, shrubs, vines, or ground covers.

Purposes

1. To aid in stabilizing soil in areas where vegetation other than turf is preferred.
2. To provide food and shelter for wildlife where wildlife habitat is desirable.

Conditions Where Practice Applies

1. In areas where turf establishment is difficult.
2. On steep or rocky slopes, where mowing is not feasible.

3. Where ornamentals are desirable for landscaping purposes.

4. Where woody plants are desirable for soil conservation, or to establish wildlife habitat.

Planning Considerations

Disturbed areas may be stabilized in many different ways. Most frequently, a permanent vegetative cover of grasses and legumes is established. There are locations, however, where other types of vegetation are preferred. The following situations are examples of ways in which trees, shrubs, vines, and ground covers may be used:

1. On cut and fill slopes adjacent to paved areas of shopping centers, schools, industrial parks, or other non-residential projects: woody plants and ground covers can be used on these slopes to control erosion. They will also help to control foot traffic, will not require as much maintenance as mowed lawns, and will be more attractive than unmowed grass cover.

2. In residential areas, slopes too steep to be mowed and areas along rights-of-way or easements may be planted in trees, shrubs, vines or ground covers to reduce maintenance and improve appearance.

3. The interested homeowner or small project developer may choose to use ornamental plants in problem areas - shade, steep slopes, inaccessible places - as alternatives to grass. Ground covers may be used to reduce or eliminate the need for mowing grass on level areas.

There are vast numbers of plants that may be used for these purposes. The plants discussed in this practice are those which are known to be adapted to Virginia, fairly easy to grow, and commonly available from commercial nurseries. Many plants suitable for use are not mentioned here. Information on such plants can be obtained from nurserymen, landscape architects, and extension agents.

Because many types of woody plants and ground covers are discussed, and because site conditions and land use vary so widely, it is not practical to give specific requirements for the establishment of every plant mentioned. This practice consists, instead, of a set of general guidelines for growing trees, shrubs, vines, and ground covers on disturbed land.

Guidelines

As noted in MS #1, <u>disturbed soil between trees and shrubs must be mulched or planted with permanent vegetation to prevent erosion</u>. Refer to the other vegetative practices to select a method for stabilizing these areas.

Trees

Selecting the Right Trees - In the urban and suburban environment, trees may be exposed to insufficient light and water; high velocity winds; salt from highway ice control programs; heat radiation from roads and buildings; pollutants from cars and industry; root amputation for water, sewer, and gas lines; topping to prevent interference with power lines; and covering of roots by pavement. New species and varieties of trees are being selected for the modern environment on the basis of their ability to withstand those difficult conditions and still provide the benefits associated with having trees (see Plate 3.37-1).

Selection of trees depends on the desired function of the tree, whether it be shade, privacy screening, noise screening, appearance, enhancement of wildlife habitat, or a combination of these. The following characteristics of the tree should be considered when making choices:

1. Hardiness - "Hardiness zones" are based on average annual minimum temperature. Virginia contains 3 such zones (Plate 3.37-2) to which different trees are adapted.

2. Mature height and spread - The eventual height of a tree must be considered in relation to planting location to avoid future problems with power lines and buildings (see Plate 3.37-3).

3. Growth rate - Some trees attain mature height at an early age, others take many years. If "instant shade" is desired, rapid growth is needed. Slow-growing trees are usually less brittle and live longer.

4. Root system - Some trees obstruct underground pipelines with fibrous roots.

5. Cleanliness - Maintenance problems can be avoided by not selecting trees that drop seedpods, flowers, or twigs in large amounts.

6. Moisture and fertility requirements - If good soil and drainage are not available, trees tolerant of poor growing conditions must be planted.

7. Ornamental effects - If a tree is unusually attractive in appearance, some other shortcomings may be overlooked.

8. Evergreen vs. deciduous - Evergreens retain their leaves throughout the year, and so are useful for privacy screens and noise screens. Deciduous trees drop their leaves in fall. They are preferable for shade trees.

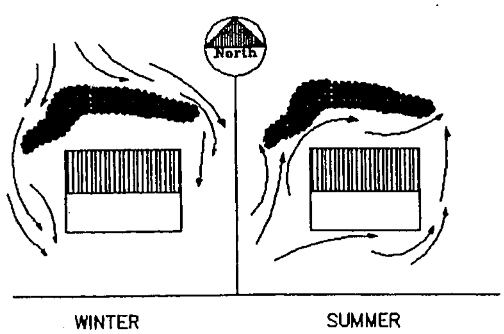
Some of these characteristics are given in Table 3.37-B for trees commonly grown in Virginia.

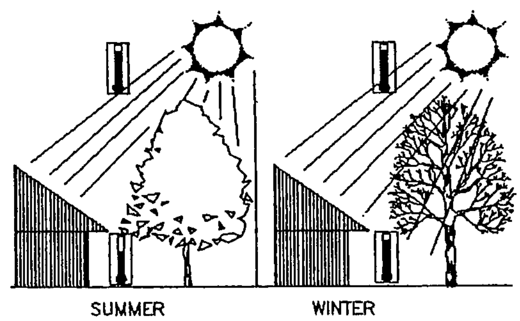
At the same time as trees are being selected, the site where they will be planted should be evaluated. Consider the prior use of the land; adverse soil conditions, such as poor drainage

BENEFITS OF TREES

TEMPERATURE MODIFICATION

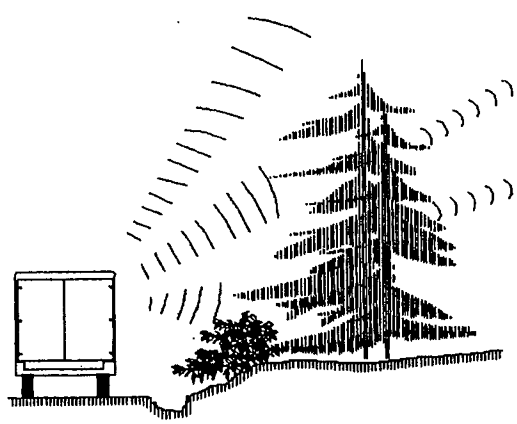
TREES AFFECT WIND SPEED AND DIRECTION, AND THUS TEMPERATURE. FOR EXAMPLE, AN EVERGREEN PLANTING ON THE NORTHWEST SIDE OF A BUILDING WILL REDUCE THE EFFECTS OF HARSH WINTER WINDS AND DIRECT COOL SUMMER BREEZES THROUGH THE AREA. TREES PROTECT THE SOIL FROM DRYING SUN AND WIND, REDUCING EVAPORATION AND MAINTAINING COOLER TEMPERATURES UNDER TREES. WHEN PROPERLY PLACED NEAR BUILDINGS, TREES OF PROPER SIZE WILL INSULATE BUILDINGS FROM EXTREME TEMPERATURE CHANGES IN WINTER AND SUMMER, HELPING REDUCE COSTS OF HEATING AND COOLING. DECIDUOUS TREES BLOCK OUT THE HOT SUMMER SUN, KEEPING THE HOME COOLER, AND ALLOW WARMTH OF WINTER SUN TO PASS THROUGH.





SOUND CONTROL

NOISES FROM NEARBY SOURCES CAN BE REDUCED THROUGH PROPER PLACEMENT OF TREES. THE DEGREE OF CONTROL DEPENDS ON THE DENSITY OF THE PLANTING AND INTENSITY AND DIRECTION OF SOUND WAVES. BOTH DECIDUOUS AND EVERGREEN TREES SHOULD BE USED FOR BEST EFFECT.

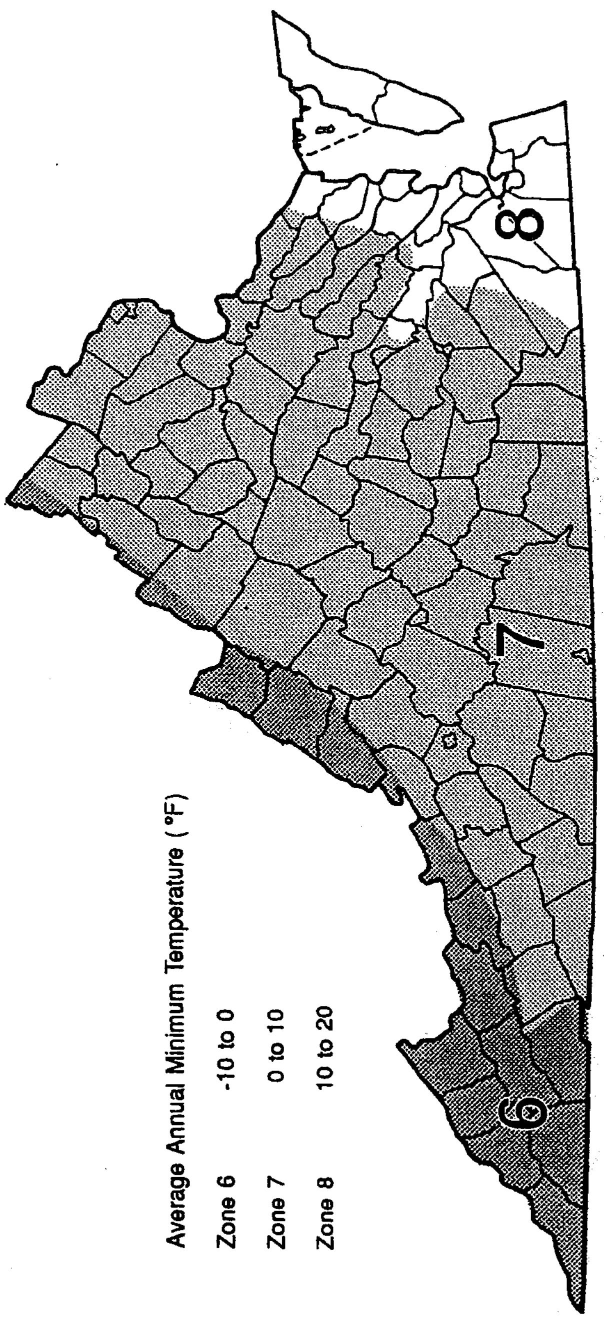


EROSION CONTROL

COARSE LEAF TEXTURES, HORIZONTAL BRANCHING HABITS, FIBROUS ROOT STSTEMS, AND ROUGH BARK ARE TREE CHARACTERISTICS MOST EFFECTIVE IN SLOWING WATER MOVEMENT AND WIND SPEED, THUS REDUCING EROSION PROBLEMS.

Source: Va. DSWC

Plate 3.37-1

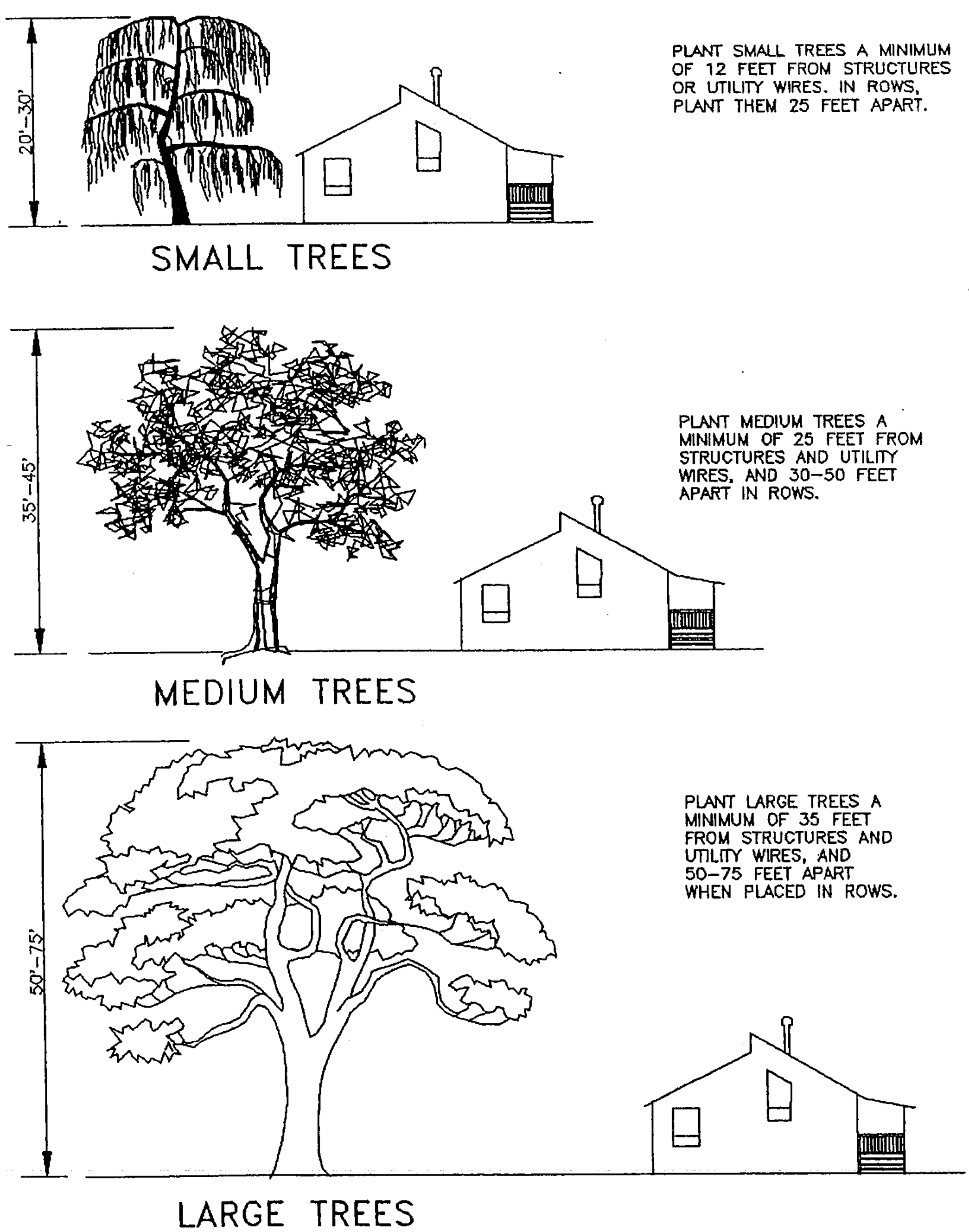


PLANT HARDINESS ZONES IN VIRGINIA FOR TREES, SHRUBS, VINES AND GROUND COVER

Source: Conservation Plants for the Northeast, USDA-SCS

Plate 3.37-2

SPACING TREES FOR SAFETY AND EFFECTIVE LANDSCAPING



Source: Va. DSWC

Plate 3.37-3

or acidity, exposure to wind; temperature extremes; location of utilities, paved areas, and security lighting; and traffic patterns.

Sources of trees and how they may be bought - The trees listed in Table 3.37-A are usually available at commercial nurseries as container-grown trees or as balled and burlapped trees. Container-grown trees can be planted at any time of year that the ground is not frozen, if sufficient water is provided. They should be purchased and planted when quite young (less than 2" diameter trunk) to avoid dealing with root-bound plants.

Balled and burlapped trees are usually larger; check to be sure that soil around roots was dug with the tree and not just packed around bare roots. The soil should have been kept moist.

Tree seedlings are available commercially and are also sold in lots of 50, 100, 500, or 1000 by the state forest nurseries. State nurseries are located in New Kent, Augusta, and Cumberland. About 20 species of trees are usually available during the height of the planting season, at nominal prices. These seedlings are not to be used as ornamentals or for fine landscaping; they are intended to be used as conservation plantings for erosion control, reforestation, and development of wildlife habitat. Since 50 seedlings will only plant an area of 3000 square feet, it is permissible to plant fairly small areas as long as the purpose is conservation. More information about this program is available through the Virginia Department of Forestry.

Planting Bare-Rooted Tree Seedlings

When - Trees to be planted as bare-rooted seedlings should be handled only while dormant in spring, or after leaf fall in autumn. Refer to Plate 3.37-4 for planting instructions.

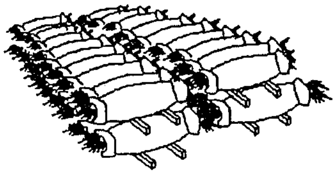
When stabilizing the disturbed area between tree plantings, do not use grasses or legumes which will overshade the new seedlings. Where possible, a circle of mulch around seedlings will help them to compete successfully with herbaceous plants.

Transplanting Trees (Planting Balled-and-Burlapped and Container-Grown Trees)

When - Hardwoods should be transplanted in the late fall following their leaf drop. There is a single exception to this rule: "Willow" Oaks seem to survive at a greater rate when they are transplanted in the spring. Evergreens may be transplanted beginning with the fall cool-down period (normally September) and may continue into spring prior to elongation of the new growth.

Tree preparation - Proper digging of a tree includes the conservation of as much of the root system as possible, particularly the fine roots. Soil adhering to the roots should be damp when tree is dug, and kept moist until planting. The soil (or "root") ball should be 12 inches in diameter for each inch of diameter of the trunk. The tree should be carefully excavated and the soil ball wrapped in burlap and tied with rope. Use of a mechanical tree spade is also acceptable.

PLANTING BARE-ROOTED SEEDLINGS



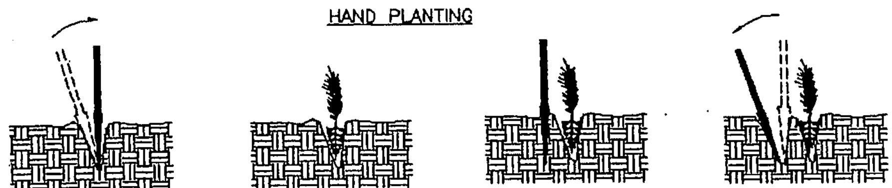
CARE OF SEEDLINGS UNTIL PLANTED

SEEDLINGS SHOULD BE PLANTED IMMEDIATELY. IF IT IS NECESSARY TO STORE MOSS-PACKED SEEDLINGS FOR MORE THAN 2 WEEKS, ONE PINT OF WATER PER PKG. SHOULD BE ADDED. IF CLAY-TREATED, DO NOT ADD WATER TO PKG. PACKAGES MUST BE SEPERATED TO PROVIDE VENTILATION TO PREVENT "HEATING". SEPARATE PACKAGES WITH WOOD STRIPS AND STORE OUT OF THE WIND IN A SHADED, COOL (NOT FREEZING) LOCATION.

CARE OF SEEDLINGS DURING PLANTING

WHEN PLANTING, ROOTS MUST BE KEPT MOIST UNTIL TREES ARE IN THE GROUND. DO NOT CARRY SEEDLINGS IN YOUR HAND EXPOSED TO THE AIR AND SUN. KEEP MOSS-PACKED SEEDLINGS IN A CONTAINER PACKED WITH WET MOSS OR FILLED WITH THICK MUDDY WATER. COVER CLAY-TREATED SEEDLINGS WITH WET BURLAP ONLY.

HAND PLANTING

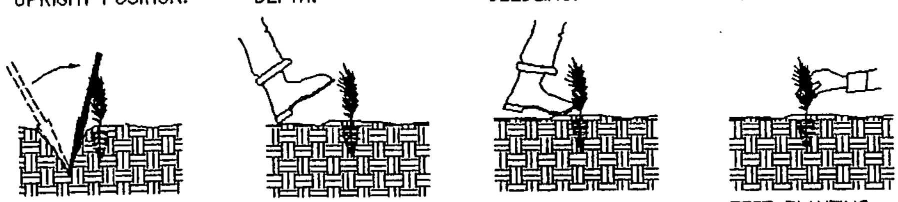


INSERT BAR AT ANGLE SHOWN AND PUSH FORWARD TO UPRIGHT POSITION.

REMOVE BAR AND PLACE SEEDLING AT CORRECT DEPTH.

INSERT BAR TWO INCHES TOWARD PLANTER FROM SEEDLING.

PULL BAR TOWARD PLANTER FIRMING SOIL AT BOTTOM OF ROOTS.

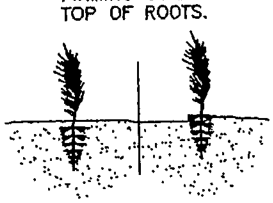


PUSH BAR FORWARD FROM PLANTER FIRMING SOIL AT TOP OF ROOTS.

FILL IN LAST HOLE BY STAMPING WITH HEEL.

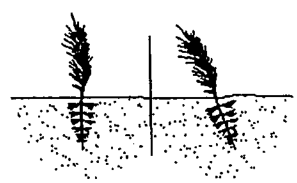
FIRM SOIL AROUND SEEDLING WITH FEET.

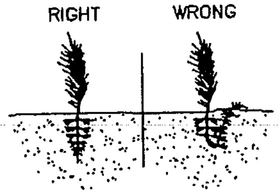
TEST PLANTING BY PULLING LIGHTLY ON SEEDLING.



DON'T EXPOSE ROOTS TO AIR DURING FREEZE OR PLANT IN FROZEN GROUND.

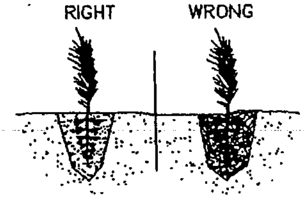
PLANT SEEDLINGS UPRIGHT – NOT AT AN ANGLE.





DO NOT BEND ROOTS SO THAT THEY GROW UPWARDS OUT OF THE GROUND.

ALWAYS PLANT IN SOIL – NEVER LOOSE LEAVES OR DEBRIS. PACK SOIL TIGHTLY.



Source: Va. Department of Forestry

Plate 3.37-4

Evergreens, or any trees which are to be transported for a distance, should have the branches bound with soft rope to prevent damage.

Site Preparation - Rather than digging a planting hole, rototill or loosen with a shovel, a shallow area the depth (height) of the soil ball and the width of five times the diameter of the soil ball or container. Organic material can be added to the loosened soil as long as the new material is used uniformly throughout the area.

Heavy or poorly drained soils are not good growth media for trees. When it is necessary to transplant trees into such soils, extra care should be taken. Properly installed drain tile will improve drainage.

Setting the tree - At the center of the prepared area, dig a shallow hole to set the tree. The hole should allow the root ball to sit on solid ground rather than loose soil. The upper surface of the root ball should be level with the existing soil. The tree may be set just a few inches higher than its former location, especially if soil is poorly drained. Do not set the tree lower than it was previously positioned. Soil to be placed around the root ball should be moist but not wet (see Plate 3.37-5).

Set the tree in the hole and remove the rope which holds the burlap. Cut away the burlap or, at a minimum, push it back into the bottom of the excavation. Do not break the soil of the root ball. Fill the hole with soil half-way, and tamp firmly around the root ball. Add water to settle the soil and eliminate air pockets. When the water has drained off, fill the hole the remainder of the way and tamp as before.

Use extra soil to form a shallow basin around the tree, somewhat smaller than the diameter of the root ball (Plate 3.37-5). This will be for holding water when the tree is irrigated.

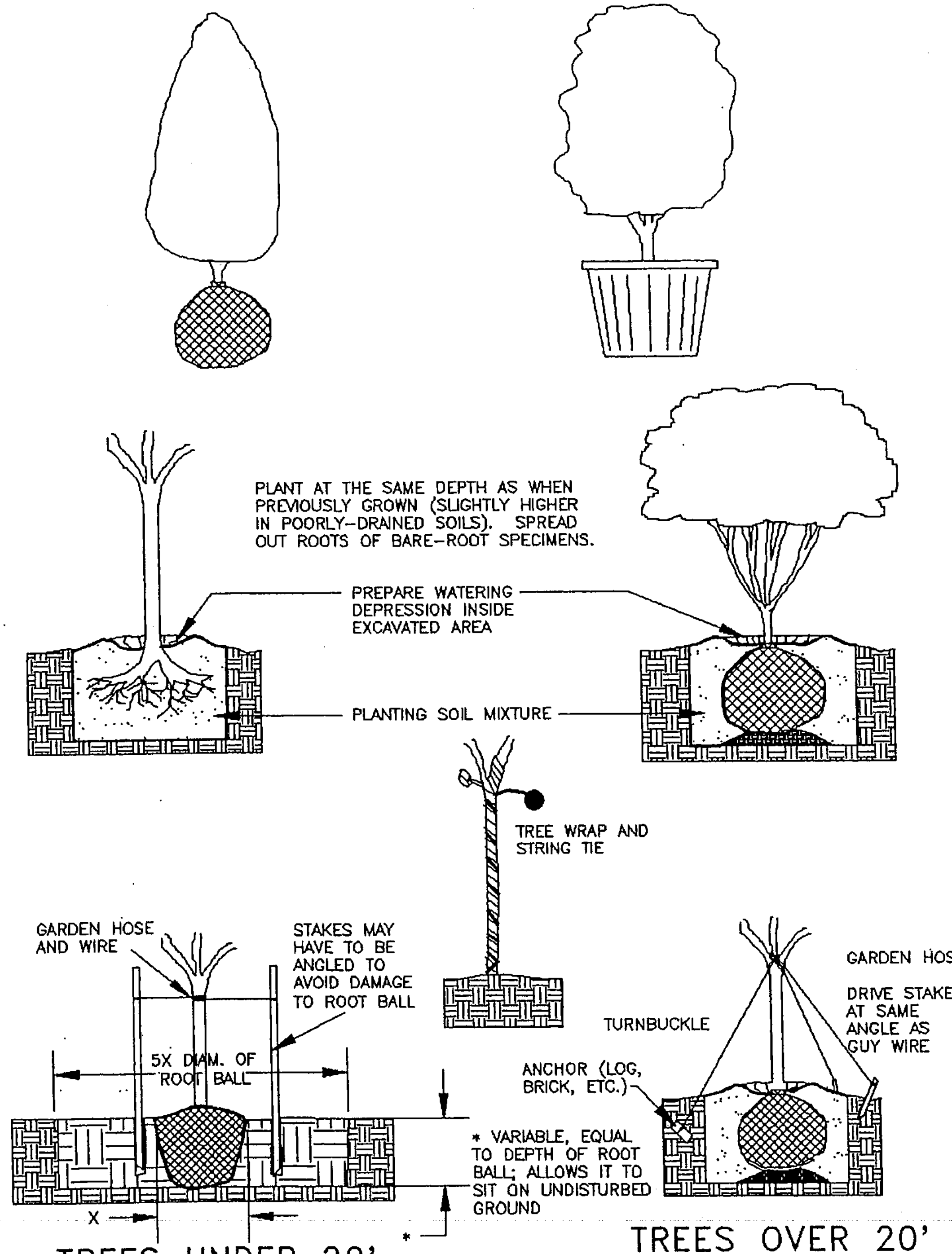
Note: Level the ground and eliminate these basins when winter sets in, as ice forming in the basin might injure the trunk.

Supporting the tree - Newly planted trees may need artificial support, especially in windy areas, to prevent excessive swaying. Stakes or guy wires may be used (see Plate 3.37-4). Use rubber hose and allow some slack in the guy to encourage strengthening of the plant. Remove all supports within six months of planting.

Watering - Soil around the tree should be thoroughly watered after the tree is set in place. When the soil becomes dry, the tree should be watered deeply but not too often. Mulching around the base of the tree is helpful in preventing roots from drying out.

Maintenance of Tree Plantings - Like all plants, trees require water and fertilizer to grow. Ideally, young trees should receive an inch of water each week for the first two years after planting. When rain does not supply this need, the tree should be watered deeply but not any more frequent than once per week.

PLANTING BALLED-&-BURLAPPED & CONTAINER-GROWN TREES



Source: Va. Department of Forestry

Plate 3.37-5

Transplanted trees should be fertilized one year or so after planting. There are many sophisticated ways to supply fertilizer to trees, but some simple methods are adequate. The best material for small trees is well-rotted stable manure, if it can be obtained. Add it as a 2-inch layer of mulch around the tree annually. If chemical fertilizers are to be used, a formulation such as 10-8-6 or 10-6-4 is preferred. Use about 2 lbs. per inch of trunk diameter measured 4 feet from the ground. Thus, if the trunk diameter at 4 feet was 5 inches, 10 lbs. of fertilizer would be applied.

Note: Evergreens - use one-half the recommended amount of chemical fertilizer or use only organic fertilizers such as cottonseed meal, bone meal, or manure.

Fertilizer must come in contact with the roots to benefit the tree. A simple way to insure this is to make holes in the tree's root area with a punchbar, crowbar, or augur. Holes should be 18-inches deep, spaced about 2 feet apart, and located around the drip line of the tree. Distribute the necessary fertilizer evenly into these holes, and close the holes with the heel of the shoe or by filling with topsoil or peat moss.

Fertilize trees in late fall or in early spring, before leaves emerge.

Shrubs

Much of what has been said about trees also applies to shrubs. A shrub is an erect, woody plant less than 15 feet tall, usually with several trunks rising from a common base. Some have the appearance of small trees, and some lie close to the ground.

Selecting appropriate shrubs - There are so many ornamental shrubs available that advising on the choice of any one is difficult. Table 3.37-B gives the basic characteristics of shrubs commonly available at commercial nurseries in Virginia, which are recommended for conservation planting because they enrich or hold the soil or encourage development of wildlife habitat. Information on other shrubs is available from nurserymen and extension agents.

Follow the general procedure for tree planting when planting shrubs.

Maintenance

Proper pruning, watering, and application of fertilizer every three years or so will keep shrubs, healthy. Maintain the mulch cover or turf cover surrounding the shrubs. A heavy layer of mulch reduces weeds and retains moisture.

VINES AND GROUND COVERS

Low-growing plants that sprawl, trail, spread, or send out runners come in many leaf types, colors and growth habits. Some are suitable only as part of a maintained landscape, and some can stabilize large areas with little care.

In addition to stabilizing disturbed soil, vines and ground covers can perform the following functions:

1. Maintain cover in areas where turf will not thrive.

2. Provide attractive cover that does not need mowing.

3. Help to define traffic areas and control pedestrian movement. People are more likely to walk on the grass than to walk on a thick bed of ivy or a prickly planting of juniper.

Table 3.37-C gives the characteristics of some commonly used vines and ground covers suitable for Virginia. Information on others is available from nurserymen.

Most all ground covers perform best when planted in the spring. Container-grown plants can be planted throughout the growing season if adequate water is provided.

Site preparation - Ground covers are plants that naturally grow very close together, causing severe competition for space, nutrients, and water. Soil for ground covers should be well-prepared. A well-drained soil high in organic matter is best.

If the area to be planted is so large that adding amendments to the soil as a whole would be impractical, organic matter may be added only to each planting hole.

Lime and fertilize according to soil test, or add 5 lbs. or 10-10-10 and 10 lbs. of ground agricultural limestone to every 100 square feet. Incorporate into the top 4 to 6 inches of the soil. Add organic matter up to one-third of the total soil volume, either over the whole area (a layer 2 inches deep mixed into the top 6 inches) or in each planting hole, if the area is large.

Plants such as ivy, pachysandra, and periwinkle should be planted on 1-foot centers; large plants such as juniper can be spaced on 3-foot centers.

Mulching - The soil between trees and shrubs must be planted with cover vegetation or must be mulched. When establishing ground covers, it is not desirable to plant species that will compete strongly with the ground cover or will make maintenance difficult. A thick, durable mulch such as shredded bark or wood chips is recommended to prevent erosion and reduce weed problems. Pre-emergent herbicides may be necessary where weeding is not practical.

On slopes where erosion may be a problem, jute mesh or excelsior blankets may be installed prior to planting, and plants tucked into the soil through slits in the net. Such plants should be put in a staggered pattern to minimize erosion.

Maintenance

Trim old growth as needed to improve the appearance of ground covers. Most covers need once-a-year trimming to promote growth. Maintain mulch cover with additions of mulch where needed. Fertilize as described above, every 3 to 4 years.

TABLE 3.37-A
TREES FOR LANDSCAPING, EROSION CONTROL AND SOIL CONSERVATION IN VIRGINIA

COMMON NAME (Botanical Name)	Leaf Type	Zones in Va.	Mature Size (in feet)	SOIL MOISTURE PREFERRED			pH Range	USES			Disease/Pest Resistance	Salt Tolerance	POLLUTION TOLERANCE			REMARKS (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	
BEECH (Fagus grandifolia)	D	6 7 8	70 - 120		X		6.5 - 7.5	X			fair	S	-	S	-	Long-lived. Has edible nuts. Needs lots of space.
BIRCH, RIVER (Betula nigra)	D	7 8	50 - 80	X	X		4.0 - 5.0	X			good	-	S	S	-	Prefers deep, moist soils such as streambanks. Graceful form.
CEDAR, EASTERN RED (Juniperus virginiana)	E	7 8	20 - 50	X	X	X	6.0 - 6.5	x			good	-	T	T	T	Long-lived.
CHERRY, JAPANESE (Prunus serrulata)	D	6 7 8	15 - 20		X		6.5 - 7.5	X	X		good	-	-	-	T	Very showy pink or white flowers. Usually grafted on 6-7 foot stem. (Kwanzan)
CRABAPPLE (Malus spp.)	D	6 7 8	15 - 20		X		6.5 - 7.5	X	X	X	fair	I	S	S	-	White or pink flowers. Many varieties, some with edible fruit.
CUCUMBER TREE (Magnolia acuminata)	D	6 7	50 - 80	X	X		4.0 - 7.0	X			good	-	-	-	-	Grows rapidly. Green flowers; scarlet fruits in fall.
DOGWOOD, FLOWERING (Cornus florida)	D	6 7 8	30 - 40		X		5.0 - 6.5	X	X		good	-	T	T	T	Ideal street tree. White or pink flowers. Has poor drought resistance.
GINKGO (Ginkgo biloba)	D	6 7 8	to 100		X	X	6.0 - 6.5	x	x		very good	-	T	T	T	Plant male trees only - fruit has an offensive odor.

Sheet 1 of 6

TABLE 3.37-A (continued)
TREES FOR LANDSCAPING, EROSION CONTROL AND SOIL CONSERVATION IN VIRGINIA

COMMON NAME (Botanical Name)	Leaf Type	Zones in Va.	Mature Size (in feet)	SOIL MOISTURE PREFERRED			pH Range	USES			Disease/Pest Resistance	Salt Tolerance	POLLUTION TOLERANCE			REMARKS (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	
GOLDEN RAIN TREE (Koelreutaria paniculata)	D	6 7 8	20 - 30		X	X	6.0 - 6.5	X	X		good	-	-	-	-	Clusters of yellow flowers. Tolerant of parking lot conditions.
HACKBERRY, SOUTHERN (Celtis Mississippiensis)	D	6 7 8	80 - 90	X	X	X	6.5 - 7.5	X	X		good	T	T	T	-	Resembles elm in appearance. European hackberry also a good street tree. Tolerant of parking lot conditions.
HAWTHORNE (Crataegus spp.)	D	6 7 8	15 - 25		X		6.0 - 7.5	X	X		good	I	-	S	-	Thorny, Washington, and Lavalle types are good ornamentals. Tolerant of parking lot conditions.
HOLLY (Ilex opaca)	E	6 7 8	40 - 50	X	X	X	4.0 - 6.0	X	X	X	good	I	-	T	T	Slow-growing. Shade tolerant. Red berries appear only on female trees.
HORNBEAM (IRONWOOD) (Carpinus spp.)	D	6 7 8	10 - 30	X	X	X	6.5 - 7.5	X	X		good	S	-	T	I	Prefers low, moist bottomlands. Will tolerate shade. Yeddo hornbeam and European hornbeam preferred.
LINDEN, LITTLE LEAF (Tilia cordata)	D	6 7 8	40 - 50		X		6.5 - 7.5	X	X	X	fair	S	S	I	T	Best streetside linden. (Rancho, Greenspire, Chancellor)
LOCUST, BLACK (Robinia pseudo-acacia)	D	6 7 8	30 - 50		X	X	5.0 - 7.5			X	fair	I	S	T	I	Suited only to erosion control on seriously disturbed areas.

Sheet 2 of 6

TABLE 3.37-A (continued)
TREES FOR LANDSCAPING, EROSION CONTROL AND SOIL CONSERVATION IN VIRGINIA

COMMON NAME (Botanical Name)	Leaf Type	Zones in Va.	Mature Size (in feet)	SOIL MOISTURE PREFERRED			pH Range	USES			Disease/Pest Resistance	Salt Tolerance	POLLUTION TOLERANCE			REMARKS (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	
LOCUST, HONEY (Gleditsia triacanthos inermis)	D	6 7	50 - 75	X	X	X	6.5 - 7.5	X	X	X	good	T	S	-	-	Sturdy, wind-firm tree. (Moraine, Sunburst, Shademaster)
MAGNOLIA, SOUTHERN (Magnolia grandiflora)	E	7 8	60 - 80	X	X		4.0 - 7.0	X		X	good	-	-	-	-	Prefers moist, rich soil. Large, glossy leaves and 6-8" white flowers. Tolerant of parking lot conditions.
MAPLE, HEDGE (Acer campestre)	D	6 7 8	20 - 30		X	X	6.5 - 7.5	X	X		good	-	T	T	I	Prefers well-drained, deep, fertile soil. May be used in clipped hedges.
MAPLE, NORWAY (Acer platanoides)	D	6 7 8	50 - 60		X	X	6.5 - 7.5	X	X	X	good	T	I	T	I	Rapid growing. Provides extremely dense shade (kills grass). (Cavalier, Summer Shade)
MAPLE, RED (Acer rubrum)	D	6 7 8	50 - 80	X	X		4.5 - 7.5	X	X	X	good	S	T	T	-	Grows rapidly when young. Good tree for suburbs, but not city. (Gerling, Tilford)
MAPLE, SUGAR (Acer saccharum)	D	6	50 - 70	X	X	X	6.5 - 7.5	X			fair	I	T	T	-	Outstanding fall foliage. Suburban, but not city, tree. Slow-growing and shapely. (Green Mountain)
OAK, CHESTNUT (Quercus montana)	D	6	60 - 70		X	X	6.0 - 6.5	X			good	T	S	T	I	Grows well in sandy, gravelly or rocky soils.

Sheet 3 of 6

TABLE 3.37-A (continued)
TREES FOR LANDSCAPING, EROSION CONTROL AND SOIL CONSERVATION IN VIRGINIA

COMMON NAME (Botanical Name)	Leaf Type	Zones in Va.	Mature Size (in feet)	SOIL MOISTURE PREFERRED			pH Range	USES			Disease/Pest Resistance	Salt Tolerance	POLLUTION TOLERANCE			REMARKS (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	
OAK, PIN (Quercus palustris)	D	6 7 8	60 - 80	X	X	X	5.5 - 6.5	X	X		good	T	S	S	I	Most easily transplanted of the oaks. (Sovereign)
OAK, RED, NORTHERN (Quercus rubra borealis)	D	6 7 8	70 - 90		X	X	4.5 - 6.0	X	X	X	good	T	T	T	I	Most rapid-growing oak. Needs plenty of space.
OAK, RED, SOUTHERN (Quercus falcata)	D	7 8	70 - 80			X	4.0 - 5.0			X	good	-	T	T	I	Characteristically an upland tree. Prefers dry, infertile soils.
OAK, SCARLET (Quercus coccinea)	D	6 7	60 - 80			X	6.0 - 6.5	X	X		good	T	S	T	I	Prefers sandy or gravelly soils.
OAK, WHITE (Quercus alba)	D	6 7 8	60 - 80		X	X	6.5 - 7.5	X	X	X	fair	T	S	S	I	Long-lived, stately tree. Grows slowly.
OAK, WILLOW (Quercus phellos)	D	7 8	40 - 50	X	X	X	4.0 - 6.5	X			good	T	S	T	I	Long-lived, but grows quickly. Easy to transplant. Prefers fertile, acid soil.
PAGODATREE, JAPANESE (Sophora japonica)	D	7 8	30 - 40		X	X	6.0 - 7.5	X	X		good	-	-	-	-	Tolerates parking lot conditions. White flowers.

Sheet 4 of 6

TABLE 3.37-A (continued)
TREES FOR LANDSCAPING, EROSION CONTROL AND SOIL CONSERVATION IN VIRGINIA

COMMON NAME (Botanical Name)	Leaf Type	Zones in Va.	Mature Size (in feet)	SOIL MOISTURE PREFERRED			pH Range	USES			Disease/Pest Resistance	Salt Tolerance	POLLUTION TOLERANCE			REMARKS (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	
PEAR, CALLERY (Pyrus Calleryana)	D	6 7 8	40 - 50		X	X	6.5 - 7.5	X	X		good	I	-	S	-	Tolerates parking lot conditions. White flowers. (Bradford, Chanticleer)
PINE, AUSTRIAN (Pinus nigra)	E	6 7 8	30 - 50		X	X	4.0 - 6.5	X		X	good	T	-	-	-	Very hardy and rapid-growing. Will tolerate shallow soil and drought.
PINE, JAPANESE BLACK (Pinus thunbergi)	E	7 8	30 - 50		X	X	4.0 - 6.5	X		X	good	T	-	-	-	Popular ornamental selection for Virginia.
PINE, LOBLOLLY (Pinus taeda)	E	7 8	90 - 120	X	X		4.0 - 6.5			X	good	-	-	S	S	Use only for conservation plantings, not as an ornamental.
PINE, SHORTLEAF (Pinus echinata Miller)	E	6 7 8	80 - 100		X	X	4.0 - 6.5	X			good	-	-	-	-	Attractive shape. Prefers well-drained, sandy or gravelly soil.
PINE, SCOTCH (Pinus sylvestris)	E	6 7	60 - 90			X	4.0 - 6.5	X			good	I	S	S	S	Moderate growth. Very hardy and disease resistant.
PINE, VIRGINIA (Pinus virginiana)	E	6 7	30 - 40		X	X	4.0 - 6.5	X			good	I	S	S	-	Tolerates poor soil. Use for conservation plantings, not as an ornamental. Shallow-rooted.

Sheet 5 of 6

TABLE 3.37-A (continued)
TREES FOR LANDSCAPING, EROSION CONTROL AND SOIL CONSERVATION IN VIRGINIA

COMMON NAME (Botanical Name)	Leaf Type	Zones in Va.	Mature Size (in feet)	SOIL MOISTURE PREFERRED			pH Range	USES			Disease/Pest Resistance	Salt Tolerance	POLLUTION TOLERANCE			REMARKS (Suggested Varieties)
				Dry	Med	Wet		Lawns	Street	Seashore			O_3	SO_2	F	
PINE, WHITE (Pinus strobus)	E	6	80 - 100			X	4.0 - 6.5	X			fair	S	S	S	S	Very attractive, rapid-growing tree. Prefers deep, sandy loam. Subject to white pine blister rust.
PLANE-TREE, LONDON (Platanus acerifolia)	D	6 7 8	50 - 70		X		6.5 - 7.5	X	X	X	good	-	-	T	T	Good city tree. Does shed bark.
SWEETGUM (Liquidambar styraciflua)	D	7 8	80 - 120	X	X	X	6.0 - 7.5	X	X		good	-	S	S	T	Disease-prone in Washington, D.C. area. Splendid fall color. Needs deep soil and full sunlight. (Festival, Burgundy)
TUPELO (BLACKGUM) (Nyssa sylvatica)	D	6 7 8	60 - 80	X	X		5.0 - 6.0	X		X	good	I	T	T	-	Scarlet fall foliage. Suitable for swampy areas.
YEW, JAPANESE (Taxus cuspidata)	E	6 7 8	15 - 20		X		6.0 - 6.5	X			good	-	T	-	I	Can be used as an ornamental.
ZELKOVA (Zelkova serrata)	D	6 7 8	70 - 80		X		6.0 - 6.5	X	X		good	-	-	-	-	Recommended as replacement for American Elm. Hardy, fast-growing. Tolerates parking lot conditions.

Note: 1. For hardiness zones in Virginia, see Plate 3.37-2.

2. "E" - Evergreen
"D" - Deciduous

3. Pollution tolerance: "S" - sensitive. Will show physical damage.
"T" - tolerant.
"I" - intermediate. Damage depends on growing conditions.
"-" - no information at this time.

Sheet 6 of 6

TABLE 3.37-B
SHRUBS FOR VEGETATING DISTURBED AREAS

COMMON NAME (Botanical Name)	Leaf Type	DRAINAGE TOLERANCE					Shade Tolerance	pH Range	Mature Height (in feet)	Flowers	FRUIT	USES
		Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained						
AMERICAN CRANBERRY BUSH (Viburnum trilobum)	D			X	X	X	fair	6.5 - 7.5	6 - 7	--*	red berries	Hedges and borders. Winter food for birds. Fruits in 4 - 5 years.
AMUR HONEYSUCKLE "Rem Red" (Lonicera maackii)	D	X	X	X	X		good	6.5 - 8.0	8 -12	white	red berries	Erect shrubs for borders and hedges. Fall and winter food for birds.
CALIFORNIA PRIVET (Ligustrum ovalifolium)	E		X	X			fair	6.0 - 7.0	12 -18	--	--	Hedges and wind-breaks. Grows rapidly. Do not use in Mountain Region.
AUTUMN OLIVE (Eleagnus umbrellata)	D	X	X	X			poor	4.5 - 7.0	12	fragrant	red berries	Reclaiming mined land, screening; abundant food for wildlife. Fixes nitrogen. Attractive silvery foliage.
BAYBERRY (Myrica pennsylvanica)	E	X	X	X			poor	5.0 - 6.0	6 - 8	--	waxy, gray berries	Revegetating sand dunes; ornamental for droughty areas; fixes nitrogen in soil.
BEACH PLUM (Prunus maritima)	D	X	X	X			fair	6.0 - 8.0	7	white	edible, purple plum-like fruits	Revegetating sand dunes/droughty areas. Fruit used for jelly and baking, also favored by wildlife.
BICOLOR LESPEDEZA "Natob" (Lespedeza bicolor)	D	X	X	X			fair	4.5 - 6.5	12	purple	--	Rapid-growing shrub, provides food and cover for quail and wild turkey. Fixes nitrogen. Holds soil on slopes.

E = Evergreen D = Deciduous * Where no comment is made, fruit or flowers are inconspicuous.

Sheet 1 of 3

TABLE 3.37-B (continued)
SHRUBS FOR VEGETATING DISTURBED AREAS

COMMON NAME (Botanical Name)	Leaf Type	DRAINAGE TOLERANCE					Shade Tolerance	pH Range	Mature Height (in feet)	Flowers	FRUIT	USES
		Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained						
BRISTLY LOCUST "Arnot" (Robinia fertilis)	D	X	X	X			fair	5.0 - 7.5	6	pink	pods	Steep slopes, gravelly infertile areas. Fixes nitrogen. Spreads by sprouting from roots.
ELDERBERRY (Sambucus canadensis)	D		X	X	X	X	fair	6.0 - 7.5	12	white	edible purple berries	Provides food for birds and deer. Fruit in 4-5 yrs.
FIRETHORN (Pyracantha coccinea)	E	X	X	X			fair	6.0 - 8.0	10 - 15	white	orange or red berries	Screens, barriers. Food for songbirds. Low-growing and upright types available.
HORIZONTAL JUNIPER (Juniperus spp.)	E	X	X				poor	5.0 - 6.0	1 - 2	--	--	Used as ground cover or ornamental. Set plants 2 feet apart for cover in 2-3 years.
JAPANESE YEW (Taxus cuspidata)	E			X	X		good	6.0 - 7.0	12 - 16	--	--	Used for hedges and screens.
RUGOSA ROSE (Rosa rugosa)	D	X	X	X			fair	6.0 - 7.0	3 - 5	white, pink	red hips in 1-2 yrs.	Stabilizing sand dunes and landscaping. Food and cover for songbirds and rabbits. Sprawling growth habit, but not aggressive.
SHORE JUNIPER "Emerald Sea" (Juniperus conferta)	E	X	X				fair	5.0 - 6.0	1	--	--	Stabilizing sand dunes and sandy road banks.

E = Evergreen D = Deciduous * Where no comment is made, fruit or flowers are inconspicuous.

Sheet 2 of 3

TABLE 3.37-B (continued)
SHRUBS FOR VEGETATING DISTURBED AREAS

COMMON NAME (Botanical Name)	Leaf Type	DRAINAGE TOLERANCE					Shade Tolerance	pH Range	Mature Height (in feet)	Flowers	FRUIT	USES
		Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained						
SWEET FERN (Comptonia peregrina)	D	X	X				poor	5.0 - 6.0	2 - 4	--	--	Pleasantly scented. Fixes nitrogen. Spreads by underground stems. Stabilizes droughty areas. Do not use in Coastal Plain.
TATARIAN HONEYSUCKLE (Lonicera tatarica)	D		X	X			fair	6.5 - 8.0	6 - 9	pink, showy	red berries in 3-4 yrs	Erect shrub; hedges, borders, summer food for birds.
WINTERBERRY (Ilex verticillata)	D		X	X	X	X	fair	5.0 - 6.0	10	--	red berries in 3-4 years	Ornamental screens. Winter food for songbirds.

E = Evergreen D = Deciduous * Where no comment is made, fruit or flowers are inconspicuous.

Sheet 3 of 3

TABLE 3.37-C
GROUND COVERS AND VINES FOR EROSION CONTROL

COMMON NAME (Botanical Name)	Leaf Type	DRAINAGE TOLERANCE					Shade Tolerance	pH Range	FLOWERS	CHARACTERISTICS
		Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained				
BEARBERRY (Arctostaphylos uva-ursi)	E	X	X				good	4.5 - 6.0	--*	Trailing shrub. Low-fertility sandy areas, dunes. Set plants 18 in. apart for cover in 2-4 yrs.
BUGLEWEED (Ajuga reptans)	E		X	X			excellent	6.0 - 7.5	blue, white or red spikes	Small, low-growing herbaceous plants, in bronze or green. Set plants 1 ft. apart for cover in 1 year.
DAYLILY (Hemerocallis spp.)	D	X	X	X	X	X	fair	6.0 - 8.0	various/showy	Grass-like foliage. Unusually adaptable and free of pests and disease.
DUSTY MILLER "Beach Wormwood" (Artemisia stelleriana)	D	X	X	X			poor	6.0 - 7.5	--	Silvery foliage, 1-2 ft. tall. Spreads by underground stems. Stabilizing groundcover on coastal dunes. Set plants 2 ft. apart for cover in 2 years.
ENGLISH IVY (Hedera helix)	E	X	X	X			good	6.0 - 8.0	--	Low-maintenance vine for large areas. Will climb on trees, walls, etc. Set plants or rooted cutting 1 ft. apart for cover in 2 yrs.
HALL'S JAPANESE HONEYSUCKLE (Lonicera japonica halliana)	sE	X	X	X	X		good	6.0 - 7.5	white, fading to yellow; fragrant	Aggressively spreading vine. Excellent cover for large sloping areas such as road banks. Set clumps or plants 18 in. apart for cover in 2 years.

E = Evergreen   D = Deciduous   sE = Semi-evergreen   * Where no comment is made, flowers are inconspicuous.

Sheet 1 of 2

TABLE 3.37-C (continued)
GROUND COVERS AND VINES FOR EROSION CONTROL

COMMON NAME (Botanical Name)	Leaf Type	DRAINAGE TOLERANCE					Shade Tolerance	pH Range	FLOWERS	CHARACTERISTICS
		Droughty	Well-Drained	Moderately Well-Drained	Somewhat Poorly Drained	Poorly Drained				
JAPANESE SPURGE "Pachysandra" (Pachysandra terminalis)	E		X	X			excellent	4.5 - 5.5	small white spikes	Low-growing, attractive cover for borders and as lawn substitute under trees and other shady areas. Set plants 1 ft. apart for cover in 2 years.
LILY-OF-THE-VALLEY (Convallaria majalis)	E	X	X	X	X		excellent	4.5 - 6.0	fragrant white bells on short stalks	Low-maintenance cover for partial or full shade. Set plants 1 ft. apart for cover in 2-3 years.
LILY-TURF (Liriope spp.)	E	X	X	X	X		good	4.5 - 6.0	white, lavender, or purple spikes	Grass-like, low-maintenance cover for droughty, infertile soils. Spreads by underground stems. Available in variegated form. Set plants 6-12 inches apart for cover in 2 years.
PERIWINKLE "Vinca" (Vinca Minor)	E		X	X			excellent	6.0 - 7.5	small, blue flowers	Lawn substitute for shady areas. Spreads by stolons; not aggressive. Grows in full sun as well as shade. Set plants 1 ft. apart for cover in 1-2 years.
SMALL-LEAVED COTONEASTER (Cotoneaster microphylla)	E		X	X			fair	6.0 - 7.0	tiny, white flowers	Prostrate shrub. Informal cover for large areas. Set plants 2 ft. apart for cover in 2 years.
VIRGINIA CREEPER (Quinquefolia parthenocissus)	D	X	X				fair	5.0 - 7.5	--*	Ground cover for dunes and other dry areas; will climb trees. Attractive crimson foliage in fall. Berries eaten by songbirds. Set plants 18 in. apart for cover in 1-2 years.

E = Evergreen D = Deciduous * Where no comment is made, flowers are inconspicuous.

Sheet 2 of 2

STD & SPEC 3.38

TREE PRESERVATION & PROTECTION

TP

Definition

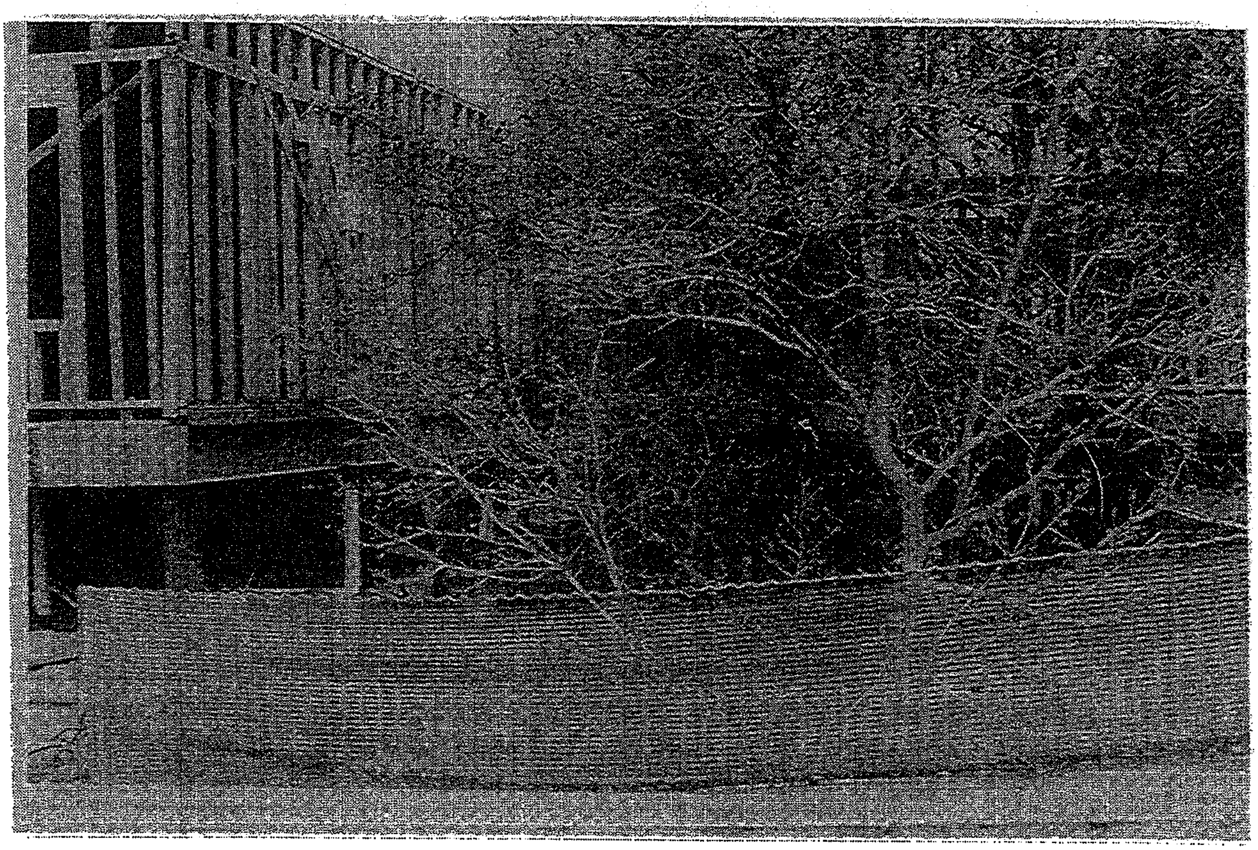
Protection of desirable trees from mechanical and other injury during land disturbing and construction activity.

Purpose

To ensure the survival of desirable trees where they will be effective for erosion and sediment control, watershed protection, landscape beautification, dust and pollution control, noise reduction, shade and other environmental benefits while the land is being converted from forest to urban-type uses.

Conditions Where Practice Applies

Tree-inhabited areas subject to land disturbing activities.



Planning Considerations

New development often takes place on tracts of forested land. In fact, building sites are often selected because of the presence of mature trees. However, unless sufficient care is taken and planning done in the interval between buying the property and completing construction, much of this resource is likely to be destroyed. The property owner is ultimately responsible for protecting as many trees as possible, with their understory and ground cover. This responsibility is usually exercised by agents-the planners, designers and contractors. It takes 20 to 30 years for newly planted trees to provide the benefits for which we value trees so highly. Trees perform the following functions on a site:

1. Assist in stabilizing the soil and preventing erosion.

2. Help to decrease stormwater runoff through canopy interception and root zone absorption.

3. Moderate temperature changes and provide shade.

4. Moderate the effects of sun and wind.

5. Provide buffers and screens against noise.

6. Filter pollutants from the air.

7. Help to remove carbon dioxide from the air and release oxygen.

8. Provide a haven for animals and birds, which help to control insect populations.

9. Conserve and increase property values.

10. Provide psychological and aesthetic counterpoints to the man-made urban setting.

Stresses of Construction

Trees may appear to be inanimate objects, but they are living organisms that are constantly involved in the process of respiration, food processing, and growth. Construction activities expose trees to a variety of stresses resulting in injury ranging from superficial wounds to death. An understanding of these stresses is helpful in planning for tree protection.

1. Surface Impacts: Natural and man-related forces exerted on the tree above the ground can cause significant damage to trees.

   a. Wind damage - Removal of some trees from groups will expose those remaining to greater wind velocities. Trees tend to develop anchorage where it is most needed. Isolated trees develop anchorage rather equally all around, with stronger root development on the side of the prevailing winds. The more a tree is protected from the wind, the less secure is its anchorage. The result of improper thinning is often wind-thrown trees. Selective removal in favor of a single tall tree may also create a lightning hazard.

b. Excessive pruning - Unprotected trees are often "topped" or carelessly pruned to prevent interference with utility wires or buildings. If too many branches are cut, the tree may not be able to sustain itself. If the pruning is done without considering the growth habit, the tree may lose all visual appeal. If the branches are not pruned correctly, decay may set in.

c. Trunk damage - Tree trunks are often nicked or scarred by trucks and construction equipment. Such superficial wounds provide access to insects and disease.

2. Root Zone Impacts: Disturbing and delicate relationship between soil, roots, and the rest of the tree can damage or kill a tree. The roots of an existing tree are established in an area where essential materials (water, oxygen, and nutrients) are present. The mass of the root system is the correct size to balance the intake of water from the soil with the transpiration of water from the leaves.

a. Raising the grade as little as 6 inches can retard the normal exchange of air and gases. Roots may suffocate due to lack of oxygen, or be damaged by toxic gases and chemicals released by soil bacteria.

b. Raising the grade may also elevate the water table. This can cause drowning of the deeper roots.

c. Lowering the grade is not usually as damaging as raising it. However, even shallow cuts of 6 to 8 inches will remove most of the topsoil, removing some feeder roots and exposing the rest to drying and freezing.

d. Deep cuts may sever a large portion of the root system, depriving the tree of water and increasing the chance of wind-throw.

e. Lowering the grade may lower the water table, inducing drought. This is a problem in large roadway cuts or underdrain installations.

f. Trenching or excavating through a tree's root zone can eliminate as much as 40 percent of the root system. Trees suffering such damage usually die within 2 to 5 years.

g. Compaction of the soil within the drip line (even a few feet beyond the drip line) of a tree by equipment operation, materials storage, or paving can block off air and water from roots.

h. Construction chemicals or refuse disposed of in the soil can change soil chemistry or be toxic to trees. Most damage to trees from construction activities is due to the invisible root zone stresses.

Design Criteria

No formal design is required. However, in planning for the development of a wooded site where some trees will be preserved, a number of criteria must be considered.

Selecting Trees to be Retained

The proper development of a wooded site requires completion of a plan for tree preservation before clearing and construction begins. Trees should be identified by species, and located on a topographical map, either as stands or as individuals, depending on the density and value of the trees. Base decisions on which trees to save on the following considerations:

1. Life expectancy and present age: Preference should be given to trees with a long life span, such as white oak, beech, and maple. Long-lived specimens that are past their prime may succumb to the stresses of construction, so smaller, younger trees of desirable species are preferred; they are more resilient and will last longer. However, if the cost of preservation is greater than the cost of replacement with a specimen of the same age and size, replacement may be preferred.

2. Health and disease susceptibility: Check for scarring caused by fire or lightning, insect or disease damage, and rotted or broken trunks or limbs. Pest- and pollution-resistant trees are preferred.

3. Structure: Check for structural defects that indicate weakness or reduce the aesthetic value of a tree: trees growing from old stumps, large trees with overhanging limbs that endanger property, trees with brittle wood (such as silver maple), misshapen trunks or crowns, and small crowns at the top of tall trunks. Open grown trees often have better form than those grown in the woods. Trees with strong tap or fibrous root systems are preferred to trees with weak rooting habits.

4. Cleanliness: Some trees such as elm and black locust are notoriously "dirty", dropping twigs, bark, fruit, or plant exudates. A clean tree is worth more than a dirty one. Trees which seed prolifically or sucker profusely are generally less desirable in urban areas. Thornless varieties are preferred.

5. Aesthetic values: Handsome bark and leaves, neat growth habit, fine fall color, and attractive flowers and fruit are desirable characteristics. Trees that

provide interest during several seasons of the year enhance the value of the site.

6. Comfort: Trees help relieve the heat of summer and buffer strong winds throughout the year. Summer temperatures may be 10 degrees cooler under hardwoods than under conifers. Deciduous trees drop their leaves in winter, allowing the sun to warm buildings and soil. Evergreens are more effective wind buffers.

7. Wildlife: Preference should be given to trees that provide food, cover, and nesting sites for birds and game.

8. Adaptability to the proposed development:

   a. Consider the mature height and spread of trees; they may interfere with proposed structures and overhead utilities. Roots may interfere with walls, walks, driveways, patios, and other paved surfaces; or water lines, septic tanks, and underground drainage.

   b. Trees must be appropriate to the proposed use of the development; select trees which are pollution-tolerant for high-traffic and industrial areas, screen and buffer trees for noise or objectionable views, salt-tolerant species for areas exposed to deicing salts or ocean spray.

   c. Consider location of landfills. Gases generated in them can travel long distances underground, to injure distant trees. Choose species tolerant of anaerobic soil conditions.

   d. Determine the effect of proposed grading on the water table. Grading should not take place within the drip line of any tree to be saved.

9. Survival needs of the tree: Chosen trees must have enough room to develop naturally. They will be subject to injury from increased exposure to sunlight, heat radiated from buildings and pavement, and wind. It is best to retain groups of trees rather than individuals. As trees mature, they can be thinned gradually.

10. Relationship to other trees: Individual species should be evaluated in relation to other species on the site. A species with low value when growing among hardwoods will increase in value if it is the only species present. Trees standing alone generally have higher landscape value than those in a wooded situation. However, tree groups are much more effective in preventing erosion and excess stormwater runoff.

Site Planning for Tree Protection

1. If lot size allows, select trees to be saved before siting the building. No tree should be destroyed or altered until the design of buildings and utility systems is final.

2. Critical areas, such as flood plains, steep slopes, and wetlands, should be left in their natural condition or only partially developed as open space.

3. Locate roadways to cause the least damage to valuable stands. Follow original contours, where feasible, to minimize cuts and fills.

4. Minimize trenching by locating several utilities in the same trench. Excavations for basements and utilities should be kept away from the drip line of trees.

5. Construction material storage areas and worker parking should be noted on the site plan, and located where they will not cause compaction over roots.

6. When retaining existing trees in parking areas, leave enough ground ungraded beyond the drip line of the tree to allow for its survival.

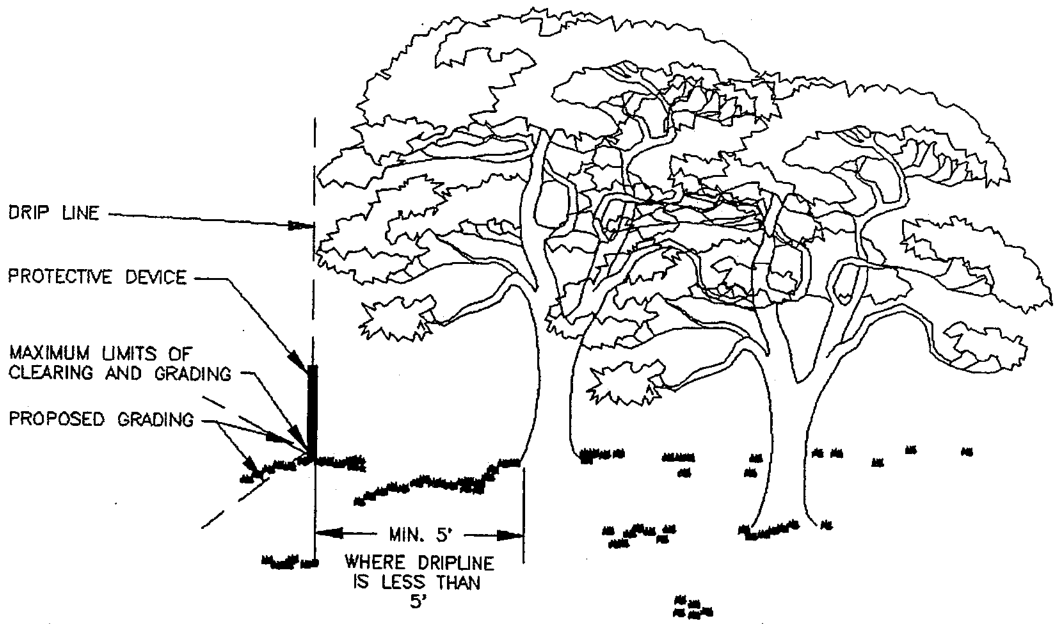
7. Locate erosion and sediment control measures at the limits of clearing and not in wooded areas, to prevent deposition of sediment within the drip line of trees being preserved. Sediment basins should be constructed in the natural terrain, if possible, rather than in locations where extensive grading and tree removal will be required.

Specifications

1. Groups of trees and individual trees selected for retention shall be accurately located on the plan and designated as "tree(s) to be saved." Individual specimens that are not part of a tree group shall also have their species and diameter noted on the plan.

2. At a minimum, the limits of clearing shall be located outside the drip line of any tree to be retained and, in no case, closer than 5 feet to the trunk of any tree (Plate 3.38-1).

3. Marking: Prior to construction and before the preconstruction conference, individual trees and stands of trees to be retained within the limits of clearing shall be marked at a height visible to equipment operators. According to the Virginia Department of Forestry, a diagonal slash of brightly colored paint approximately 8 to 10 inches in length is a common practice in areas where an accidental or purposeful alteration of the proper markings is a concern. In most situations, such as an area which is supposed to receive formal landscaping, a surveyor's ribbon or a similar material applied at a reasonable height encircling the tree will suffice.



CONSTRUCTION OPERATIONS RELATIVE TO THE LOCATION OF PROTECTED TREES

Source: Public Facilities Manual, Vol. III, Fairfax Co., Va., 1976 Plate 3.38-1

4. Pre-Construction Conference: During any preconstruction conference, tree preservation and protection measures should be reviewed with the contractor as they apply to that specific project.

5. Equipment Operation and Storage: Heavy equipment, vehicular traffic, or stockpiles of any construction materials (including topsoil) shall not be permitted within the drip line of any tree to be retained. Trees being removed shall not be felled, pushed or pulled into trees being retained. Equipment operators shall not clean any part of their equipment by slamming it against the trunks of trees to be retained.

6. Fires: Fires shall not be permitted within 100 feet from the drip line of any trees to be retained. Fires shall be limited in size to prevent adverse effects on trees, and kept under surveillance.

7. Storage and Disposal of Toxic Materials: No toxic materials shall be stored closer than 100 feet to the drip line of any trees to be retained. Paint, acid, nails, gypsum board, wire, chemicals, fuels, and lubricants shall not be disposed of in such a way as to injure vegetation.

8. Fencing and Armoring (Plate 3.38-2): Any device may be used which will effectively protect the roots, trunk and tops of trees retained on the site. However, trees to be retained within 40 feet of a proposed building or excavation shall be protected by fencing. Personnel must be instructed to honor protective devices. The devices described are suggested only, and are not intended to exclude the use of other devices which will protect the trees to be retained.

   a. Snow Fence - Standard 40-inch high snow fence shall be placed at the limits of clearing on standard steel posts set 6 feet apart.

   b. Board Fence - Board fencing consisting of 4-inch square posts set securely in the ground and protruding at least 4 feet above the ground shall be placed at the limits of clearing with a minimum of two horizontal boards between posts. If it is not practical to erect a fence at the drip line, construct a triangular fence nearer the trunk. The limits of clearing will still be located at the drip line, since the root zone within the drip line will still require protection.

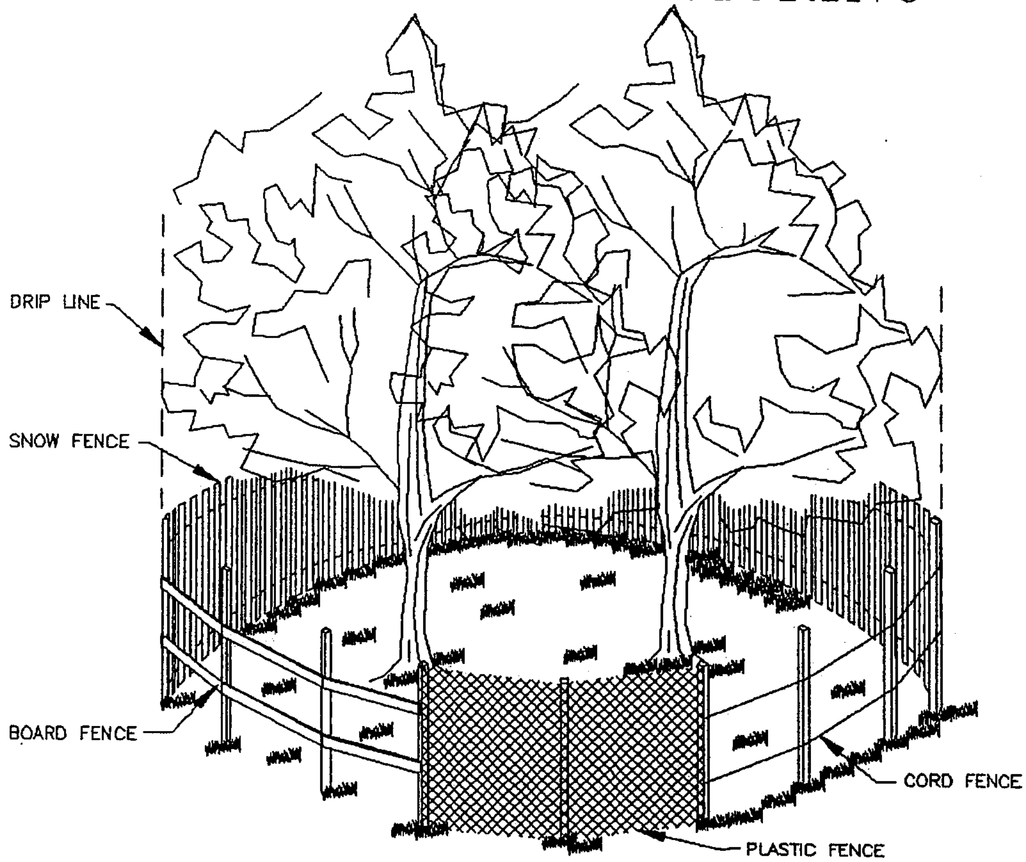
   c. Cord Fence - Posts with a minimum size of 2 inches square or 2 inches in diameter set securely in the ground and protruding at least 4 feet above the ground shall be placed at the limits of clearing with two rows of cord 1/4-inch or thicker at least 2 feet apart running between posts with strips of colored surveyor's flagging tied securely to the string at intervals no greater than 3 feet.

   d. Plastic Fencing - 40-inch high "international orange" plastic (polyethylene) web fencing secured to conventional metal "T" or "U" posts driven to a minimum depth of 18 inches on 6-foot minimum centers shall be installed at the limits of clearing. The fence should have the following minimum physical qualities:

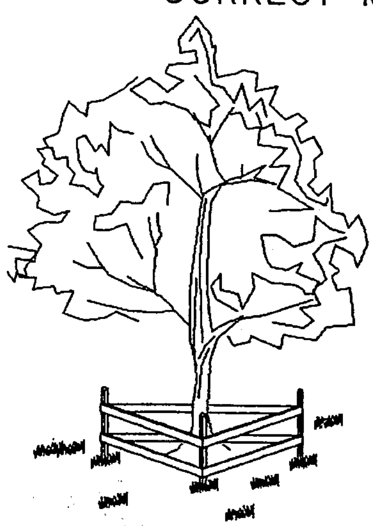
Tensile yield:	Average 2,000 lbs. per 4-foot width (ASTM D638)
Ultimate tensile yield:	Average 2,900 lbs. per 4-foot width (ASTM D638)
Elongation at break (%):	Greater than 1000% (ASTM D638)
Chemical resistance:	Inert to most chemicals and acids

   e. Earth Berms - Temporary earth berms shall be constructed according to specifications for a TEMPORARY DIVERSION DIKE (Std. & Spec. 3.9) with the base of the berm on the tree side located along the limits of clearing. Earth berms may not be used for this purpose if their presence will conflict with drainage patterns.

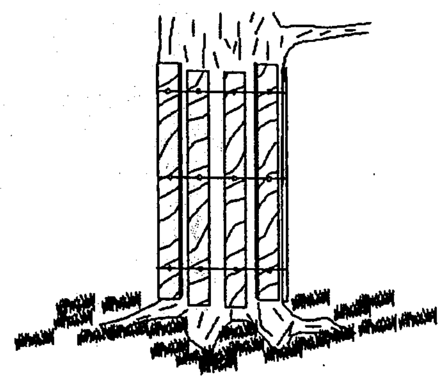
FENCING AND ARMORING



CORRECT METHODS OF TREE FENCING



TRIANGULAR BOARD FENCE



CORRECT TRUNK ARMORING

Source: Va. DSWC

Plate 3.38-2

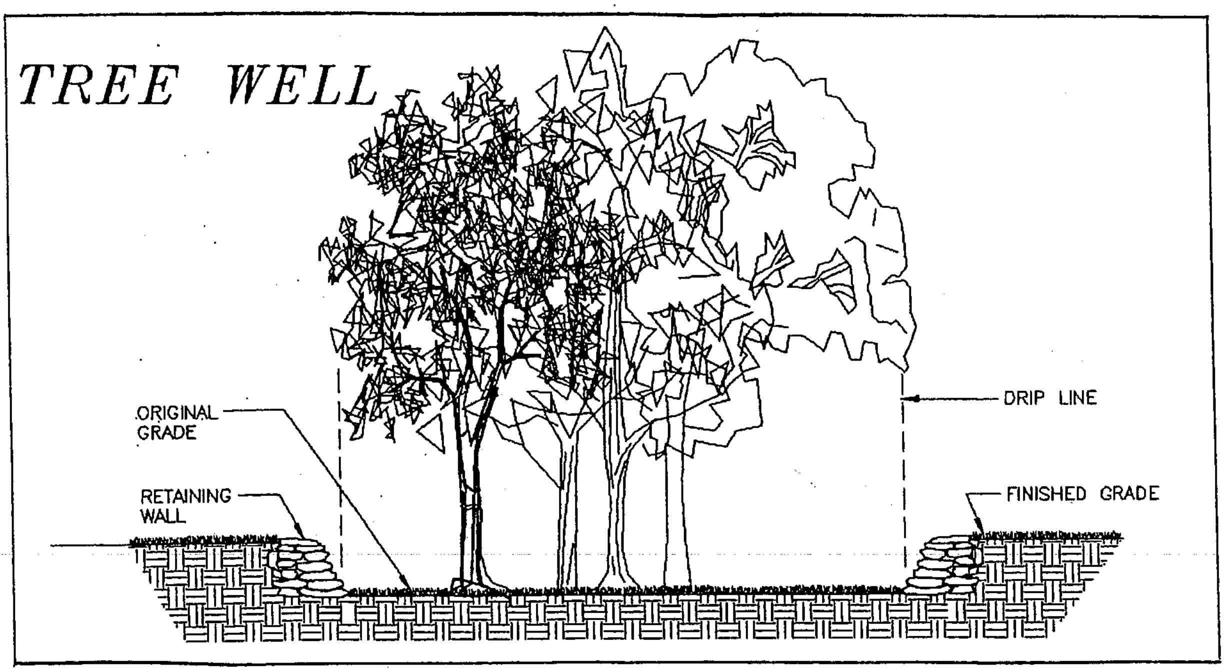
f. Additional Trees - Additional trees may be left standing as protection between the trunks of the trees to be retained and the limits of clearing. However, in order for this alternative to be used, the trunks of the trees in the buffer must be no more than 6 feet apart to prevent passage of equipment and material through the buffer. These additional trees shall be reexamined prior to the completion of construction and either be given sufficient treatment to ensure survival or be removed.

g. Trunk Armoring - As a last resort, a tree trunk can be armored with burlap wrapping and 2-inch studs wired vertically no more than 2 inches apart to a height of 5 feet encircling the trunk. If this alternative is used, the root zone within the drip line will still require protection. Nothing should ever be nailed to a tree.

Fencing and armoring devices shall be in place before any excavation or grading is begun, shall be kept in good repair for the duration of construction activities, and shall be the last items removed during the final cleanup after the completion of the project.

9. Raising the grade: When the ground level must be raised around an existing tree or tree group, the following considerations shall be made and steps taken to adequately care for the affected tree.

a. A well may be created around the tree(s) slightly beyond the drip line to retain the natural soil in the area of the feeder roots (Plate 3.38-3).



Source: Va. DSWC Plate 3.38-3

b. In the case of an individual tree, when the above alternative is not practical or desirable, the following method is recommended to ensure survival of the tree (Plate 3.38-4).

1) Before making the fill, remove the green vegetation, sod, leaf litter, and other organic matter from beneath the tree or trees to a distance of 3 feet beyond the drip line and loosen the surface soil to a depth of approximately 3 inches without damaging the roots.

2) Apply fertilizer in the root area of the tree to be retained. Fertilizer formulations and application rates and methods shall conform to the guidelines provided in Table 3.38-A.

3) The dry well shall be constructed so as to allow for tree trunk diameter growth. A space of at least 1 foot between the tree trunk and the well wall is adequate for large, old, slow-growing trees. Clearance for younger trees shall be at least 2 feet.

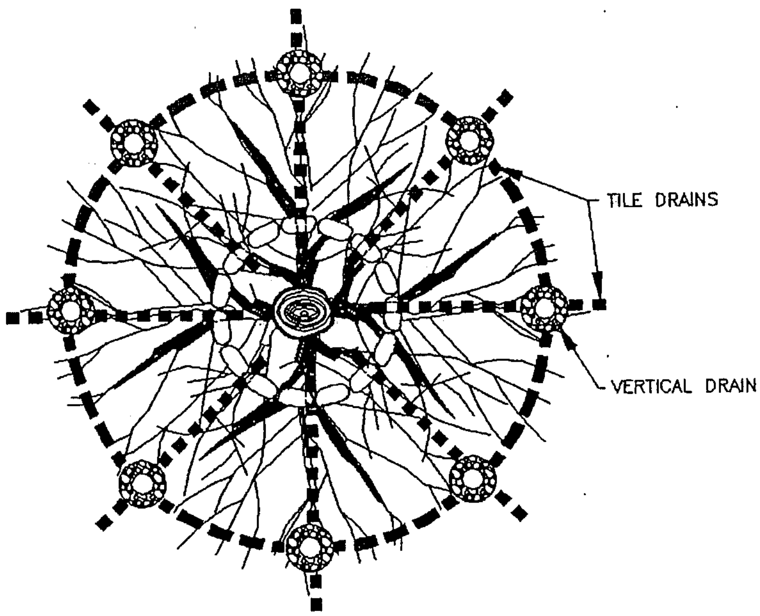
4) The well shall be high enough to bring the top just above the level of the proposed fill. The well wall shall taper slightly away from the tree trunk at a rate of 1 inch per foot of wall height.

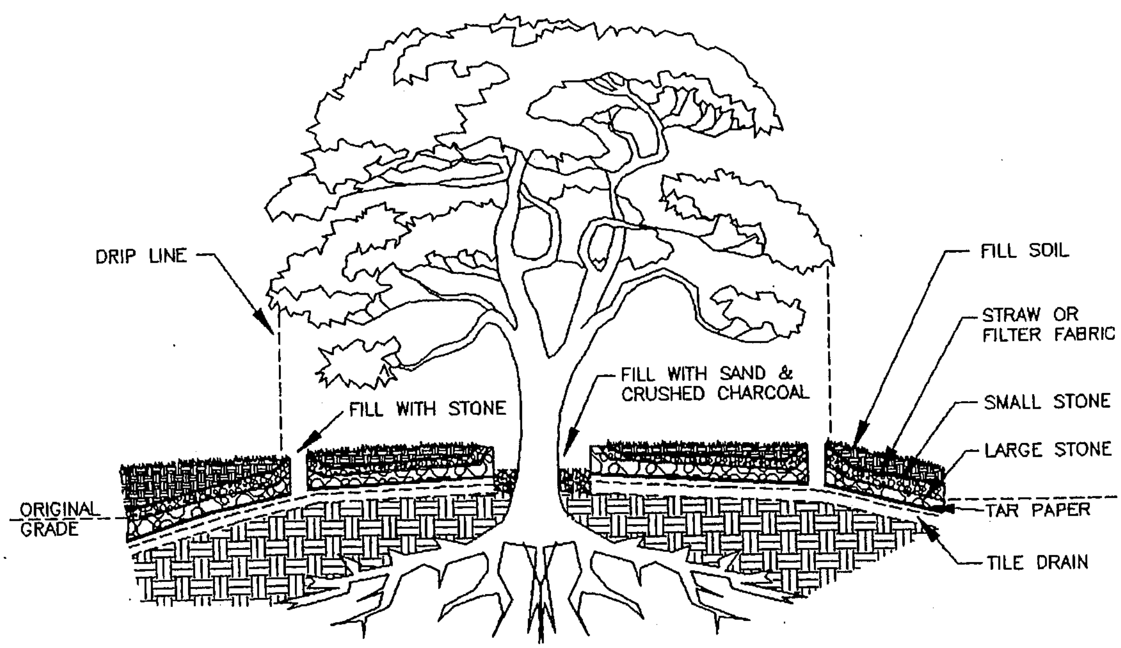
5) The well wall shall be constructed of large stones, brick, building tile, concrete blocks, or cinder blocks with care being taken to ensure that ample openings are left through the wall of the well to allow for free movement of air and water. Mortar shall only be used near the top of the well and only above the porous fill.

6) Drain lines composed of 4-inch, high-quality drain tiles shall begin at the lowest point inside the well and extend outward from the tree trunk in a wheel-and-spoke pattern with the trunk as the hub. These radial drain lines shall slope away from the well at a rate of 1/8 inch per foot. The circumferential line of tiles should be located beneath the drip line of the tree. Vertical tiles or pipes shall be placed over the intersections of the two tile systems if a fill of more than 2 feet is contemplated. These vertical tiles shall be held in place with stone fill. Tile joints shall be tight. A few radial tiles shall extend beyond each intersection and shall slope sharply downward to ensure good drainage.

7) Tar paper or its approved equivalent shall be placed over the tile and/or pipe joints to prevent clogging, and large stone shall be placed around and over drain tiles and/or pipes for protection.

TREE WELL DETAIL





Source: Adapted from Tree Maintenance, 5th ed., Pirone, 1978.

Plate 3.38-4

TABLE 3.38-A
TREE FERTILIZATION FOR PROTECTION FROM CONSTRUCTION ACTIVITY

TREE TYPE	SPECIAL CONDITIONS	APPLICATION RATE & METHOD		FORMULATION
Broad-Leaf Deciduous	Greater than 6 inches dbh* except American Beeches and Crabapples	Normal	2-4 lbs. per inch dbh; broadcast	Commercial 10-8-6 or 10-6-4
		Grade Change	4-5 lbs. per inch dbh; broadcast	Commercial 10-6-4
	Smaller than 6 inches dbh, including all American Beeches and Crabapples	Normal	1-2 lbs. per inch dbh; broadcast	Commercial 10-8-6 or 10-6-4
		Grade Change	2-3 lbs. per inch dbh; broadcast	Commercial 10-6-4
Narrow-Leaf Evergreen	Greater than 6 inches dbh, located in groups	2-4 lbs per 100 sq. ft. of bed area; broadcast		Commercial 10-6-4
	Greater than 6 inches dbh, single specimens in open area	2 lbs. per inch dbh; broadcast		Commercial 10-6-4
	Smaller than 6 inches dbh	5 lbs. per 100 sq. ft. of bed area; incorporated into soil		Tankage or Cottonseed Meal
Broad-leaf Evergreen	Where nitrogen in soil is sufficient	Liberal quantities incorporated into soil and applied as mulch		Acid Peat Moss or Rotted Oak Leaf Mold
	Where additional nitrogen is necessary	Also add 5 lbs. per 100 sq. ft. of bed area incorporated into soil		Tankage or Cottonseed Meal

* dbh : Diameter at breast height (4.5 feet above ground level).

Source: Information taken from Tree Maintenance, P. P. Pirone, 1978.

8) A layer of 2- to 6-inches of stone shall be placed over the entire area under the tree from the well outward at least as far as the drip line. For fills up to 2-feet deep, a layer of stone 8- to 12-inches thick should be adequate. A thicker layer of this stone, not to exceed 30 inches, will be needed for deeper fills.

9) A layer of 3/4-inch to 1-inch stone covered by straw, fiber-glass mat or a manufactured filter fabric shall be used to prevent soil from clogging the space between stones. Cinders shall not be used as fill material.

10) Filling shall be completed with porous soil such as topsoil until the desired grade is reached. This soil shall be suitable to sustain specified vegetation.

11) To prevent clogging of the drain lines, crushed stone shall be placed inside the dry well over the openings of the radial tiles. Vertical tiles shall also be filled with crushed rock and may also be covered with a screen.

12) To prevent anyone from falling into the dry well and leaves and debris from accumulating there, the area between the trunk and the well wall shall either be covered by an iron grate or filled with a 50-50 mixture of crushed charcoal and sand. (This will also prevent rodent infestation and mosquito breeding.)

c. Where water drainage through the soil is not a problem, coarse gravel in the fill may be substituted for the tile. This material has sufficient porosity to ensure air drainage. Instead of the vertical tiles or pipes in the system, stones, crushed rock, and gravel may be added so that the upper level of these porous materials slants toward the surface in the vicinity below the drip line (Plate 3.38-5).

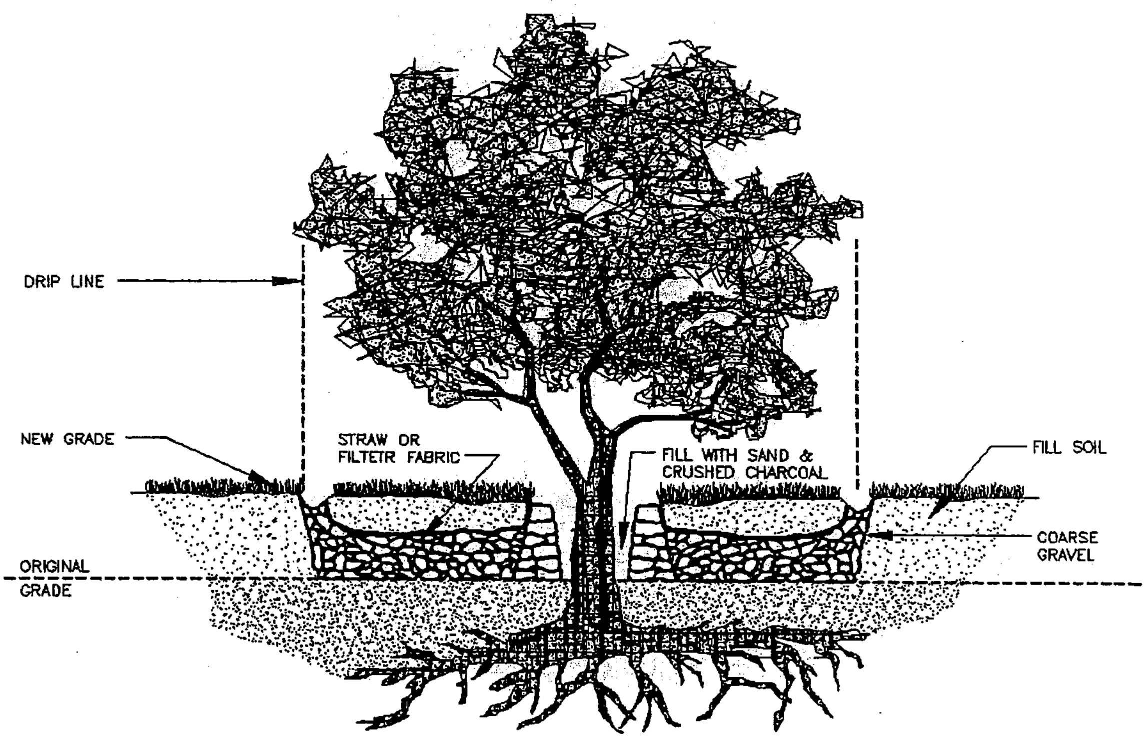
d. Raising the grade on only one side of a tree or group of trees may be accomplished by constructing only half of one of these systems.

10. Lowering the grade: Trees shall be protected from harmful grade cuts by the construction of a tree wall (Plate 3.38-6).

a. Following excavation, all tree roots that are exposed and/or damaged shall be trimmed cleanly, painted with tree paint, and covered with moist peat moss, burlap, or other suitable material to keep them from drying out.

b. The wall shall be constructed of large stones, brick, building tile, or concrete block or cinder block in accordance with the detail in Plate 3.38-6.

TREE WELL WITHOUT DRAIN TILES



Source: Va. DSWC Plate 3.38-5

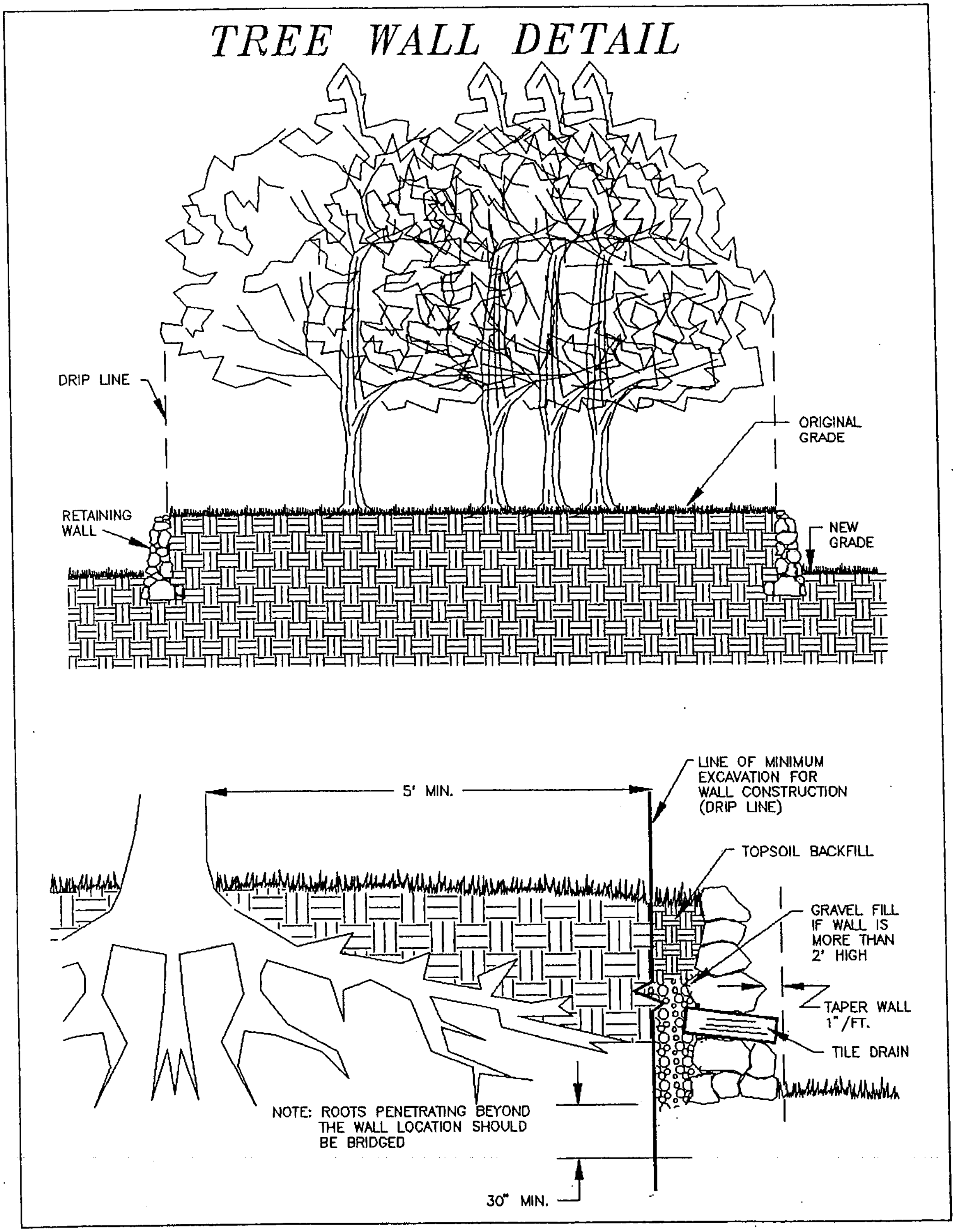
c. Backfill with peat moss or other organic material or with topsoil to retain moisture and aid in root development.

d. Apply fertilizer and water thoroughly. Fertilizer formulations and application rates and methods shall conform to the guidelines provided in Table 3.38-A.

e. Prune the tree crown, reducing the leaf surface in proportion to the amount of root loss.

f. Provide drainage through the wall so water will not accumulate behind the wall.

g. Lowering the grade on only one side of a tree or group of trees may be accomplished by constructing only half of this system.



Source: Adapted from Trees for Architecture and the Landscape, Zion, 1968.

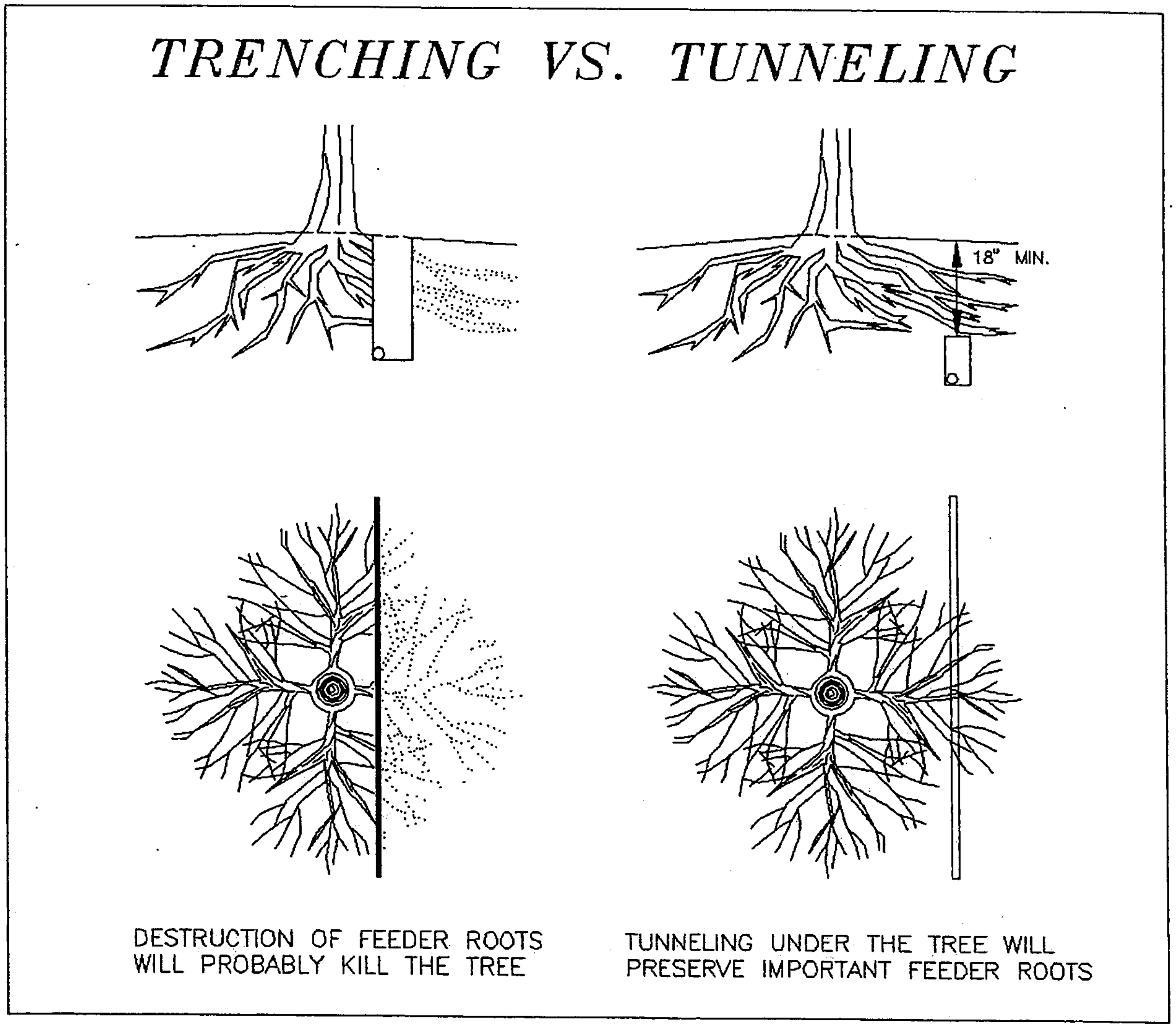
Plate 3.38-6

11. Trenching and Tunnelling:

a. Trenching shall be done as far away from the trunks of trees as possible, preferably outside the branches or crown spreads of trees, to reduce the amount of root area damaged, or killed by trenching activities.

b. Wherever possible, trenches should avoid large roots or root concentrations. This can be accomplished by curving the trench or by tunnelling under large roots and areas of heavy root concentration.

c. Tunnelling is more expensive initially, but it usually causes less soil disturbance and physiological impact on the root system (Plate 3.38-7). The extra cost may offset the potential cost of tree removal and replacement should the tree die.



Source: Tree Maintenance, Pirone, 1979.

Plate 3.38-7

Tunnelling is almost always preferred over the trenching method. The tunnel should be 18 inches or greater below the ground surface and should not be located under the center of the tree (an off-center tunnel has the least impact on the roots).

d. Roots shall not be left exposed to the air. They shall be covered with soil as soon as possible or protected and kept moistened with wet burlap or peat moss until the trench or tunnel can be filled.

e. The ends of damaged and cut roots shall be cut off smoothly and protected by painting promptly with a tree-wound dressing.

f. Trenches and tunnels shall be filled as soon as possible. Air spaces in the soil shall be avoided by careful filling and tamping.

g. Peat moss or other suitable material shall be added to the fill material as an aid to inducing and developing new root growth.

h. The tree shall be mulched and fertilized to conserve moisture, stimulate new root growth, and enhance general tree vigor.

i. If a large amount of the root system has been damaged and killed, the crown leaf surface shall be proportionately reduced to balance the reduced root system. This may be accomplished by pruning 20 to 30 percent of the crown foliage. If roots are cut during the winter, pruning shall be accomplished before the next growing season. If roots are cut during the growing season, pruning shall be done immediately.

12. Removal and Replacement of Damaged Trees: Should a tree intended and marked to be retained be damaged seriously enough that survival and normal growth are not possible, the tree shall be removed. If replacement is desirable and/or required, the replacement tree shall be of the same or similar species, 2-inch to 2½-inch (minimum) caliper balled and burlapped nursery stock. However, today, with the aid of a "tree spade," the same caliper tree may be required as a replacement.

13. Clean-Up: Clean-up after a construction project can be a critical time for tree damage. Trees protected throughout the development operation are often destroyed by carelessness during the final clean-up and landscaping. Fences and barriers shall be removed last, after everything else is cleaned-up and carried away.

14. Maintenance: In spite of precautions, some damage to protected trees may occur. In such cases, the following maintenance guidelines should be followed:

a. Soil Aeration - If the soil has become compacted over the root zone of any tree, the ground shall be aerated by punching holes with an iron bar. The bar shall be driven 1-foot deep and then moved back and forth until the soil is loosened. This procedure shall be repeated every 18 inches until all of the compacted soil beneath the crown of the tree has been loosened.

b. Repair of Damage

1) Any damage to the crown, trunk, or root system of any tree retained on the site shall be repaired immediately.

2) Whenever major root or bark damage occurs, remove some foliage to reduce the demand for water and nutrients.

3) Damaged roots shall immediately be cut off cleanly inside the exposed or damaged area. Cut surfaces shall be painted with approved tree paint, and moist peat moss, burlap, or top-soil shall be spread over the exposed area.

4) To treat bark damage, carefully cut away all loosened bark back into the undamaged area, taper the cut at the top and bottom, and provide drainage at the base of the wound (Plate 3.38-8).

5) All tree limbs damaged during construction or removed for any other reason shall be cut off above the collar at the preceding branch junction (Plate 3.38-8).

6) Care for serious injuries shall be prescribed by a forester or a tree specialist.

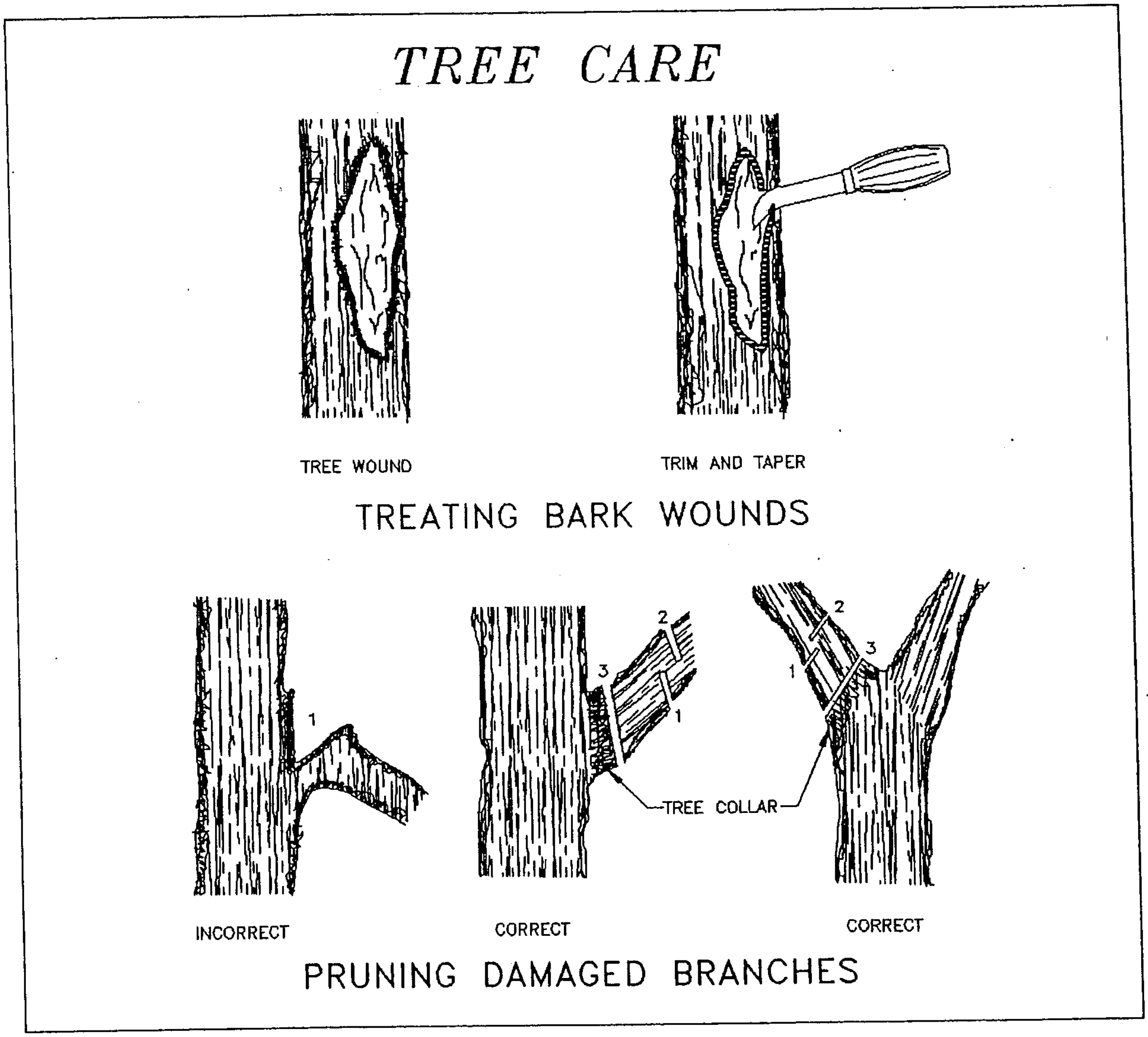
c. Fertilization: Broadleaf trees that have been stressed or damaged shall receive a heavy application of fertilizer to aid their recovery.

1) Trees shall be fertilized in the late fall (after October 1) or the early spring (from the time frost is out of the ground until May 1). Fall applications are preferred, as the nutrients will be made available over a longer period of time.

2) Fertilizer shall be applied to the soil over the feeder roots (see Plate 3.38-9). In no case should it be applied closer than 3 feet to the trunk.

The root system of conifers extends some distance beyond the drip line. Increase the area to be fertilized by one fourth the area of the crown.

3) Fertilizer shall be applied using approved fertilization methods and equipment.

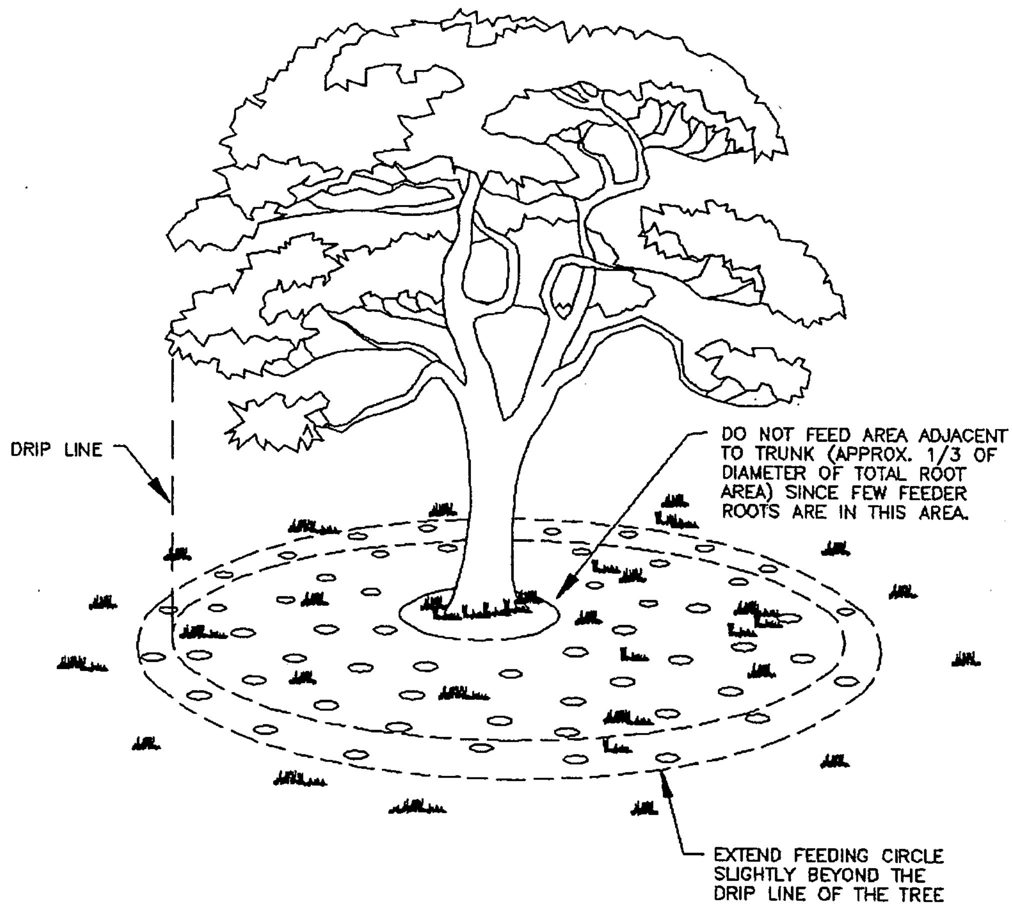


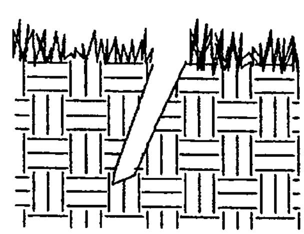
Source: Public Facilities Manual, Vol. III, Fairfax Co., Va., 1976. Plate 3.38-8

4) Formulations and application rates shall conform to the guidelines given in Table 3.38-A.

Maintain a ground cover of organic mulch around trees that is adequate to prevent erosion, protect roots, and hold water.

TREE FERTILIZATION





HOLES SHOULD BE APPROXIMATELY 18" DEEP AND 2' APART, AND THEY SHOULD SLANT TOWARD THE TRUNK.

Source: Tree Maintenance, Pirone, 1979.

Plate 3.38-9

STD & SPEC 3.39

DUST CONTROL

DC

Definition

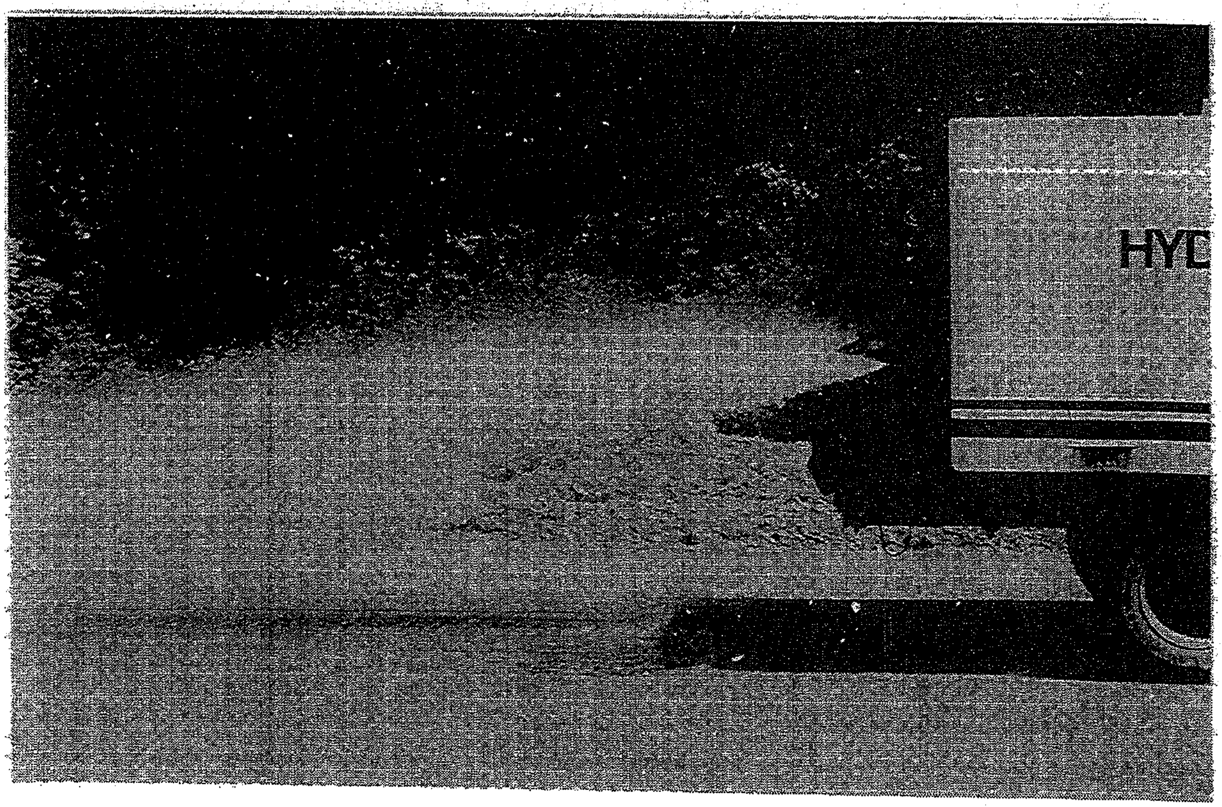
Reducing surface and air movement of dust during land disturbing, demolition and construction activities.

Purpose

To prevent surface and air movement of dust from exposed soil surfaces and reduce the presence of airborne substances which may present health hazards, traffic safety problems or harm animal or plant life.

Conditions Where Practice Applies

In areas subject to surface and air movement of dust where on-site and off-site damage is likely to occur if preventive measures are not taken.



Planning Considerations

Construction activities inevitably result in the exposure and disturbance of soil. Fugitive dust is emitted both during the activities (i.e., excavation, demolition, vehicle traffic, human activity) and as a result of wind erosion over the exposed earth surfaces. Large quantities of dust are typically generated in "heavy" construction activities, such as road and street construction and subdivision, commercial or industrial development, which involve disturbance of significant areas of the soil surface. Research of construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earth-moving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control, limiting the amount of soil disturbance at any one time should be a key objective. Therefore, phased clearing and grading operations and the utilization of temporary stabilization in accordance with MS #1 can significantly reduce dust emissions. Undisturbed vegetative buffers (minimum 50-foot widths) left between graded areas and protected areas can also be very helpful in dust control.

Temporary Measures Used During Construction

1. Vegetative Cover - In areas subject to little or no construction traffic, a vegetatively stabilized surface will reduce dust emissions (see TEMPORARY SEEDING, Std. & Spec. 3.31).

2. Mulch - When properly applied, mulch offers a fast, effective means of controlling dust. Not recommended for areas within heavy traffic pathways. Binders or tackifiers should be used to tack organic mulches (see MULCHING, Std. & Spec. 3.35).

3. Tillage - This practice is designed to roughen and bring clods to the surface. It is an emergency measure which should be used before wind erosion starts. Begin plowing on windward side of site. Chisel-type plows spaced about 12 inches apart, spring-toothed harrows, and similar plows are examples of equipment which may produce the desired effect.

4. Irrigation - This is the most commonly used dust control practice. Site is sprinkled with water until the surface is wet. Repeat as needed. It offers fast protection for haul roads and other heavy traffic routes.

5. Spray-On Adhesives - Tremendous progress has been made in recent years in the development of products of this type. Most are effective on "mineral" soils and are ineffective on "muck" soils. These coherics are derived from a variety of compounds, both organic and synthetic based. Many of the adhesives will withstand heavy traffic loads. The organics include derivatives from pine tar and vegetable gum; synthetics may be acrylic or petroleum based.

The following table list various adhesives and provides corresponding information on mixing and application:

TABLE 3.39-A

ADHESIVES USED FOR DUST CONTROL

Adhesive	Water Dilution (Adhesive: Water)	Type of Nozzle	Application Rate Gallons/Acre
Anionic Asphalt Emulsion	7:1	Coarse Spray	1,200
Latex Emulsion	12.5:1	Fine Spray	235
Resin in Water	4:1	Fine Spray	300
Acrylic Emulsion (Non-Traffic)	7:1	Coarse Spray	450
Acrylic Emulsion (Traffic)	3.5:1	Coarse Spray	350

Source: Va. DSWC

6. Stone - Stone can be used to stabilize roads or other areas during construction using crushed stone or coarse gravel (see CONSTRUCTION ROAD STABILIZATION, Std. & Spec. 3.3).

7. Barriers - A board fence, wind fence, sediment fence, or similar barrier can help to control air currents and blowing soil. Place barriers perpendicular to prevailing air currents at intervals of about 15 times the barrier height. Where dust is a known problem, existing windbreak vegetation should be preserved.

8. Calcium Chloride - This chemical may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage. Application rates should be strictly in accordance with suppliers' specified rates.

Permanent Methods

1. Permanent Vegetation - The application of PERMANENT SEEDING (see Std. & Spec. 3.32) and saving existing trees and large shrubs can help reduce soil and air movement from construction sites.

2. Stone - Crushed stone or coarse gravel can be used as a permanent cover which will provide control of soil emissions.

CHAPTER 4

Stormwater Runoff

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STORMWATER RUNOFF

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Criteria Development Reasoning

The problems associated with stormwater runoff in rapidly urbanizing watersheds have become well-known. These problems relate to both the quantity and quality of stormwater runoff. Major problems include increased flooding magnitude and frequency, accelerated stream channel erosion, and water quality degradation.

The basic underlying cause of these problems is not difficult to understand. The hydrologic systems which have reached a natural equilibrium over centuries simply cannot adjust gracefully to the sudden impact of urban development. Flooding occurs because the increased volume and peak rate of runoff exceeds the natural carrying capacity of the streams more often. Stream channel erosion accelerates due to suddenly increased flow velocities and flooding frequency. The water quality itself is degraded by sedimentation and because numerous other pollutants become available to be washed off the land surface and into the streams, rivers and lakes.

Studies have shown that most natural stream channels are formed with a bankfull capacity to pass runoff from a storm with a 1.5- to 2-year recurrence interval. As upstream development occurs, the volume and velocity of flow from these relatively frequent storms increase. Consequently, even smaller storms with less than 1-year recurrence intervals begin to cause streams to flow full or flood.

According to Leopold (76), stream channels are subject to a 3- to 5-fold increase in the frequency of bankfull flows in a typical urbanizing watershed. This increase in the flooding frequency places a stress on the channel to adjust its shape and alignment to accommodate the increased flow. Unfortunately, this adjustment takes place in a very short time period (in geologic terms), and the transition is usually not a smooth one. Meandering stream channels which were once parabolic in shape and covered with vegetation, typically become straight, wide rectangular channels with barren vertical banks. This process of channel erosion often causes significant property damage, and the resulting sediment which is generated is transported downstream, further contributing to channel degradation.

One strategy for dealing with this problem is to increase the carrying capacity and stability of affected streams through channel modifications (e.g., straightening, widening, lining with non-erodible material, etc.). This strategy may be employed most effectively on man-made channels or small, intermittent streams. Significant modifications to natural, continuous flowing steams, however, can be the subject of intense local controversy.

Wherever modification to natural flowing streams are being considered, extreme care must be taken to weigh the benefits of such modifications against the cost and the concerns of the local citizens. Where channel modifications are necessary, an attempt should be made to incorporate conservation practices which will minimize adverse impacts to fish, wildlife, and the aesthetic quality of the stream.

The following stormwater runoff requirements were developed to provide localities with maximum flexibility to deal with their stormwater runoff problems according to local needs and priorities. The only condition which is imposed statewide is that all local stormwater runoff criteria must contain provisions for the control of off-site erosion and sedimentation.

Statewide Stormwater Runoff Standard

The Erosion and Sediment Control Regulations (Minimum Standard #19) require that properties and waterways downstream from new development sites shall be protected from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff. (See Chapter 8 for the text of the law and regulations.) In the absence of a local stormwater management program, the following criteria shall apply:

A. Increased volumes of sheet flow that may cause erosion or sedimentation on adjacent property must be diverted to a stable outlet, adequate channel or detention facility.

B. Concentrated stormwater runoff leaving a development site must be discharged directly into an adequate natural or manmade receiving channel, pipe or storm sewer system.

An adequate channel is defined as "a watercourse that will convey a chosen frequency storm event without overtopping its banks or causing erosive damage to the bed, banks and overbank sections of the watercourse."

A receiving channel may be considered adequate if the total drainage area to the point of analysis in the channel is 100 times greater than the contributing drainage area of the project site.

For natural channels, the two-year frequency storm is used to verify that stormwater will not overtop the channel banks nor cause erosion of the channel bed or banks.

For manmade channels, the ten-year frequency storm is used to verify that stormwater will not overtop the channel banks and the two-year storm is used to demonstrate that stormwater will not cause erosion of the channel bed or banks.

For pipes and storm sewer systems, the ten-year frequency storm is used to verify that stormwater will be contained within the pipe or storm sewer.

C. If existing natural receiving channels or previously constructed manmade channels or pipes are not adequate, the applicant must choose one of the following options.

1. Improve the channels to a condition where the ten-year frequency storm will not overtop the channel banks and the two-year frequency storm will not cause erosion to the channel bed or banks. The applicant must provide evidence of permission to make the improvements.

2. Improve the pipe or storm sewer system to a condition where the ten-year frequency storm is contained within the appurtenances. The applicant must provide evidence of permission to make the improvements.

3. Develop a site design that will not cause the pre-development peak runoff rate from a two-year frequency storm to increase when runoff discharges into a natural channel or will not cause the pre-development peak runoff rate from a ten-year storm to increase when runoff discharges into a manmade channel.

4. Provide a combination of channel improvements, stormwater detention or other measures which is satisfactory to the plan-approving authority to prevent downstream erosion.

D. If the applicant chooses an option that includes stormwater detention, the applicant must obtain approval from the locality of a plan for maintenance of the detention facility. The plan must establish the maintenance requirements of the facility and identify the person responsible for performing the maintenance.

E. All hydrologic analyses must be based on the existing watershed characteristics and the ultimate development condition of the project site.

F. In applying these stormwater runoff criteria, individual lots in a residential subdivision development are not considered separate development projects. Instead, the residential subdivision development, as a whole, is considered to be a single development project. Hydrologic parameters that reflect the ultimate subdivision development must be used in all engineering calculations.

G. Proposed commercial or industrial subdivisions must apply these stormwater runoff criteria to the development as a whole. Hydrologic parameters that reflect the ultimate subdivision development must be used in all engineering calculations.

Applying the Criteria

The following commentary is intended to aid the handbook user in understanding and applying the stormwater runoff criteria in the Erosion and Sediment Control Regulations (Minimum Standard #19) for localities which have not adopted comprehensive stormwater management programs.

The basic concept of the state criteria is simple. An applicant must show that the runoff from the development project, (from a 2-year frequency storm) will not damage adjacent properties, or exceed the capacity or cause erosion of receiving streams. This must be proven by engineering calculations in the erosion and sediment control plan. The following items should be considered when determining compliance:

1. The stormwater runoff requirements apply to all land development projects which require an erosion and sediment control plan under state law. With regard to residential subdivision projects, the criteria should be applied to the entire subdivision development, not to the individual lots.

2. The stormwater runoff criteria apply primarily at points of concentrated discharge along the perimeter of the development site. However, the project must also be designed so that increased sheet runoff (e.g., runoff from newly paved areas) will not cause damage to adjacent properties. Such increased sheet flows should be diverted to an outlet where the stormwater runoff criteria can be applied.

3. The applicant must show that, wherever concentrated stormwater will be discharged from the site (e.g., pipe or channel outlets), there is an adequate channel or pipe to receive the flow and carry it into the natural drainage system.

4. Each receiving channel must be tested for adequacy. A channel is considered adequate if any of the following conditions can be met:

   a. The bankfull capacity of the natural receiving channel is sufficient to pass the post development peak flow from the 2-year frequency storm and the channel velocity (2-year frequency storm) does not exceed the permissible (non-erodible) velocity of the channel lining.

   b. The bankfull capacity of the manmade receiving channel is sufficient to pass the post development peak flow from the 10-year frequency storm and the channel velocity (2-year frequency storm) does not exceed the permissible (non-erodible velocity of the channel lining.)

      [Engineering procedures for determining channel adequacy are contained in Chapter 5.]

   c. The 10-year frequency storm is contained within the pipe or storm sewer system.

   d. The contributing drainage area of the development site is less than 1% of the total drainage area to the point of consideration in the channel.

   e. There is no increase in the peak runoff rate for the 2-year frequency storm (for natural receiving channels) or the 10-year frequency storm (for manmade receiving channels) at the point of discharge after development

5. If the receiving channel is found to be inadequate, the applicant must incorporate measures to either improve the receiving channel to an adequate

condition, or detain runoff on his site so that the post-development peak runoff rate for the 2-year storm will not exceed the pre-development peak rate. The plan-approving authority may also approve a combination of channel improvements and detention or other measures deemed satisfactory to protect the channel.

6. If a channel-improvement option is chosen, the applicant must obtain necessary easements and comply with applicable regulations regarding channel modifications. Channel improvements must extend downstream until an adequate channel section is reached or until a point is reached where the total drainage area is at least 100-times greater than the drainage area of the development site.

7. If a stormwater detention option is chosen, the applicant must submit a plan for the continued maintenance requirements of the structure and designate someone who has consented to be responsible to carry out the maintenance. The local government may choose to accept the maintenance responsibility for detention structures. However, where this is not done, the responsibility must be borne by the landowner, a homeowners association, or other legal entity. In this case, a maintenance agreement should be executed between the responsible entity and the local government.

CHAPTER 5

Engineering Calculations

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CHAPTER 5

ENGINEERING CALCULATIONS

This chapter is intended to provide site planners and plan reviewers with basic engineering calculation procedures needed to design or evaluate erosion and sediment control and stormwater management structures and systems. The chapter is divided into three parts:

Part I - Estimating Runoff: An attempt is made to standardize the methods used to calculate runoff from a site or watershed. Criteria for selecting an appropriate calculation method are presented along with step-by-step procedures for using three different methods.

Part II - Stormwater Detention: The subject of flood routing is introduced, and a simplified procedure for sizing small, single-stage detention basins is presented.

Part III - Open Channel Flow: This part contains step-by-step procedures for designing new stormwater conveyance channels and for determining the capacity and stability of existing natural channels by using the Manning and Continuity Equations.

Use of the calculation methods outlined in this chapter is not mandated under the state program. Plan-approving authorities may use their discretion to require or accept any calculation method which they feel will best accomplish the desired objective under local conditions.

These engineering procedures are simplified primarily for the benefit of local officials without extensive engineering training who must review erosion and sediment control plans and check design adequacy. These procedures are not recommended for use by non-professionals to design permanent drainage systems or structures.

PART 1

ESTIMATING RUNOFF

Selecting a Calculation Method

Selection of the appropriate method of calculating runoff should be based upon the size of the drainage area and the output information required. Table 5-1 lists acceptable calculation methods for different drainage areas and output requirements. The plan approving authority may require or accept other calculation methods deemed more appropriate for local conditions.

TABLE 5-1

RUNOFF CALCULATION METHODS: SELECTION CRITERIA

Calculation Methods*

1. Rational Method
2. Peak Discharge Method
3. Tabular Method (TR-55)
4. Unit Hydrograph Method

Output Requirements	Drainage Area	Appropriate Calculation Methods
Peak Discharge only	up to 200 acres up to 2000 acres up to 20 sq. mi.	1, 2, 3, 4 2, 3, 4 3, 4
Peak Discharge and Total Runoff Volume	up to 2000 acres up to 20 sq. mi.	2, 3, 4 3, 4
Runoff Hydrograph	up to 20 sq. mi.	3, 4

* The Rational, Graphical Peak Discharge and Tabular methods of runoff determination are described in this chapter. The Unit Hydrograph method is described in the SCS National Engineering Handbook, Section 4, Hydrology.

RATIONAL METHOD

The rational formula is the most commonly used method of determining peak discharge from small drainage areas. This method is traditionally used to size storm sewers, channels, and other drainage structures which handle runoff from drainage areas less than 200 acres. This method is not recommended for routing stormwater through a basin or for developing a runoff hydrograph.

LIMITATIONS THAT AFFECT ACCURACY

(A) Drainage basin characteristics should be fairly homogeneous, otherwise another method should be selected.

(B) The method is less accurate for larger areas and is not recommended for use with drainage areas larger than 200 acres.

(C) The method becomes more accurate as the amount of impervious surface increases.

(D) For this method, it is assumed that a rainfall duration equal to the time of concentration results in the greatest peak discharge.

The rational formula is:

$$Q = CiA$$

where,

Q = Peak rate of runoff in cubic feet per second
C = Runoff coefficient, an empirical coefficient representing a relationship between rainfall and runoff
i = Average intensity of rainfall for the time of concentration (T_c) for a selected design storm
A = Drainage area in acres.

The rational method is based on empirical data and hypothetical rainfall-runoff events which are assumed to model natural storm events. During an actual storm event, the peak discharge is dependent on many factors including antecedent moisture conditions; rainfall magnitude, intensity, duration, and distribution; and, the effects of infiltration, detention, retention, and flow routing throughout the watershed.

The accuracy of the rational method is highly dependent upon the judgement and experience of the user. The method's simplicity belies the complexity in predicting a watershed's response to a rainfall event, especially when the rational method is used to predict post-development runoff. For that purpose, the user must select the appropriate runoff coefficient(s) and determine the time of concentration based on plan information (including proposed hydrologic changes) and experience in working with development and its effects on hydrology.

Runoff Coefficients

The engineer must use judgement in selecting the appropriate runoff coefficient within the range of values for the landuse. Generally, areas with permeable soils, flat slopes and dense vegetation should have the lowest values. Areas with dense soils, moderate to steep slopes, and sparse vegetation should be assigned the highest values.

Time of Concentration

Time of concentration is the time required for runoff to flow from the most hydraulically remote part of the drainage area to the point under consideration. The path that the runoff follows is called the hydraulic length or flow path. As the runoff moves down the flow path, the flow is characterized into flow types or flow regimes.

The three types of flow (or flow regimes) are presented below:

> **Overland flow** (or sheet flow) is shallow flow (usually less than one inch deep) over plane surfaces. For purposes of determining time of concentration, overland flow usually exists in the upper reaches of the hydraulic flow path. The recommended maximum length for this type of flow is 300 feet; however, many engineers agree that overland flow should be limited to 200 feet or less. The actual length of overland flow varies considerably according to actual field conditions. The length of overland flow should be verified by field investigation, if possible.
>
> **Shallow concentrated flow** usually begins where overland flow converges to form small rills or gullies and swales. Shallow concentrated flow can exist in small, man-made drainage ditches (paved and unpaved) and in curb and gutters. The recommended maximum length for shallow concentrated flow is 1000 feet.
>
> **Channel flow** occurs where flow converges in gullies, ditches, and natural or man-made water conveyances (including pipes not running full). Channel flow is assumed to exist in perennial streams or wherever there is a well-defined channel cross-section.

Calculation of Time of Concentration

Time of concentration equals the summation of the travel times for each flow regime. There are numerous methods used to calculate the travel time for each of the flow regimes. The following procedure outlines three methods for determining overland or sheet flow. These methods are: (1) Seelye method; (2) kinematic wave; (3) SCS-TR-55. The user must select the appropriate method for the site. A comprehensive discussion of each of these methods is beyond the scope of this handbook; the reader should consult other sources, such as SCS-TR-55, for more information. (See the reference section for a listing of other sources.)

General Procedure for the Rational Method

The general procedure for determining peak discharge using the rational method is as follows:

Step 1 - Determine the drainage area (in acres). Use survey information, USGS Quadrangle sheets, etc.

Step 2 - Determine the runoff coefficient (C) for the drainage area. Table 5-2 presents a range of runoff coefficient values for various landuses. If the landuse and soil cover are homogeneous for the entire drainage area, a runoff coefficient value can be determined directly from Table 5-2. If there are multiple landuses or soil conditions, a weighted average must be calculated as follows:

Weighted Average "C" = (area landuse$_1$) x "C" = CA_1
(area landuse$_2$) x "C" = CA_2
[continue for each landuse]
Total Area Total CA

$$= \frac{\text{Total CA}}{\text{Total Area}}$$

Step 3 - Determine the hydraulic length or flow path that will be used to determine the time of concentration. Also, determine the types of flow (or flow regimes) that occur along the flow path.

Step 4 - Determine the time of concentration (T_c) for the drainage area.

(A) Overland Flow L_0

The travel time for overland flow may be determined by using the following methods as appropriate. If the ground cover conditions are not homogenous for the entire overland flow path, determine the travel time for each ground cover condition separately and add the travel times to get overland flow travel time. Do not use an average ground cover condition. **Note: the hydraulic length for overland flow should be determined for each site. Do not assume that the length of overland flow equals the maximum recommended length.**

(a) Seelye Method: Travel time for overland flow can be determined by using the Seelye chart (Plate 5-1). This method is perhaps the simplest and is most commonly used for small developments where a greater margin of error is acceptable.

Determine the length of overland flow and enter the nomograph on the left axis, "Length of Strip." Intersect the "Character of Ground" to determine the turn point on the "Pivot" line. Intersect the "Percent of slope" and read the travel time for overland flow.

(b) Kinematic Wave Method: This method allows for the input of rainfall intensity values, thereby providing the specific overland flow travel time for the selected design storm. The equation is:

$$T_t = \frac{(0.93)\ L^{0.6}\ n^{0.6}}{i^{0.4}\ S^{0.3}}$$

where,

L = length of overland flow in feet
n = Manning's roughness coefficient (from Table 5-3)
i = rainfall intensity (from Plates 5-4 to 5-18)
S = slope in feet/foot

Since the equation contains two unknown variables (travel time and rainfall intensity), a trial and error process is used to determine the overland flow time. First, assume a rainfall intensity value (from Plates 5-4 to 5-18) or use the Seelye chart for an approximate duration value) and solve the equation for travel time (T_t). Next, compare the assumed rainfall intensity value with the rainfall intensity value (from Plates 5-4 to 5-18) that corresponds with the travel time. If the assumed rainfall intensity value equals the corresponding rainfall intensity value, the process is complete. If not, adjust the assumed rainfall intensity value accordingly and repeat the procedure until the assumed value compares favorably with the corresponding rainfall intensity value. (See the VDOT Drainage Manual for more details.)

(c) SCS-TR-55 method: [See the Graphical Peak Discharge section or the SCS-TR-55 Manual for details.]

(B) Shallow Concentrated Flow L_{sc}
Determine the velocity of the flow by using Plate 5-2. Then calculate the travel time by the following equation:

$$Tt(\text{minutes}) = \frac{L}{60\ V}$$

where,

L = length of shallow concentrated flow in feet
V = velocity (in feet per second, from Plate 5-2)

Note: The calculation of shallow concentrated flow time is frequently not included when using the rational method. However, the procedure is included in this text for consistency with other runoff methods.

(C) Channel Flow L_c

For small drainage basins, Plate 5-3 can be used to calculate the travel time for the channel flow portion of the flow path.

For larger drainage areas, Manning's Equation is the preferable method for calculating channel flow. The following procedure is used:

$$V = \frac{1.49 \; r^{2/3} \; s^{1/2}}{n}$$

where,

V = average velocity (ft/s)
r = hydraulic radius (ft); $r = a/p_w$
a = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
s = slope of the grade line (channel slope, ft/ft)
n = Manning's roughness coefficient.

Calculate the velocity (V), then calculate the travel time by using the following equation:

$$T_{t(minutes)} = \frac{L}{60\,V}$$

where,

L = Length of channel flow in feet
V = Velocity in feet per second

[For more information on use of the Manning Equation, see Part III, Open Channel Flow.]

Step 4 - Add all of the travel times to get the time of concentration (T_c) for the entire hydraulic length or flow path.

Step 5 - Determine the Rainfall Intensity Factor (i) for the selected design storm by using the Rainfall Intensity charts (Plates 5-4 to 5-18). Select the chart for the locality closest to project. Enter the "Duration" axis of the chart with the time of concentration (T_c). Move vertically to intersect the curve of the appropriate design storm, then move horizontally to read the Rainfall Intensity Factor (i) in inches per hour.

Step 6 - Determine the peak discharge (Q) in cubic feet per second by multiplying the runoff coefficient (or weighted average) (C), the rainfall intensity (i), and the drainage area (A):

$$Q = CiA$$

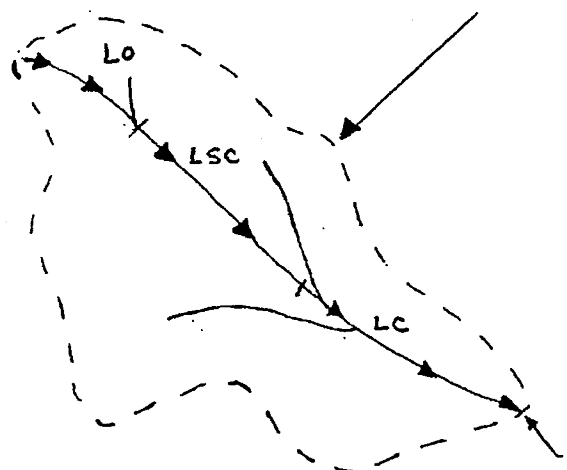
Example 5-1

A project is to be built in southwest Campbell County, Virginia. The following information was determined from field measurement and/or proposed design data:

Drainage Area: 80 acres

30% - Rooftops (24 acres)
10% - Streets and driveways (8 acres)
20% - Average lawns @ 5% slope on sandy soil (16 acres)
40% - Woodland (32 acres)

Watershed = 80 acres at the design point



Design Point

L_o = 200 ft. (4% slope or 0.04 ft./ft.); average grass lawn.

L_{sc} = 1000 ft. (4% slope or 0.04 ft./ft.); paved ditch.

L_c = 2000 ft. (1% slope or 0.01 ft./ft.); stream channel.

Find: Peak runoff rate from the 2-year frequency storm.

Solution:

1. Drainage Area (A) = 80 acres (given).

2. Determine runoff coefficient (C):

Calculate Weighted Average

	Area	x	C (Table 5-2)		
Rooftops	24	x	0.9	=	21.6
Streets	8	x	0.9	=	7.2
Lawns	16	x	0.15	=	2.4
Woodland	32	x	0.10	=	3.2
	80				34.4

$$C = \frac{34.4}{80} = 0.43$$

3. Determine the Time of Concentration (T_c) to the Design Point:

A. Overland flow (L_o)

Using Plate 5-1, T_t = 15 minutes

B. Shallow concentrated flow (L_{sc})

Using Plate 5-2 and the equation, $T_t = \frac{L}{60V}$

1000 ft. length, paved ditch, 4% slope (.04 ft./ft.);
V = 4 fps (from Plate 5-2)

$$L_{sc} = \frac{1100}{60(4)} = 4.2 \text{ minutes}$$

C. Channel Flow (L_c)

Using Plate 5-3:

2000 ft. length and 1% slope (.01 ft./ft.)

(2000) (.01) = 20 ft. height of most remote point of channel above outlet.

L_c = 16 minutes.

4. Add all the travel times to get T_c.

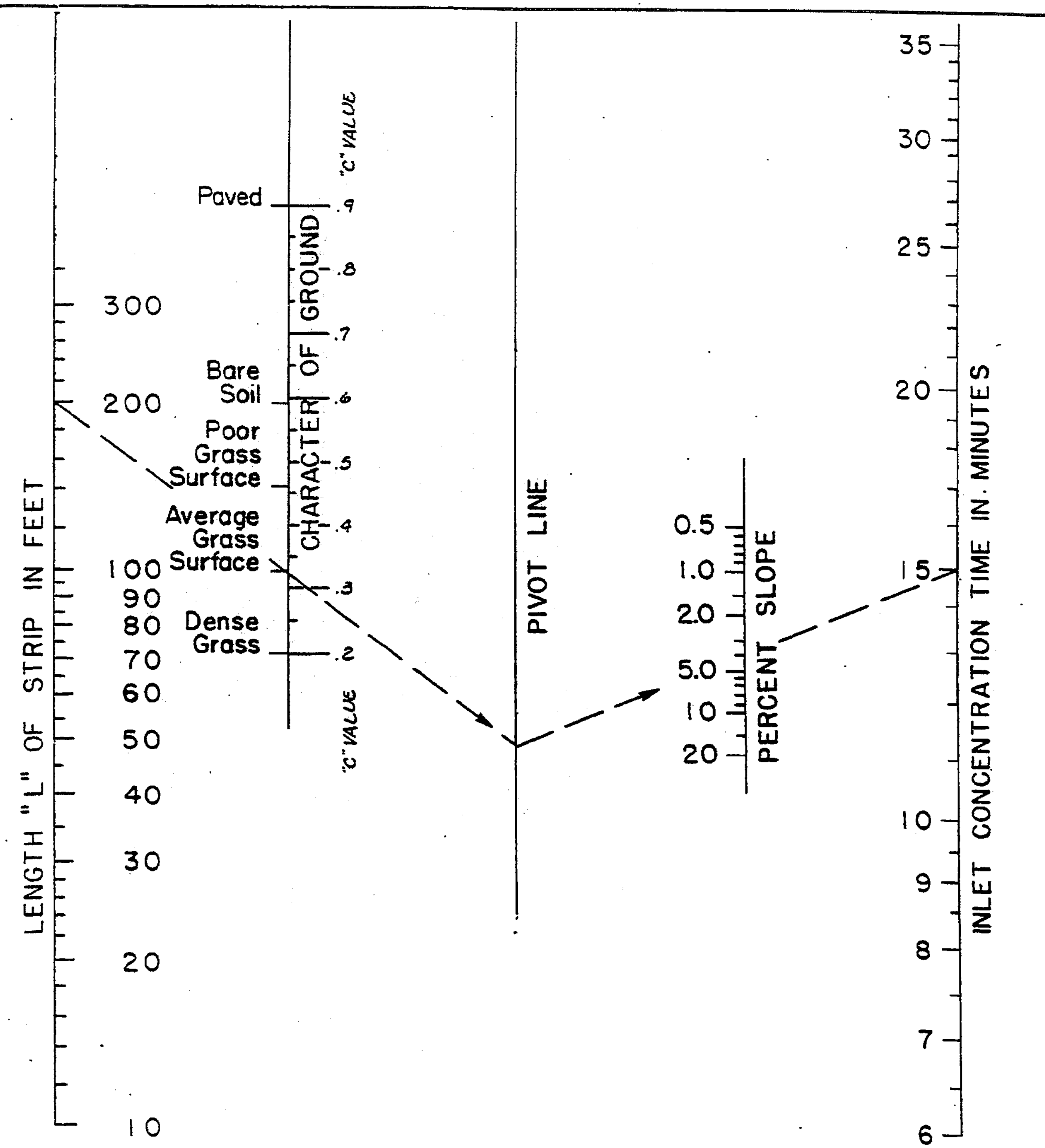
$$15 + 4.2 + 16 = 35.2$$
$$T_c = 35.2 \text{ minutes.}$$

5. Determine the Rainfall Intensity value (i) for the 2-year design storm (using Plate 5-4, Lynchburg Chart).

$$(i) = 2.1 \text{ inches per hour.}$$

6. Determine the peak discharge Q in cfs.

$$\begin{aligned} Q &= (C)\,(i)\,(A) \\ &= (.43)(2.1)(80) \\ &= 72.2 \text{ cfs} \end{aligned}$$

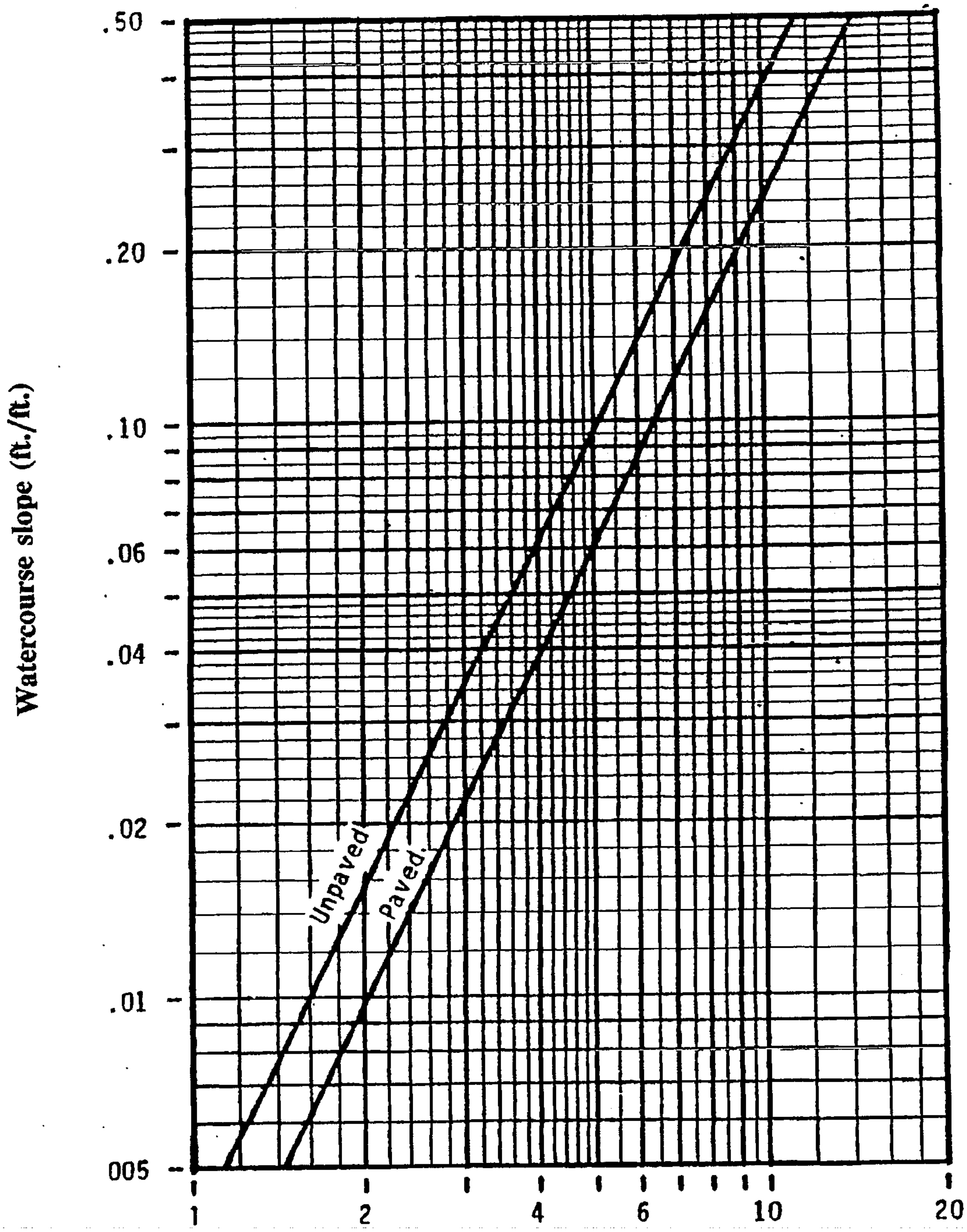


OVERLAND FLOW TIME
(Seelye Chart)

Source: Data Book for Civil Engineers, E.E. Seelye

Plate 5-1

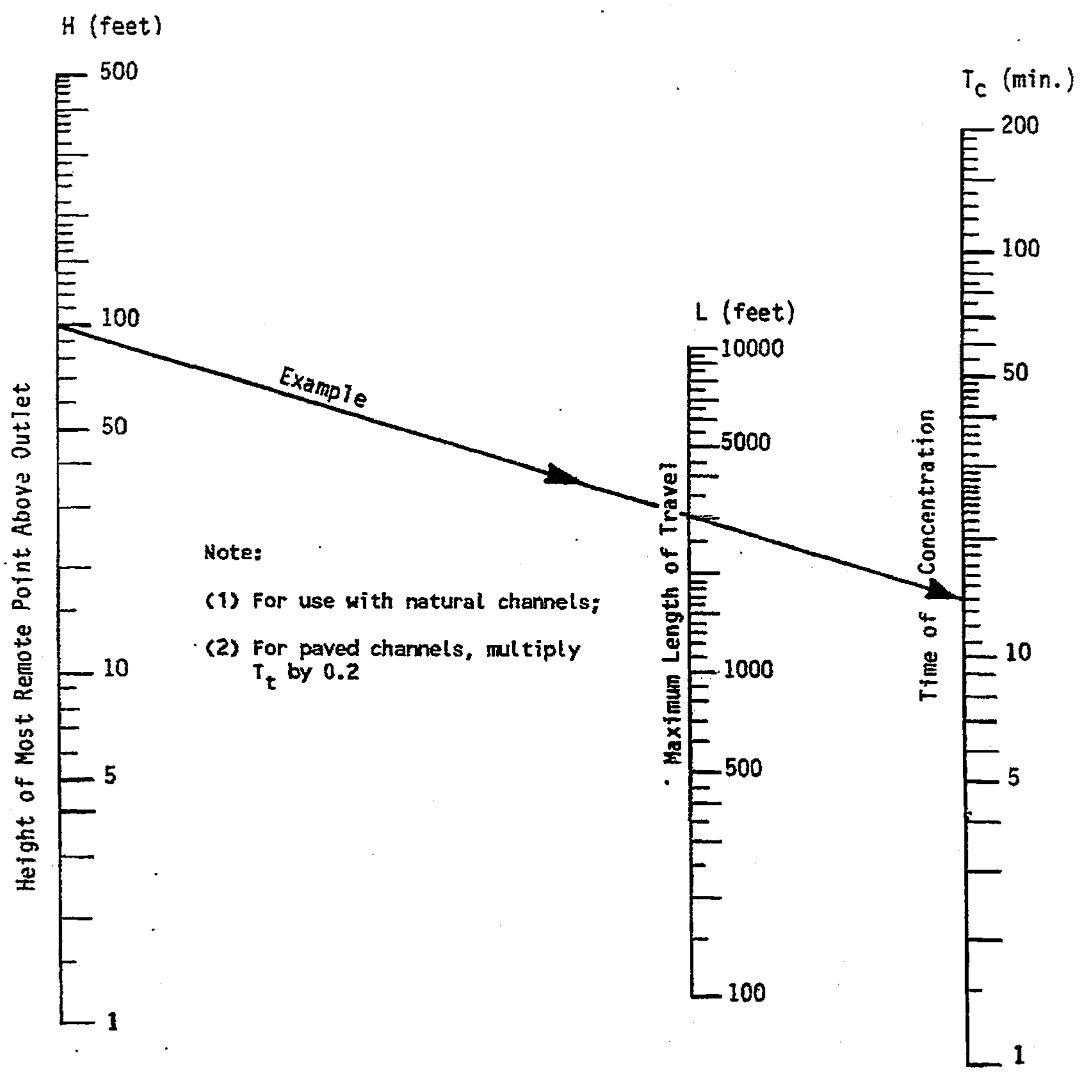
AVERAGE VELOCITIES FOR ESTIMATING TRAVEL TIME FOR SHALLOW CONCENTRATED FLOW



Source: USDA-SCS

Plate 5-2

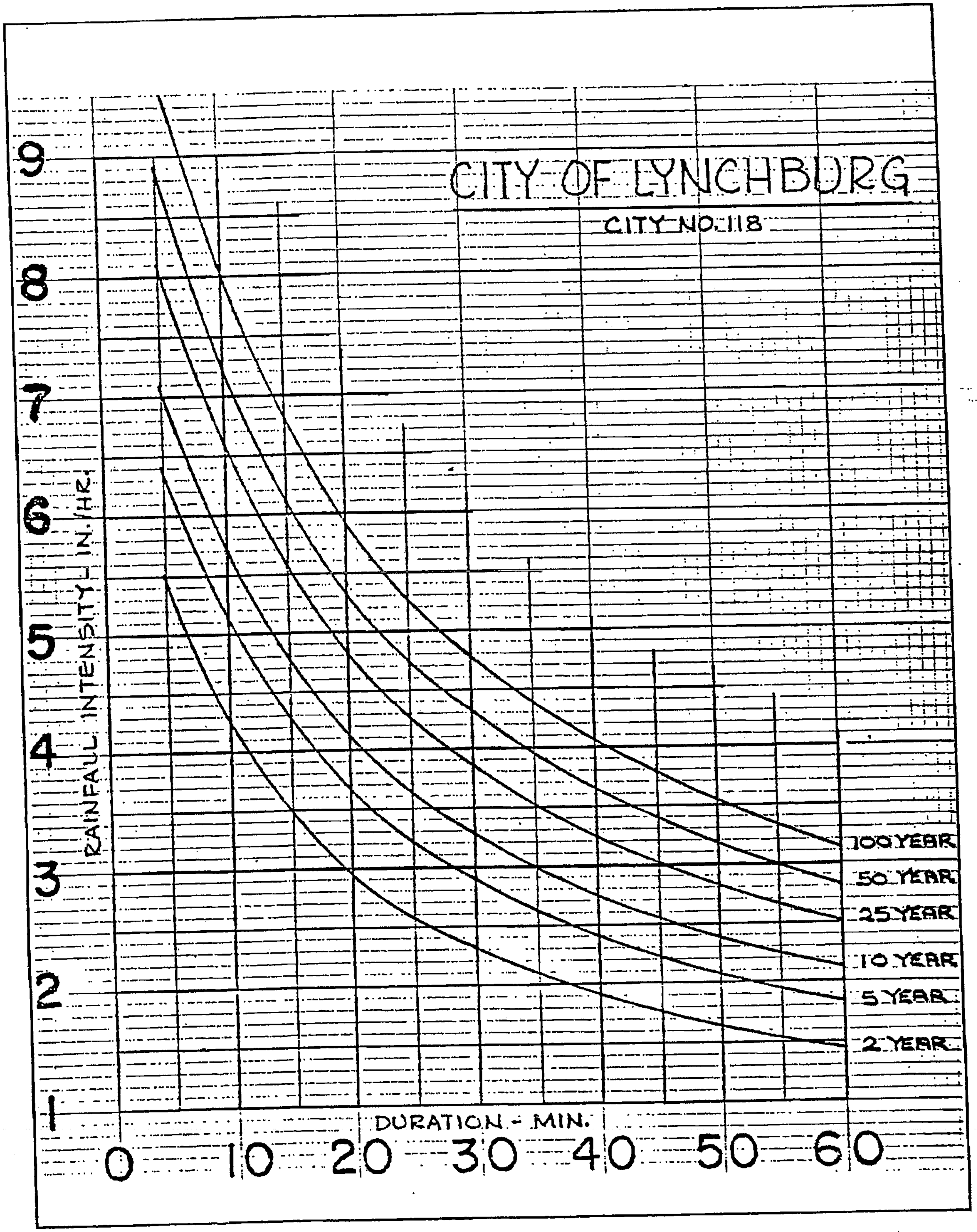
TRAVEL TIME FOR CHANNEL FLOW
(Kirpich Chart)



TIME OF CONCENTRATION OF SMALL DRAINAGE BASINS

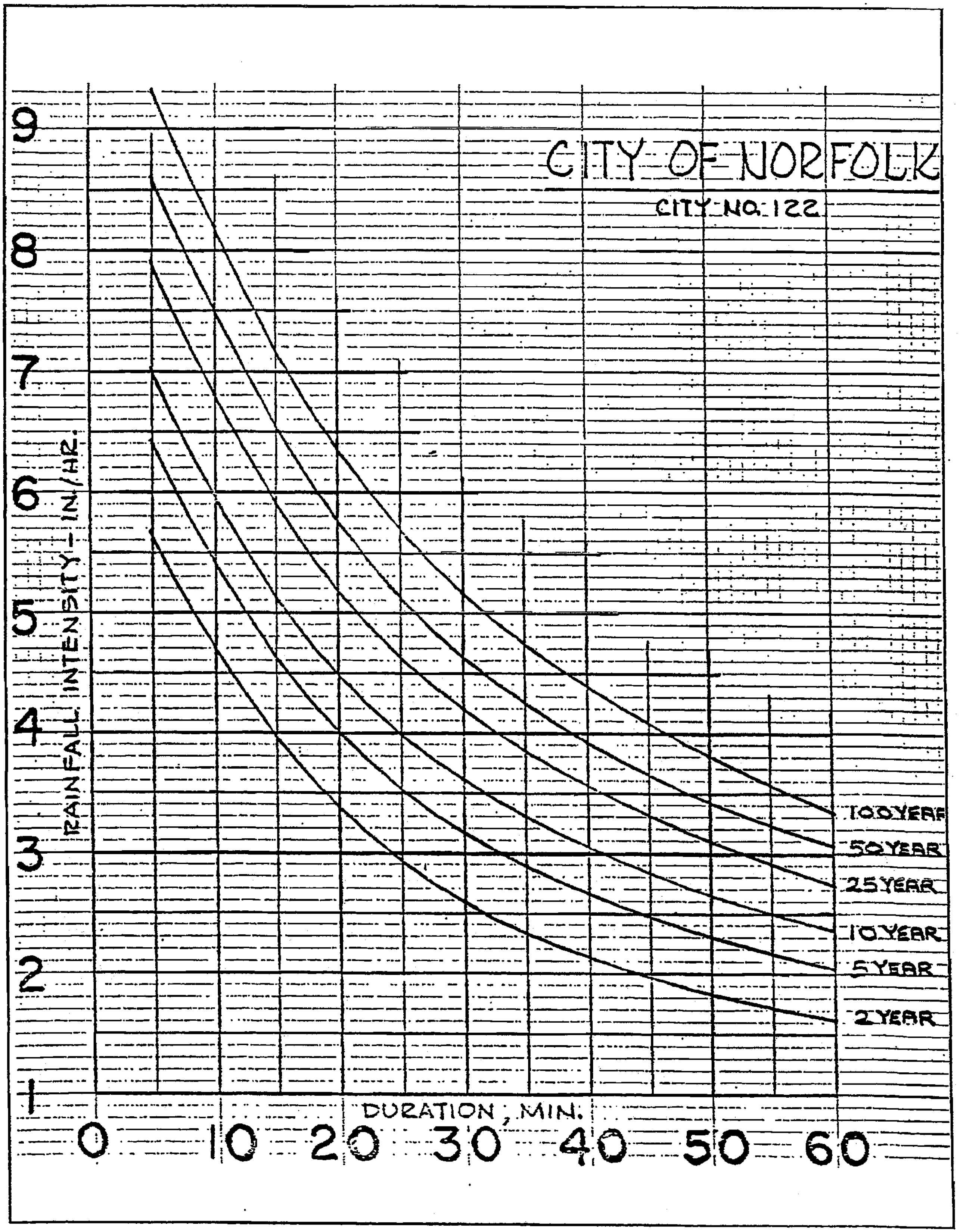
Source: VDOT

Plate 5-3



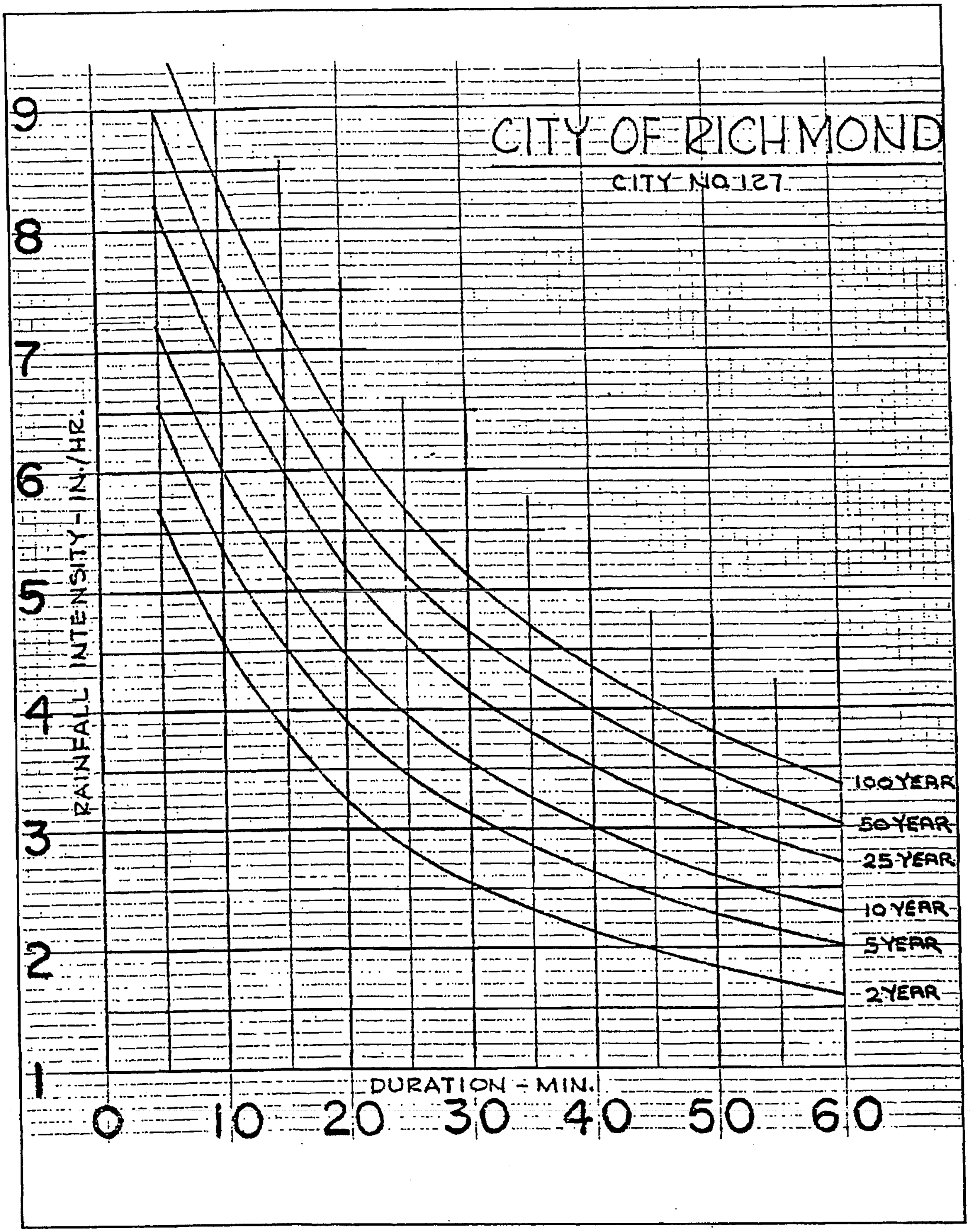
Source: VDOT

Plate 5-4



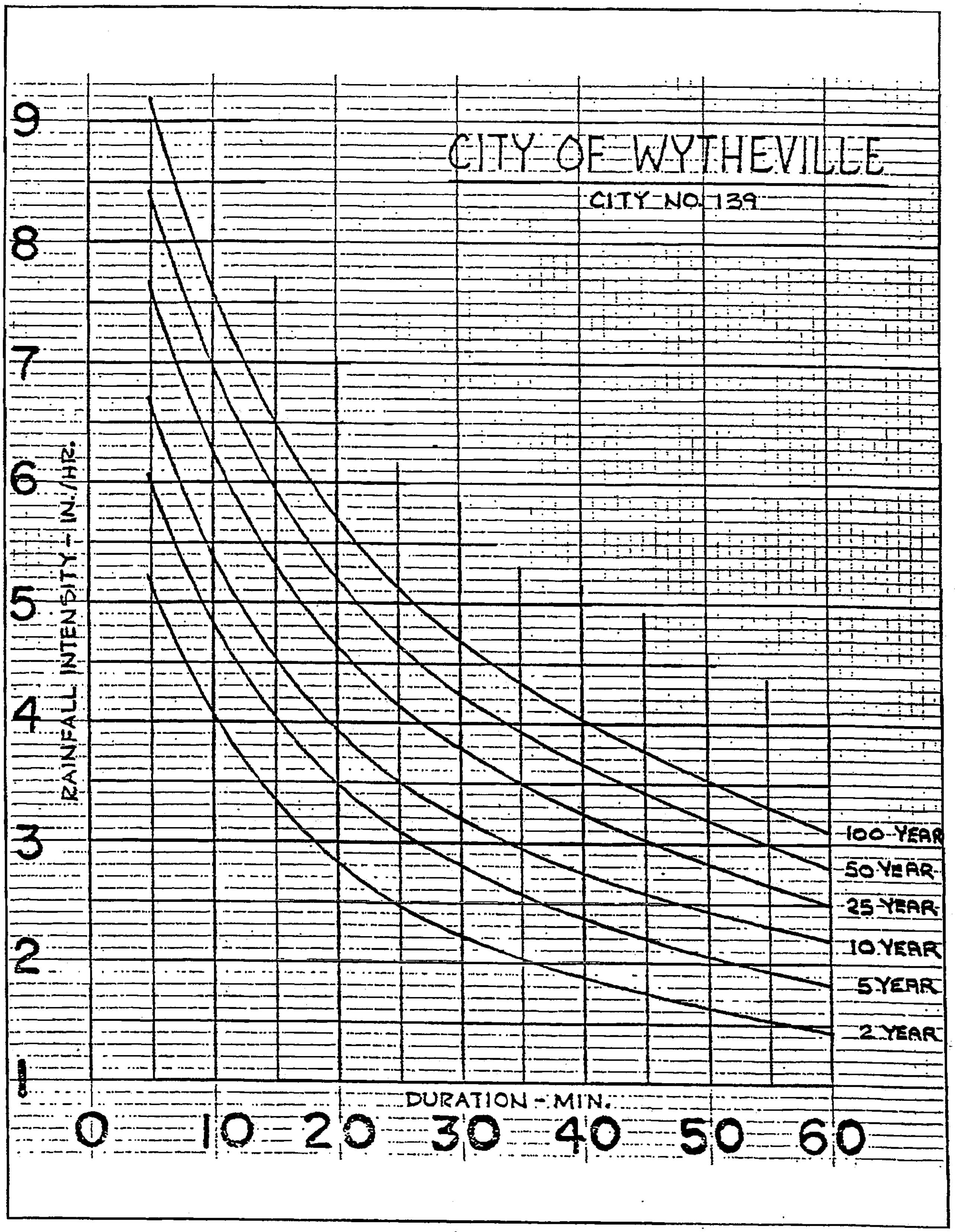
Source: VDOT

Plate 5-5



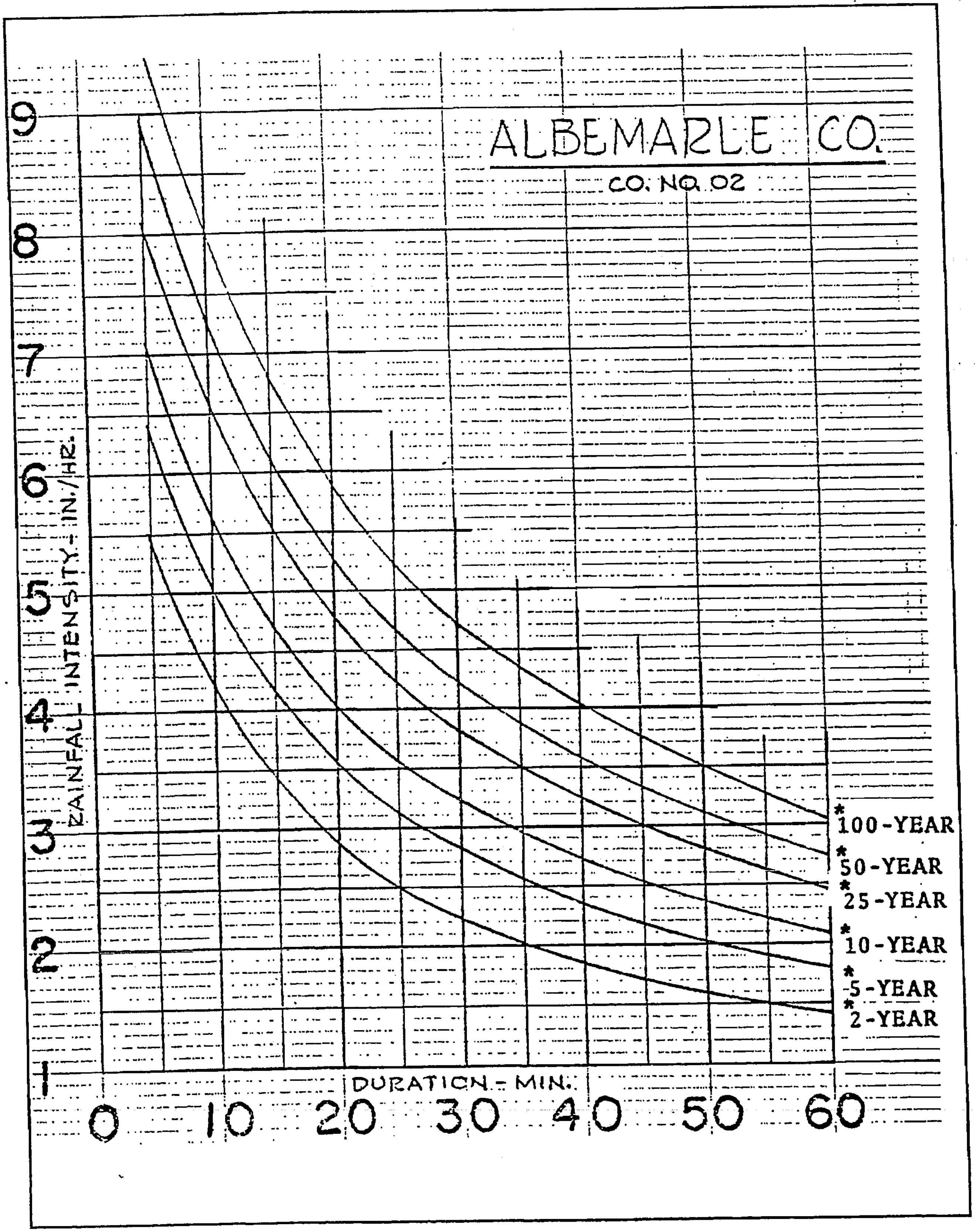
Source: VDOT

Plate 5-6



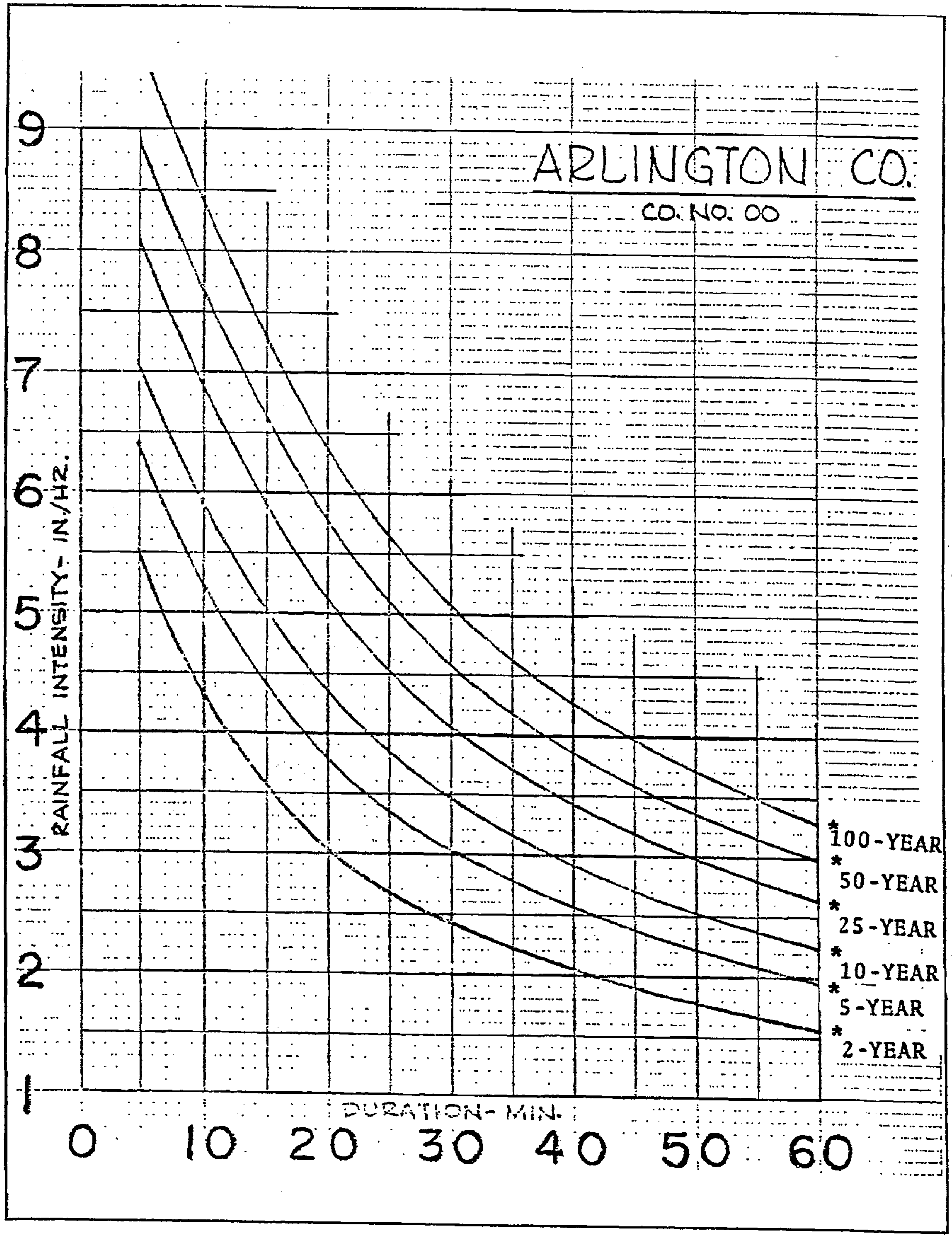
Source: VDOT

Plate 5-7



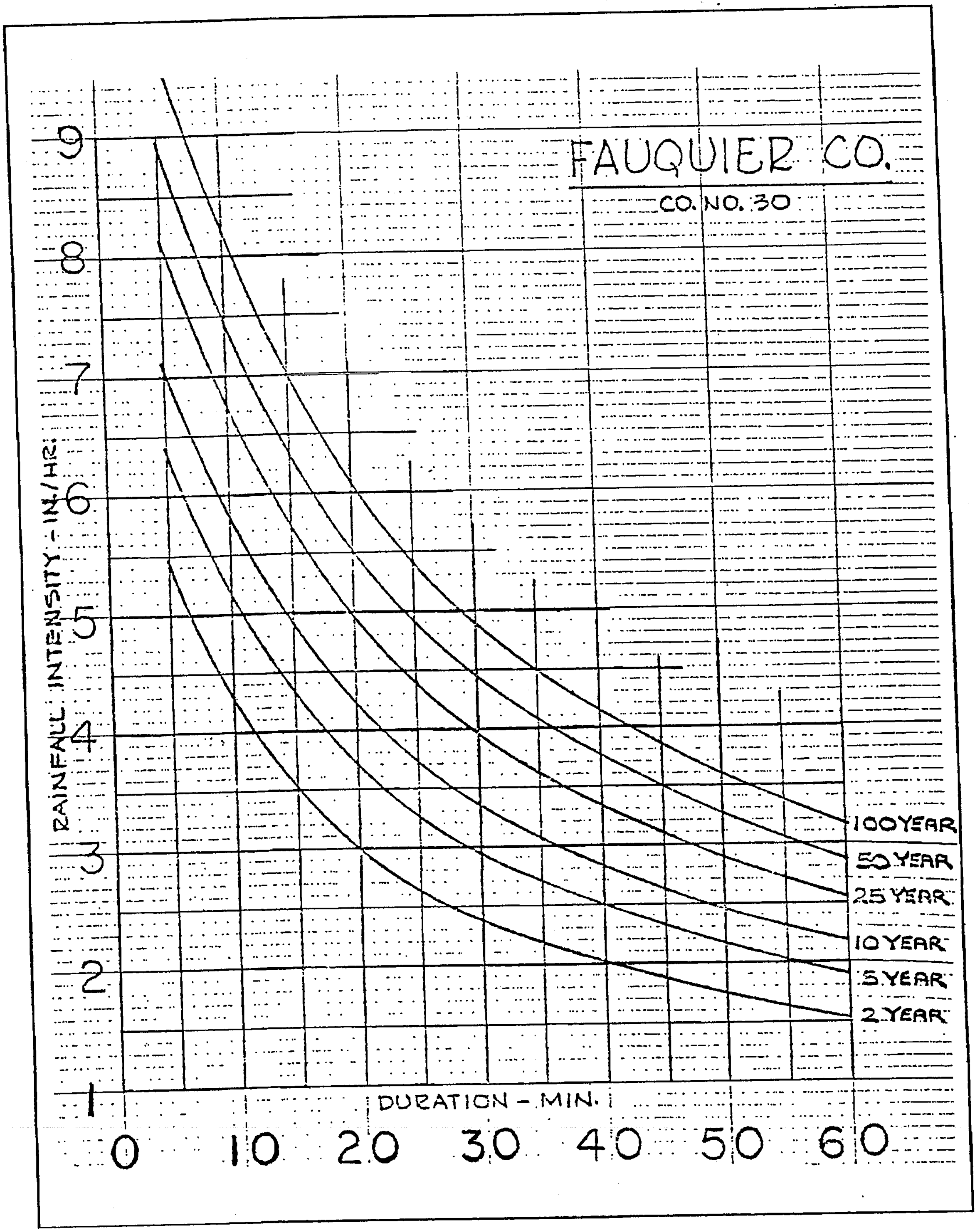
Source: VDOT

Plate 5-8



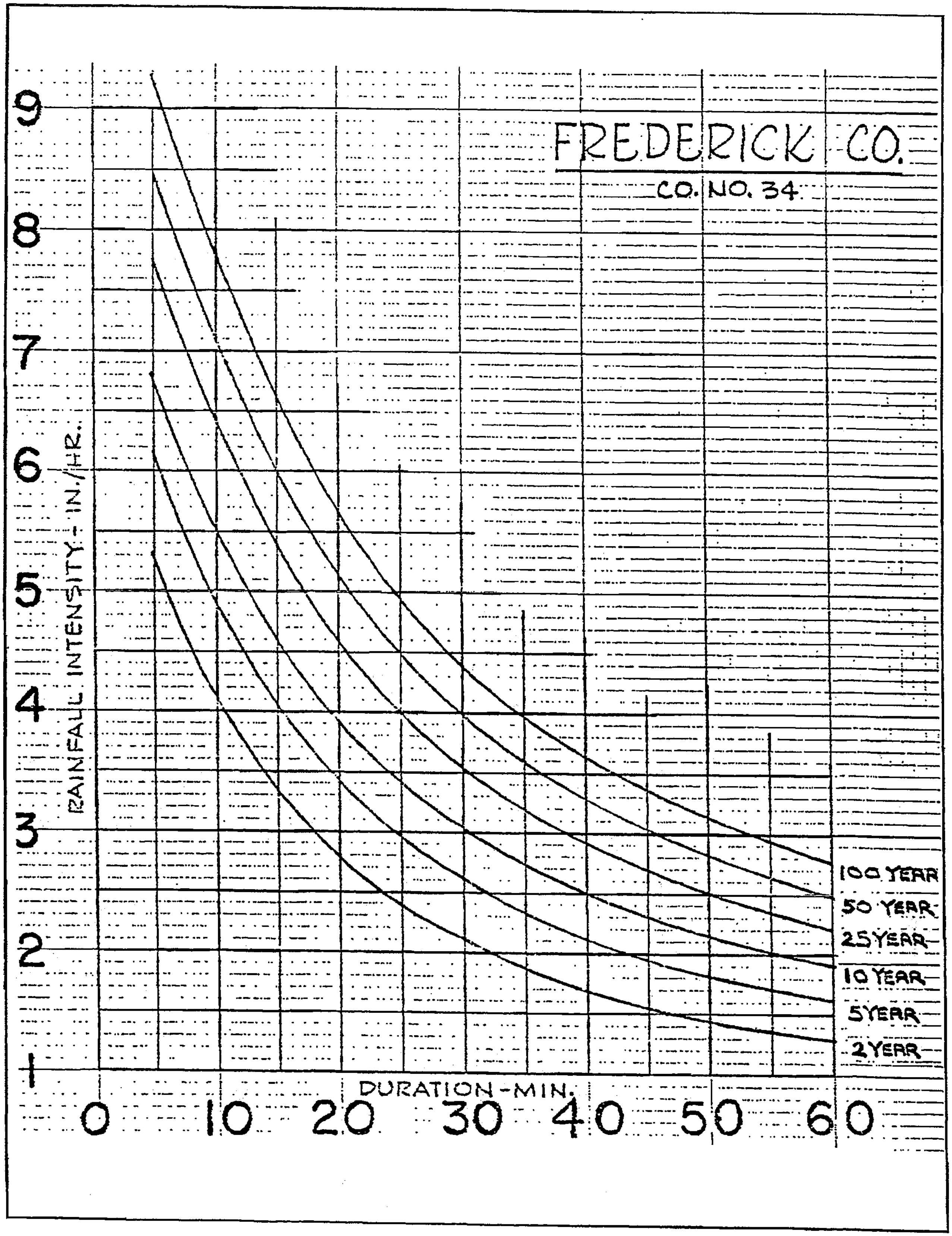
Source: VDOT

Plate 5-9



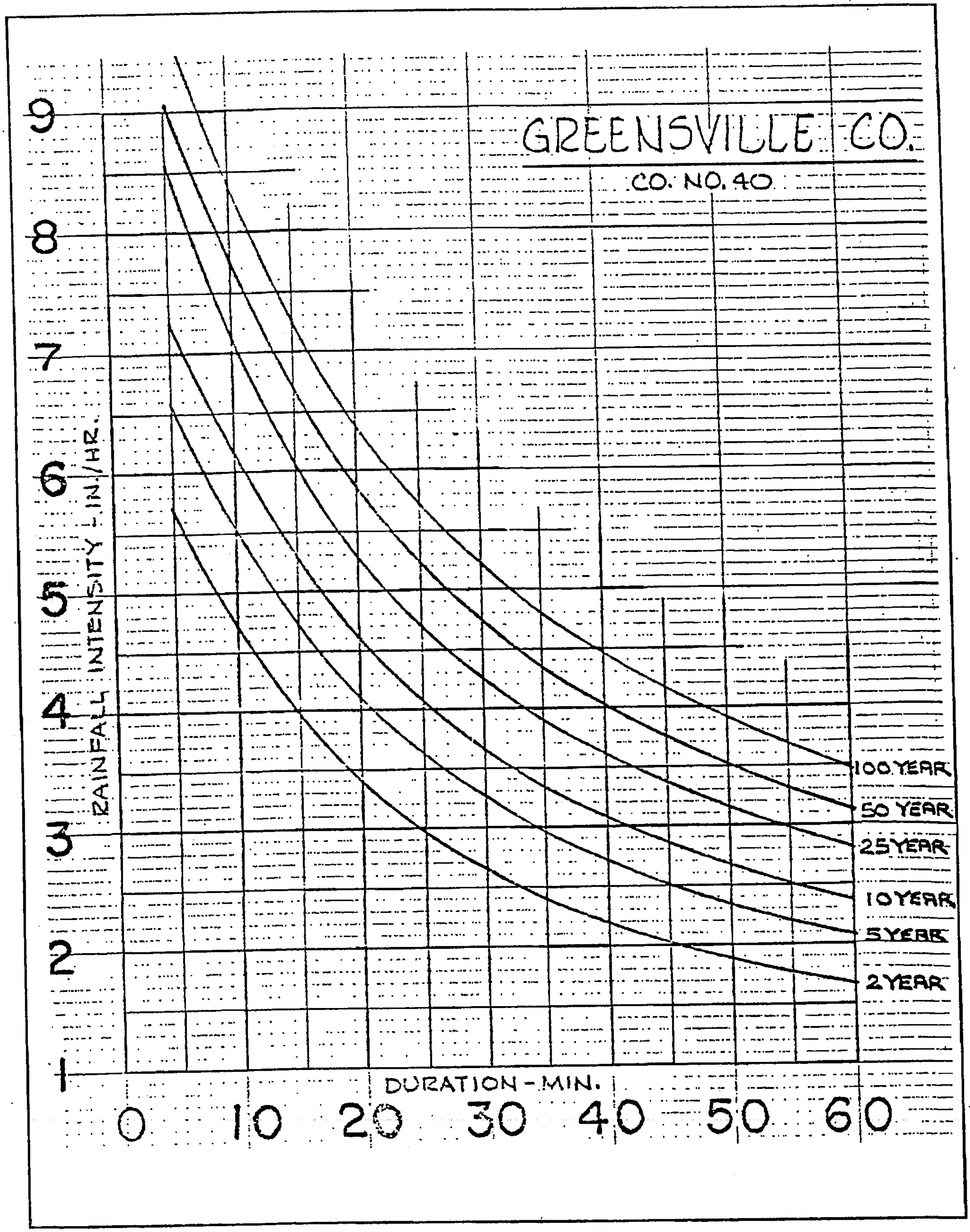
Source: VDOT

Plate 5-10



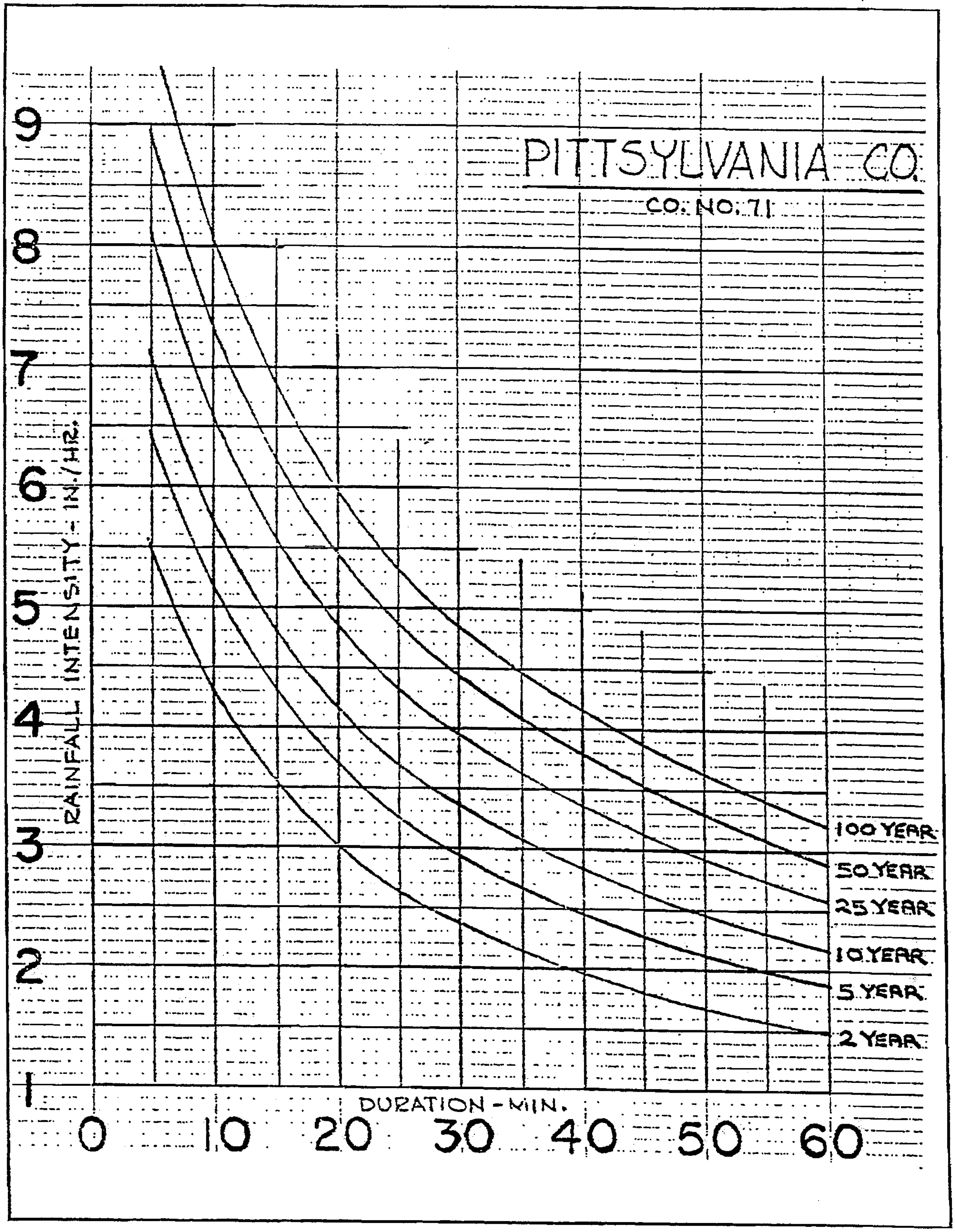
Source: VDOT

Plate 5-11



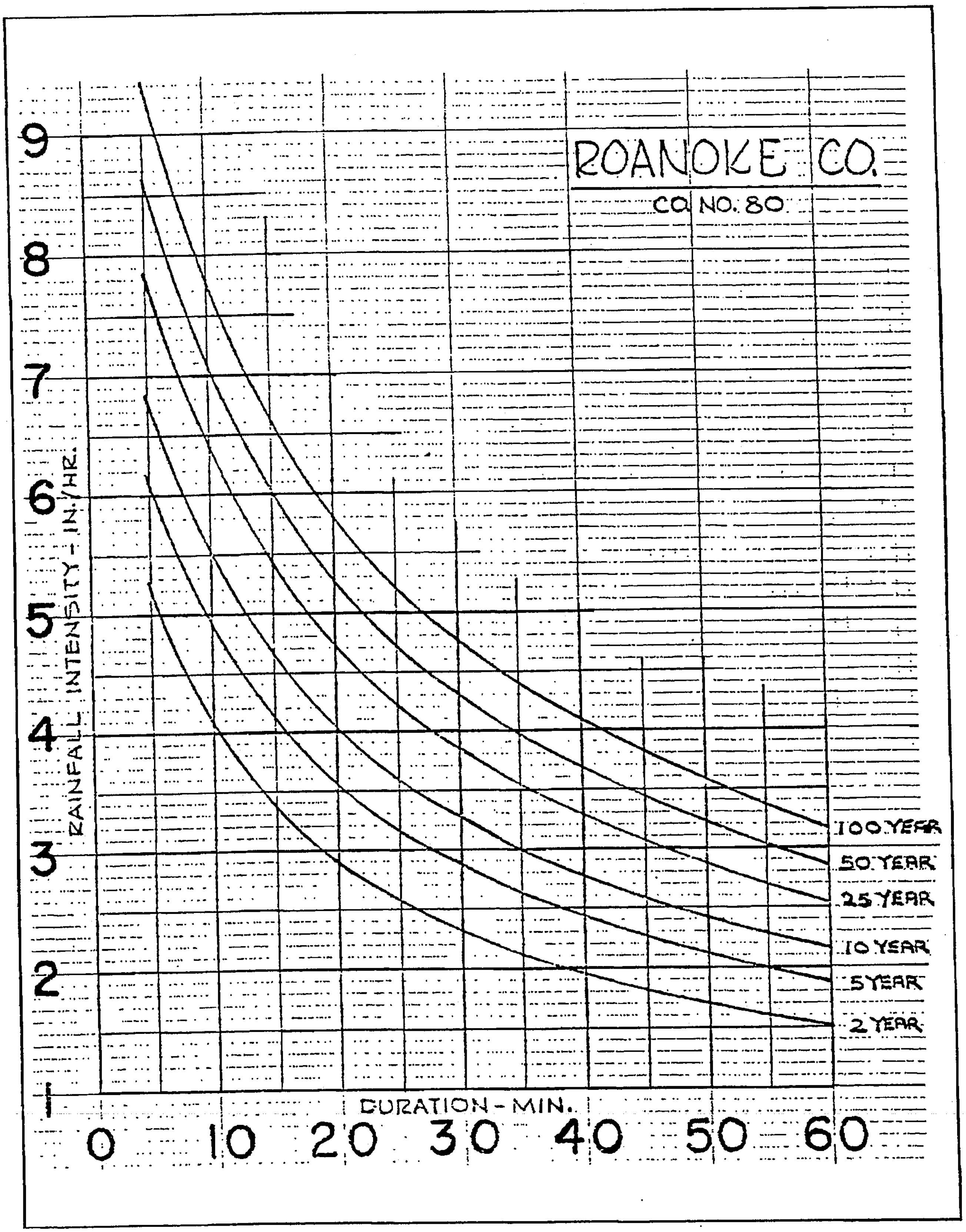
Source: VDOT

Plate 5-12



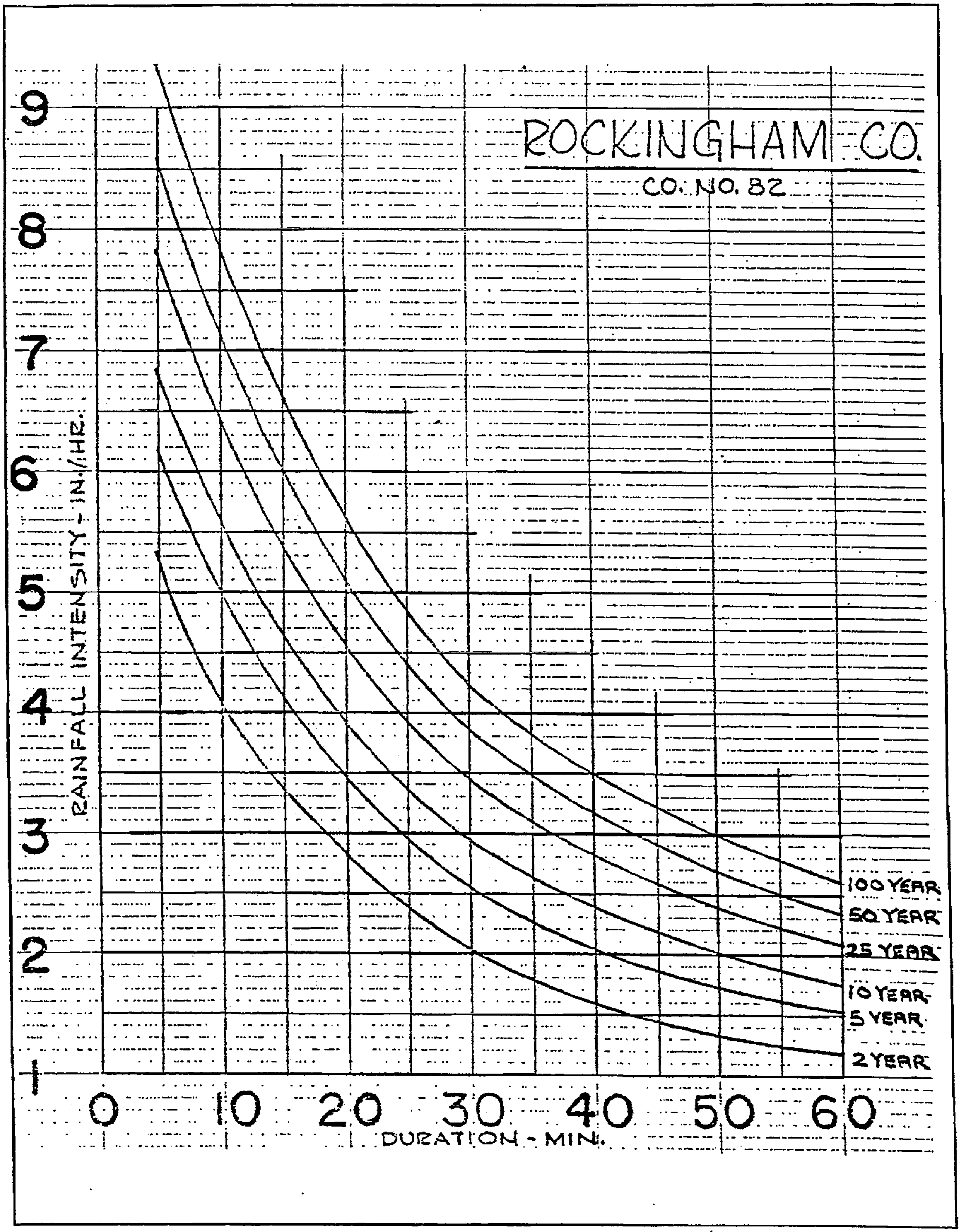
Source: VDOT

Plate 5-13



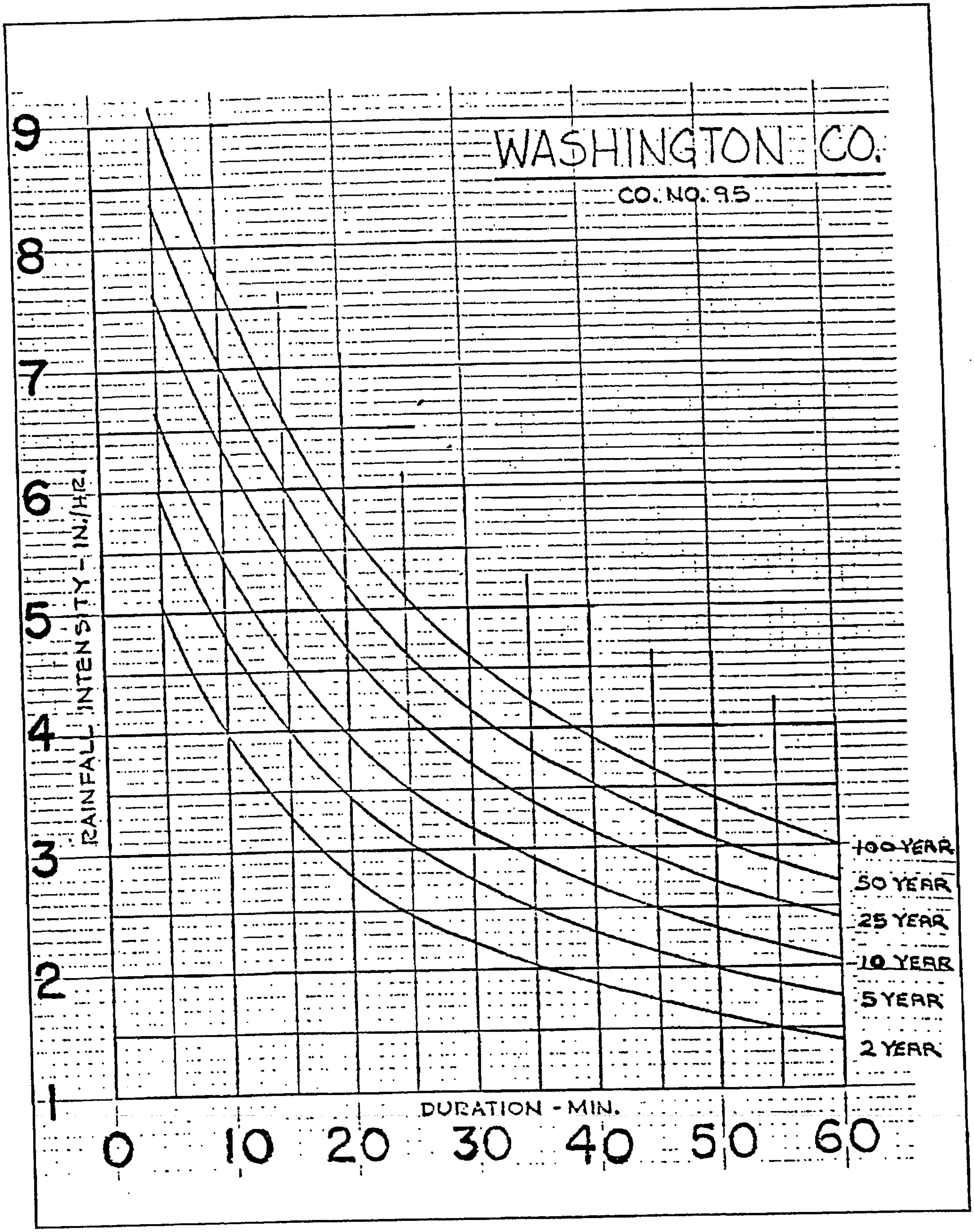
Source: VDOT

Plate 5-14



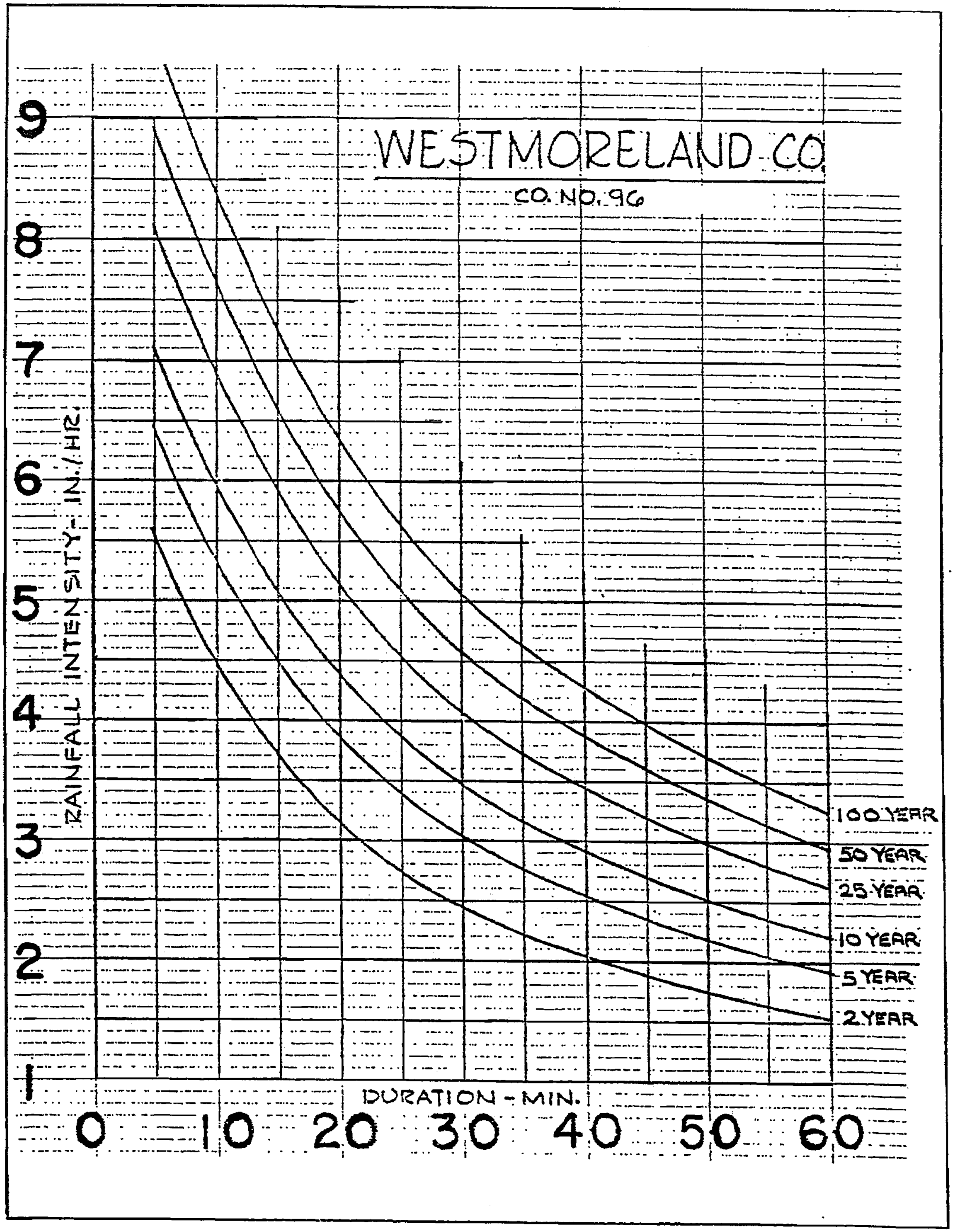
Source: VDOT

Plate 5-15



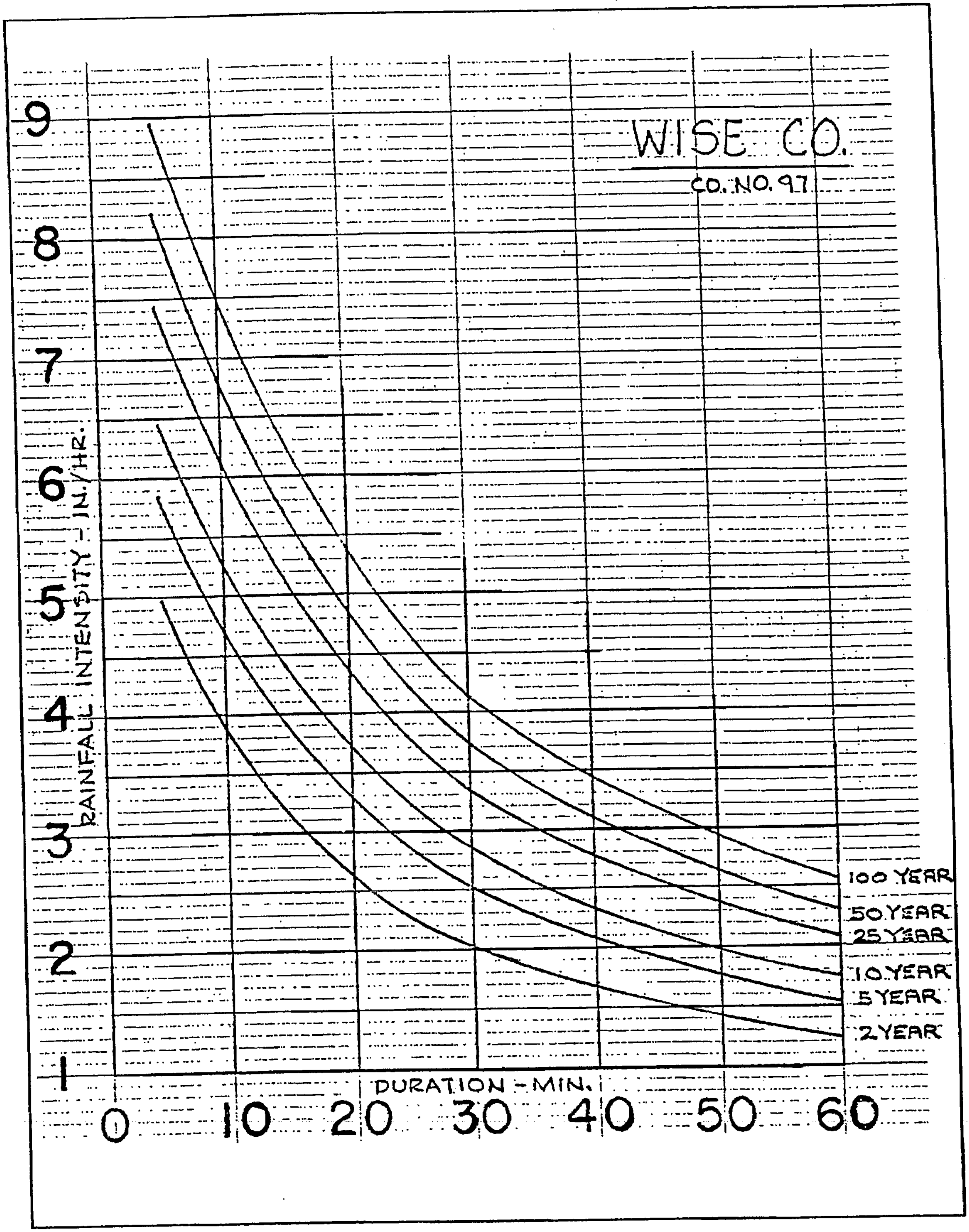
Source: VDOT

Plate 5-16



Source: VDOT

Plate 5-17



Source: VDOT

Plate 5-18

TABLE 5-2
VALUES OF RUNOFF COEFFICIENT (C) FOR RATIONAL FORMULA

Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, average, 2-7%	0.10-0.15
		Sandy soil, steep, 7%	0.15-0.20
		Heavy soil, flat, 2%	0.13-0.17
		Heavy soil, average, 2-7%	0.18-0.22
		Heavy soil, steep, 7%	0.25-0.35
Residential:		Agricultural land:	
Single-family areas	0.30-0.50	Bare packed soil	
Multi units, detached	0.40-0.60	* Smooth	0.30-0.60
Multi units, attached	0.60-0.75	* Rough	0.20-0.50
Suburban	0.25-0.40	Cultivated rows	
		* Heavy soil, no crop	0.30-0.60
		* Heavy soil, with crop	0.20-0.50
		* Sandy soil, no crop	0.20-0.40
		* Sandy soil, with crop	0.10-0.25
		Pasture	
		* Heavy soil	0.15-0.45
		* Sandy soil	0.05-0.25
		Woodlands	0.05-0.25
Industrial:		Streets:	
Light areas	0.50-0.80	Asphaltic	0.70-0.95
Heavy areas	0.60-0.90	Concrete	0.80-0.95
		Brick	0.70-0.85
Parks, cemeteries	0.10-0.25	Unimproved areas	0.10-0.30
Playgrounds	0.20-0.35	Drives and walks	0.75-0.85
Railroad yard areas	0.20-0.40	Roofs	0.75-0.95

Note: The designer must use judgement to select the appropriate "C" value within the range. Generally, larger areas with permeable soils, flat slopes and dense vegetation should have the lowest C values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should be assigned the highest C values.

Source: American Society of Civil Engineers

TABLE 5-3
ROUGHNESS COEFFICIENTS
(MANNING'S "N") FOR SHEET FLOW

Surface Description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods[3]:	
Light underbrush	0.40
Dense underbrush	0.80

1 The "n" values are a composite of information compiled by Engman (1986).

2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

3 When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Source: USDA-SCS

Graphical Peak Discharge Method

The graphical peak discharge method of calculating runoff was developed by the USDA - Soil Conservation Service and is contained in SCS Technical Release No. 55 (210-VI-TR-55, Second Ed., June 1986) entitled Urban Hydrology for Small Watersheds. (62)

This method of runoff calculation yields a total runoff volume as well as a peak discharge. It takes into consideration infiltration rates of soils, as well as land cover and other losses to obtain the net runoff. As with the rational formula, it is an empirical model and its accuracy is dependent upon the judgement of the user.

The information presented in this section is intended as (1) an introduction to the graphical peak discharge method, and (2) an illustration of how the E&S program requirements should be applied to the method. This information should not be used as a set of guidelines in lieu of the source document.

Following is the procedure to use the peak discharge method of runoff determination:

Step 1 - Measure the drainage area. Use surveyed topography, USGS Quadrangle sheets, aerial photographs, soils maps, etc.

Step 2 - Calculate a curve number (CN) for the drainage area.

The curve number (CN) is similar to the runoff coefficient of the rational formula. It is an empirical value which establishes a relationship between rainfall and runoff based upon characteristics of the drainage area.

The soil type also influences the curve number. Each soil belongs to a different hydrologic soil group. Table 5-4 describes the hydrologic soil groups.

Appendix 6C (Chapter 6) lists various soil names and their corresponding hydrologic soil group. If the soil name is unknown, a judgement must be made based upon a knowledge of the soils and the soil group description. Soil names can be obtained from county soil surveys, the local Soil Conservation Service office, or analysis of actual soil borings.

Table 5-5 contains curve number values for different landuse/cover conditions and hydrologic soil groups.

TABLE 5-4

HYDROLOGIC SOIL GROUPS

Soil Group A	Represents soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well-drained sands and gravels.
Soil Group B	Represents soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures.
Soil Group C	Represents soils having a moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water, or soils with moderately fine to fine texture.
Soil Group D	Represents soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

If the watershed has uniform landuse and soils, the curve number value can be easily determined directly from Table 5-5. Curve numbers for non-homogeneous watersheds may be determined by dividing the watershed into homogeneous sub-areas and performing a weighted average.

$$CN = \frac{\Sigma\ (CN\ of\ sub\text{-}area\ \ x\ \ sub\text{-}area)}{Total\ Area}$$

Step 3 - Determine <u>runoff depth and volume</u> for the design storm.

a. The <u>rainfall depth</u> (in inches) can be determined from the maps contained on Plates 5-19 through 5-21 for the selected design storm. (For the examples in this section, the design storms are based upon the

SCS Type II 24-hour rainfall distribution. See the SCS-TR-55 document for other rainfall distributions.)

b. The <u>runoff depth</u> (in inches) can be determined from the graph contained on Plate 5-22. Enter the graph with the rainfall depth (inches) at the bottom, move vertically to intersect the appropriate curve, then move horizontally and read inches of runoff. The equations on Plate 5-22 can also be used, as well as Table 5-6 to determine runoff depth. The volume of runoff from the site can be calculated by simply multiplying the drainage area of the site by the runoff depth.

$$\frac{\text{(in. runoff)} \quad \text{x} \quad \text{acres}}{12 \text{ in./ft.}} = \text{acre-foot}$$

or

$$\frac{\text{(in. runoff)} \quad \text{x} \quad \text{sq. ft.}}{12 \text{ in./ft.}} = \text{cubic feet}$$

Step 4 - Determine time of concentration.

This can be done by using the method outlined in TR-55 or as in the rational method. (See Chapter 5, Part I, Rational Method.) In TR-55, Tc is a summation of travel time for sheet flow, shallow concentrated flow and channel flow as determined by the point of interest in the watershed.

Overland flow or sheet flow:

The maximum flow length (as defined by TR-55) for overland flow is 300 feet; however, it is generally accepted that overland flow is limited to flow paths of less than 200 feet. The engineer should use information from the site to make this determination.

Use Manning's kinematic equation to compute travel time:

$$T_t = \frac{0.007 \ (nL)^{0.8}}{(P_2)^{0.5} \ s^{0.4}}$$

where:

T_t	=	travel time (hr)
n	=	Manning's roughness coefficient (Table 5-7)
L	=	flow length (ft)
P_2	=	2-year, 24-hour rainfall (in)
s	=	slope of hydraulic grade line (feet/foot).

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from Plate 5-23.

Open channels are well defined on the landscape and usually are represented by surveyed cross sections representing certain reach lengths. Manning's equation for open channel flow is used to calculate the average velocity for flow at bank-full elevation for the represented channel reach. A nomograph for solving Manning's equation is provided in Plate 5-24.

Manning's equation is:

$$V = \frac{1.49 \ r^{2/3} \ s^{1/2}}{n}$$

where:

V	=	average velocity (ft/s)
r	=	hydraulic radius (ft) and is equal to a/p_w
a	=	cross sectional flow area (ft^2)
p_w	=	wetted perimeter (ft)
s	=	slope of the hydraulic grade line (channel slope, ft/ft)
n	=	Manning's roughness coefficient for open channel flow. Manning's "n" values for open channel flow can be obtained from Table 5-8, or from standard textbooks such as Chow (1959) or Linsley et al. (1982). (See Chapter 5, Part III, Open Channel Flow, for details.)

After average velocity is obtained, travel time is computed using the following equation for shallow concentrated flow and for open channel flow:

$$T_t = \frac{L}{3600 \ V}$$

where:

T_t	=	travel time (hr.)
L	=	flow length (ft.)
V	=	average velocity (ft./sec.)
3600	=	conversion factor from seconds to hours.

Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed. This travel time is normally very small and can be assumed to be zero.

Step 5 - Determine initial abstraction (I_a).

Initial abstraction (I_a) refers to all losses that occur before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, and evaporation and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. The relationship of I_a to curve number is presented in Table 5-9.

Step 6 - Determine the unit peak discharge.

Divide the initial abstraction by the rainfall to obtain the I_a/P ratio. Enter Plate 5-25 with the calculated T_c in hours, move up to the I_a/P ratio (this can be a linear interpolation) and read the unit peak discharge (q_u) on the left in cubic-feet per second per square mile of drainage area per inch of runoff (csm/in).

To determine the peak discharge (q), multiply the value obtained from Plate 5-25 (q_u) by the drainage area in square miles and by the runoff in inches.

$$q = Q_u \; A_m \; Q$$

where:

q	=	peak discharge in cfs
q_u	=	unit peak discharge in cfs/sq.mi./in. (csm/in.),
A_m	=	drainage area in square miles, and
Q	=	runoff in inches.

Step 7 - Determine whether ponding and swampy conditions in the watershed area will affect the peak discharge. This adjustment is not always needed. Ponds or swamps on the main stream or that are in the path used for calculating time of concentration (T_c) are not considered here. Only ponds and swamps scattered throughout the watershed that are not in the T_c path are considered.

Table 5-10 contains the adjustment factors for ponds and swamps spread throughout the watershed. Measure or estimate the area covered by ponds and/or swamps, convert to percentage of the watershed drainage area, enter the Table and read (or interpolate) the multiplying factor (F_p).

If the F_p adjustment is needed, then the discharge from step 5 is multiplied by the Table value to obtain the final peak discharge (q_p).

$$q_p = (q) \; (F_p)$$

Example 5-2 (present or pre-development condition)

The watershed is located in eastern Campbell County, Virginia and covers 250 acres. Fifty percent of the watershed is Appling soil which is hydrologic soil group B. Fifty percent is Helena soil which is hydrologic soil group C.

Given: Landuse cover and treatment by soil group

Row crops, contour, good	- B soils - 10%
Pasture, good	- C Soils - 30%
Woods, fair	- B Soils - 40%
Woods, good	- C Soils - 20%

Find: Composite (weighted) curve numbers (CN) and runoff volume (Q) in watershed inches for the 2-year and 10-year, 24 hour storms.

Solution:

1. See worksheet 2 (at the end of solution for Example 5-2) for runoff curve number and runoff depth.

2. Determine hydrologic soil group by using Appendix 6C in Chapter 6.

Soil Name	Hydrologic Soil Group
Appling	B
Helena	C

3. Determine runoff curve number for each cover and condition for each hydrologic soil group from Table 5-5.

Cover Description	Soil Group	CN
Row crops, contour, good	B	75
Pasture, good condition	C	74
Woods, fair condition	B	60
Woods, good condition	C	70

4. Perform weighted average curve number computation.

	% Area	x	CN		
Row crops, contour, good	10	x	75	=	750
Pasture, good	30	x	74	=	2200
Woods, fair	40	x	60	=	2400
Woods, good	20	x	70	=	1400
	100				6770

$$CN = \frac{6770}{100} = 67.70 \text{ or } 68$$

5. Determine rainfall (P) on Plates 5-19 and 5-20 in eastern Campbell County for the 2-year and 10-year storms.

   2-year P = 3.5 inches and 10-year P = 5.5 inches.

6. Determine runoff (Q) in watershed inches from Table 5-6, Plate 5-22 or the equations on Plate 5-22.

   2-year Q = 0.90 inches and 10-year Q = 2.24 inches

Worksheet 2: Runoff curve number and runoff

1992

Project Defiance Ridge By ESC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present Developed D.A. 250 Acres

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix 6C)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 5.5	Fig. 2-3	Fig. 2-4	Area ☐acres ☐mi² ☑%	Product of CN x area
Appling, B	Row Crop, Contour, Good	75			10	750
Helena, C	Pasture, Good Condition	74			30	2220
Appling, B	Woods, Fair Condition	60			40	2400
Helena, C	Woods, Good Condition	70			20	1400
					Totals = 100	6770

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{6770}{100} = 67.7$; Use CN = $\boxed{68}$

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	
Rainfall, P (24-hour) (Plates 5-19, 5-20) in	3.5	5.5	
Runoff, Q .... in (Use P and CN with table 5-6, Plate 5-22 or eqs. on Plate 5-22	0.90	2.24	

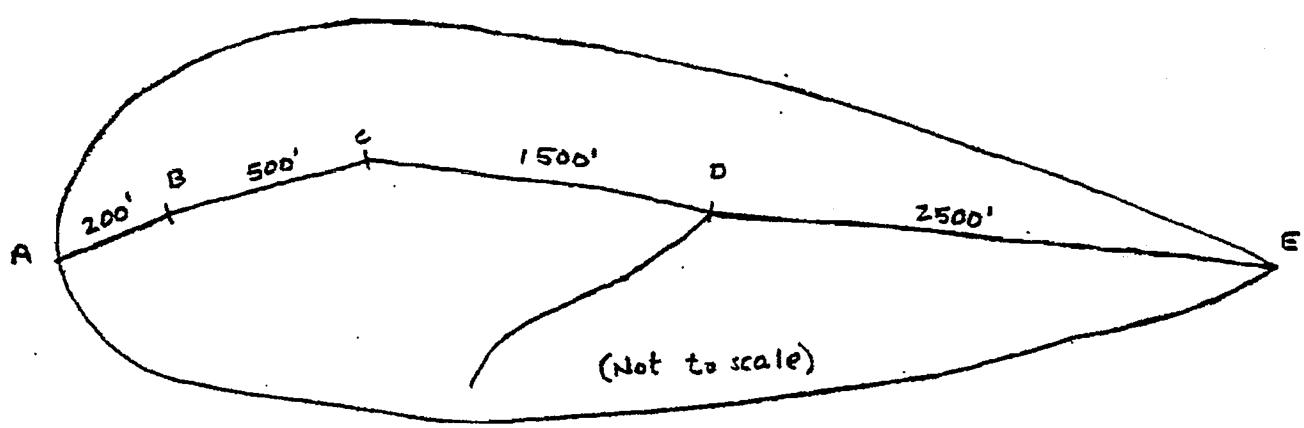
Example 5-3

Given: For present conditions, the flow path was determined to be 4700 feet long by using field surveys and topographic maps. Reach AB is 200 feet of sheet flow in woods and light brush at 2% slope.

Reach BC is 500 feet of shallow concentrated flow at 4% slope.

Reach CD is 1500 feet in a natural channel with 8 square feet cross sectional area, 7.6 feet wetted perimeter, 2% slope and a Manning's "n" of 0.08.

Reach DE is 2500 feet in a natural channel with 27 square feet cross sectional area 21.6 feet wetted perimeter, 0.5% slope and a Manning's "n" of 0.06.



Find: Time of concentration (T_c) for the watershed for the present or pre-developed condition. (See worksheet 3 at the end of solution for Example 5-3.)

Solution:

1. Calculate sheet flow travel time by using Manning's kinematic equation.

$$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ s^{0.4}}$$

where,

n = 0.40 (from Table 5-7)
L = 200 ft.
P_2 = 3.5 in. (from Plate 5-19)
s = 0.02 ft./ft.

$$T_t = \frac{0.007\ (0.40 \times 200)^{0.8}}{(3.5)^{0.5}\ (0.02)^{0.4}} = 0.60\ hr. \quad (Reach\ AB)$$

2. Calculate travel time for shallow concentrated flow.
Surface description: unpaved

$$T_t = \frac{L}{3600V}$$

where,

L = 500 ft.
S = 0.04 ft./ft.
V = 3.2 ft./s (Plate 5-23)

$$T_t = \frac{500}{3600(3.2)} = 0.04 \text{ hr. (Reach BC)}$$

3. Calculate travel time for first channel reach, using Manning's equation for open channel flow. (See also Plate 5-24 for nomograph solution to equation.)

$$V = \frac{1.49 r^{2/3}\ s^{1/2}}{n}$$

where,

a = 8 $ft.^2$
p_w = 7.6 ft.
r = a/p_w = 8/7.6 = 1.05 ft.
s = 0.02 ft/ft
n = 0.08

$$V = \frac{1.49(1.05)^{2/3}(0.02)^{1/2}}{.08} = 2.72 \text{ ft./s}$$

$$T_t = \frac{L}{3600V}$$

$$L = 1500 \text{ ft.}$$

$$T_t = \frac{1500}{3600(2.72)} = 0.15 \text{ hr. (Reach CD)}$$

4. Calculate travel time for second channel reach, using Manning's equation for open channel flow.

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$$

where,

$a = 27 \text{ ft.}^2$

$p_w = 21.6 \text{ ft.}$

$r = a/p_w = 27/21.6 = 1.25$

$s = 0.005 \text{ ft/ft}$

$n = 0.06$

$$V = \frac{1.49\ (1.25)^{2/3}(0.005)^{1/2}}{0.06} = 2.04 \text{ ft./s}$$

$$T_t = \frac{L}{3600V}$$

$$L = 2500 \text{ ft.}$$

$$T_t = \frac{2500}{3600\ (2.04)} = 0.34 \text{ hr. (Reach DE)}$$

5. Find T_c by adding the travel times (T_t):

$$T_c = \Sigma T_t = 0.60 + 0.04 + 0.15 + 0.34 = 1.13 \text{ hr.}$$

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project Defiance Ridge By ESC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Units	Segment ID: AB		Total
1. Surface description (table 5-7)		Woods, lt.brush		
2. Manning's roughness coeff., n (table 5-7)		0.40		
3. Flow length, L (total L ≤ 300 ft)	ft	200		
4. Two-yr 24-hr rainfall, P_2 (worksheet 2)	in	3.5		
5. Land slope, s	ft/ft	0.02		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.60	+	= 0.60

Shallow concentrated flow

	Units	Segment ID: BC		Total
7. Surface description (paved or unpaved)		Unpaved		
8. Flow length, L	ft	500		
9. Watercourse slope, s	ft/ft	0.04		
10. Average velocity, V (Plate 5-23)	ft/s	3.2		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.04	+	= 0.04

Channel flow

	Units	Segment ID: CD	DE	Total
12. Cross sectional flow area, a	ft^2	8.0	27	
13. Wetted perimeter, p_w	ft	7.6	21.6	
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1.05	1.25	
15. Channel slope, s	ft/ft	0.02	0.005	
16. Manning's roughness coeff., n		0.08	0.06	
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	2.72	2.04	
18. Flow length, L	ft	1500	2500	
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.15	+ 0.34	= 0.49
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			1.13

Example 5-4

Given: Drainage Area = 250 Acs. (0.39 mi^2)

$CN = 68$
$T_c = 1.13$ hr.

Find: Pre-developed peak discharge for 2-year and 10-year storms.

Solution: (See worksheet 4 at the end of solution for Example 5-4.)

2-year storm	10-year storm
P_2 = 3.5 in. (Plate 5-19)	P_{10} = 5.5 in. (Plate 5-20)
I_a = 0.941 in.	I_a = 0.941 in. (Table 5-9)
$I_a/P_2 = \frac{0.941}{3.5} = 0.27$	$I_a/P_{10} = \frac{0.941}{5.5} = 0.17$

Peak discharge: $q = q_u A_m Q$ A_m = 250/640 = 0.39 $mile^2$

2-year storm	10-year storm
q_{u2} = 290 csm/in	q_{u10} = 320 csm/in (Plate 5-25)
Q_2 = 0.90	Q_{10} = 2.24 (Plate 5-22)
q_2 = 290 x 0.39 x 0.90 = 102 cfs	q_{10} = 320 x 0.39 x 2.24 = 280cfs

Since there are no ponds or swamps, the correction factor (F_p) is 1.0. Therefore, peak discharges are correct as computed above.

Worksheet 4: Graphical Peak Discharge method

Project Defiance Ridge By ESC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present Developed

1. Data:

Drainage area .... A_m = 0.39 mi^2 (acres/640)

Runoff curve number .... CN = 68 (From worksheet 2)

Time of concentration .. T_c = 1.13 hr (From worksheet 3)

Rainfall distribution type = II (I, IA, II, III) (From Plate 5-27)

Pond and swamp areas spread throughout watershed ...... = 0 percent of A_m (0 acres or mi^2 covered)

			Storm #1	Storm #2	Storm #3
2.	Frequency	yr	2	10	
3.	Rainfall, P (24-hour) (Worksheet 2)	in	3.5	5.5	
4.	Initial abstraction, I_a (Use CN with table 5-5 .)	in	0.941	0.941	
5.	Compute I_a/P		0.27	0.17	
6.	Unit peak discharge, q_u (Use T_c and I_a/P with Plate 5-25)	csm/in	290	320	
7.	Runoff, Q (From worksheet 2).	in	0.90	2.24	
8.	Pond and swamp adjustment factor, F_p (Use percent pond and swamp area with table 5-10. Factor is 1.0 for zero percent pond and swamp area.)		1.0	1.0	
9.	Peak discharge, q_p (Where $q_p = q_u A_m Q F_p$)	cfs	102	280	

Example 5-5 (developed condition):

The same watershed as in the previous examples is subdivided and developed. The project is named Defiance Ridge. 40% of the 250 acres is 1/2 acre lots on the Appling soil; 10% is commercial on the Appling soil; 30% is 1/2 acre lots on the Helena soil; and 20% is open space on the Helena soil. All hydrologic conditions are good cover. The streets are paved with curb and gutter. They are laid out in such a way as to decrease overland flow to 100' in a lawn. Then water flows onto the streets and paved gutters and continues until it reaches the natural channel. (This is the same point at which channel flow began in pre-developed conditions.) Total length of street and gutter flow is 700' at an average of 3% grade.

Find: The post-development runoff curve number for the drainage area, the runoff for the 2-year and 10-year storms, the time of concentration, and the peak discharges for the 2-year and 10-year storms.

Solution: See worksheets 2, 3, and 4, labeled example 5-5 "developed condition," (next three pages) for the solutions.

Since the development of Defiance Ridge will increase the peak discharge of the 2-year storm over the pre-developed conditions, provisions must be made to address the increase in runoff. (The 1/100 rule does not apply since the project area is greater than one percent of total drainage area at the discharge end of the project. See Chapter 4 for more details.)

The site design could include measures that would reduce the volume of runoff (by using infiltration and retention), reduce the peak discharge rate (detention), or improve the receiving channel to convey the increased runoff. Note that any improvements to the channel should be based on the post-development hydrology. See Chapter 4 and the E&S Regulations, Minimum Standard #19, for more details. Detention storage can be provided at the lower end of the development to store and release the post-development 2-year storm runoff at the pre-development 2-year storm peak. See Chapter 5, Part II, Stormwater Detention, for more information.

Worksheet 2: Runoff curve number and runoff

Project Defiance Ridge By ESC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present (Developed) D.A. 250 acs.

1. Runoff curve number (CN)

Soil name and hydrologic group Appendix 6C	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 5-5	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐ acres ☐ mi² ☑ %	Product of CN x area
Appling, B	1/2 Ac. Lots, Good Condition	70			40	2800
Appling, B	Commercial	92			10	920
Helena, C	1/2 Ac. Lots, Good Condition	80			30	2400
Helena, C	Open Space, Good Condition	74			20	1480
				Totals =	100	7600

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{7600}{100} =$ 76; Use CN = $\boxed{76}$

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	2	10	
Rainfall, P (24-hour) (Plates 5-19,5-20)	in	3.5	5.5	
Runoff, Q .... (Use P and CN with table 5-6, Plate 5-20 or eqs. Plate 5-22)	in	1.36	2.95	

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project Defiance Ridge By ESC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID		AB		
1. Surface description (table 5-7)		Lawn		
2. Manning's roughness coeff., n (table 5-7)		0.24		
3. Flow length, L (total L ≤ 300 ft)	ft	100		
4. Two-yr 24-hr rainfall, P_2 (Worksheet 2)	in	3.5		
5. Land slope, s (From Problem # 5-3)	ft/ft	0.02		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.23	+	= 0.23

Shallow concentrated flow

Segment ID		BC		
7. Surface description (paved or unpaved)		Paved		
8. Flow length, L	ft	700		
9. Watercourse slope, s	ft/ft	0.03		
10. Average velocity, V (Plate 5-23)	ft/s	3.5		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.06	+	= 0.06

Channel flow

Segment ID		CD	DE	
12. Cross sectional flow area, a	ft^2	8	27	
13. Wetted perimeter, p_w	ft	7.6	21.6	
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1.05	1.25	
15. Channel slope, s	ft/ft	0.02	0.005	
16. Manning's roughness coeff., n		0.08	0.06	
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	2.70	2.04	
18. Flow length, L	ft	1500	2500	
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.15	+ 0.34	= 0.49
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			0.78

Worksheet 4: Graphical Peak Discharge method

Project Defiance Ridge   By ESC   Date 2-4-91

Location Campbell County, Virginia   Checked SWM   Date 2-5-91

Circle one: Present (Developed)

1. Data:

   Drainage area .... A_m = 0.39 mi^2 (acres/640)

   Runoff curve number .... CN = 76 (From worksheet 2)

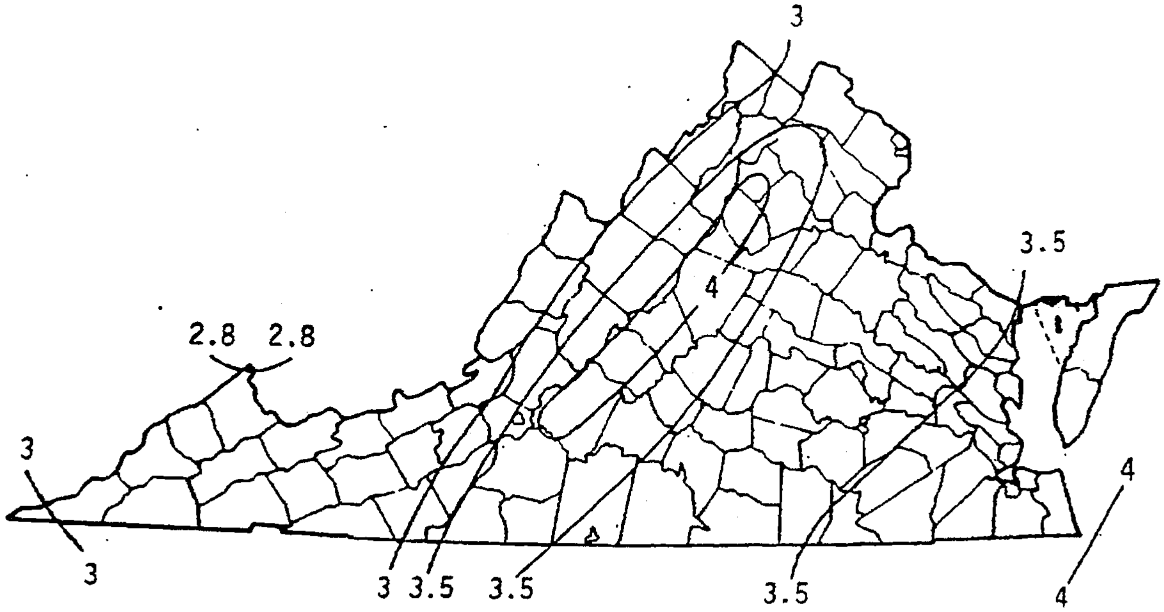
   Time of concentration .. T_c = 0.78 hr (From worksheet 3)

   Rainfall distribution type = II (I, IA, II, III)

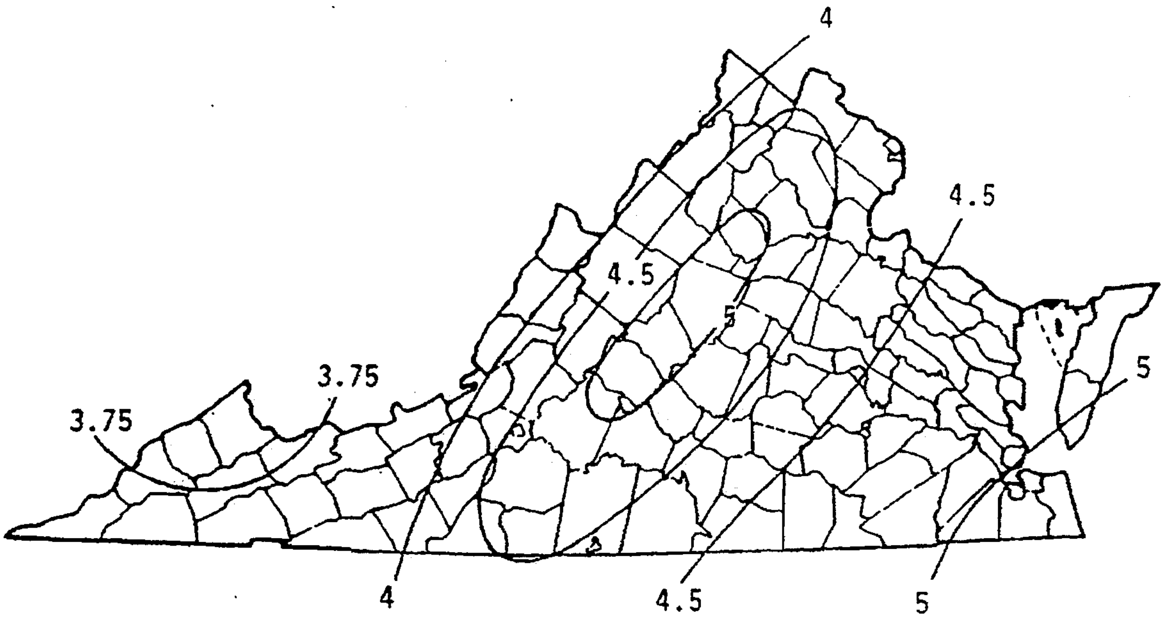
   Pond and swamp areas spread throughout watershed ...... = 0 percent of A_m (0 acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	2	10	
3. Rainfall, P (24-hour) ..(Worksheet 2)...	in	3.5	5.5	
4. Initial abstraction, I_a .... (Use CN with table 5-5)	in	0.632	0.632	
5. Compute I_a/P		0.18	0.11	
6. Unit peak discharge, q_u .... (Use T_c and I_a/P with Plate 5-25)	csm/in	380	410	
7. Runoff, Q .... (From worksheet 2).	in	1.36	2.95	
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 5-10. Factor is 1.0 for zero percent pond and swamp area.)		1.0	1.0	
9. Peak discharge, q_p .... (Where $q_p = q_u A_m Q F_p$)	cfs	202	472	

RAINFALL DEPTHS FOR SELECTED DESIGN STORMS



2-YEAR 24-HOUR RAINFALL (INCHES)

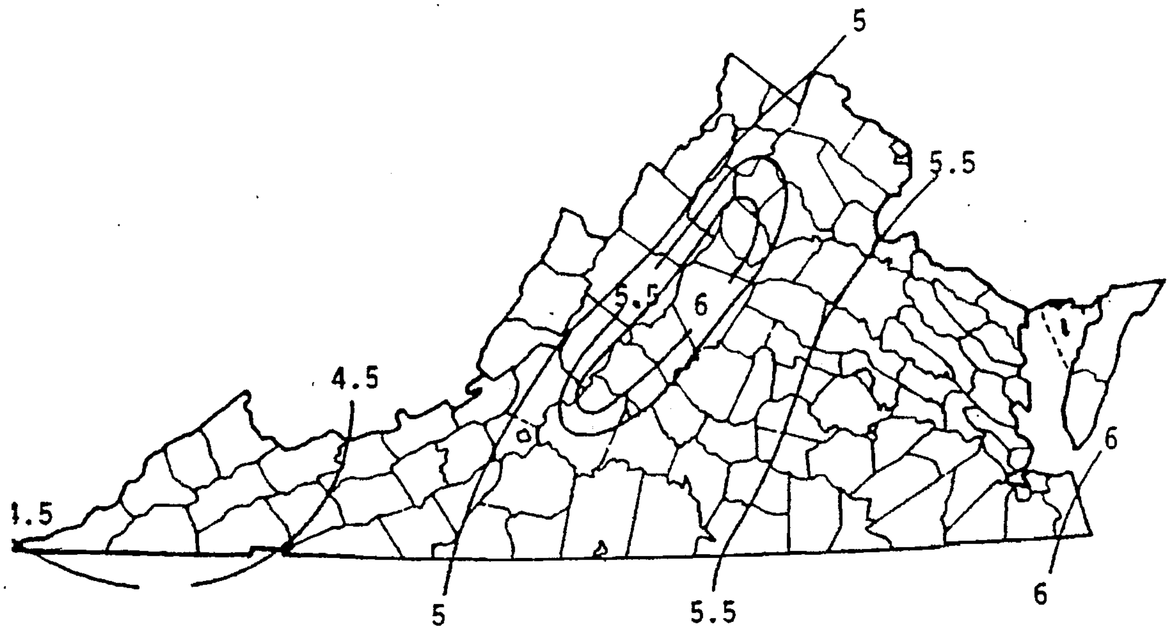


5-YEAR 24-HOUR RAINFALL (INCHES)

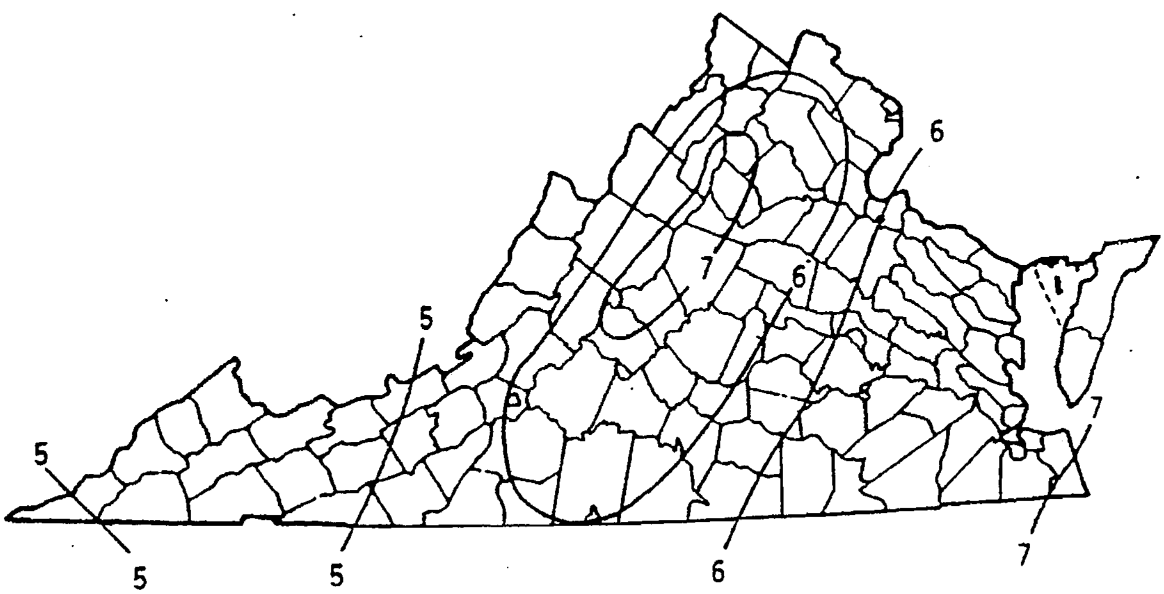
Source: USDA-SCS and U.S. Weather Bureau

Plate 5-19

RAINFALL DEPTHS FOR SELECTED DESIGN STORMS (continued)



10-YEAR 24-HOUR RAINFALL (INCHES)

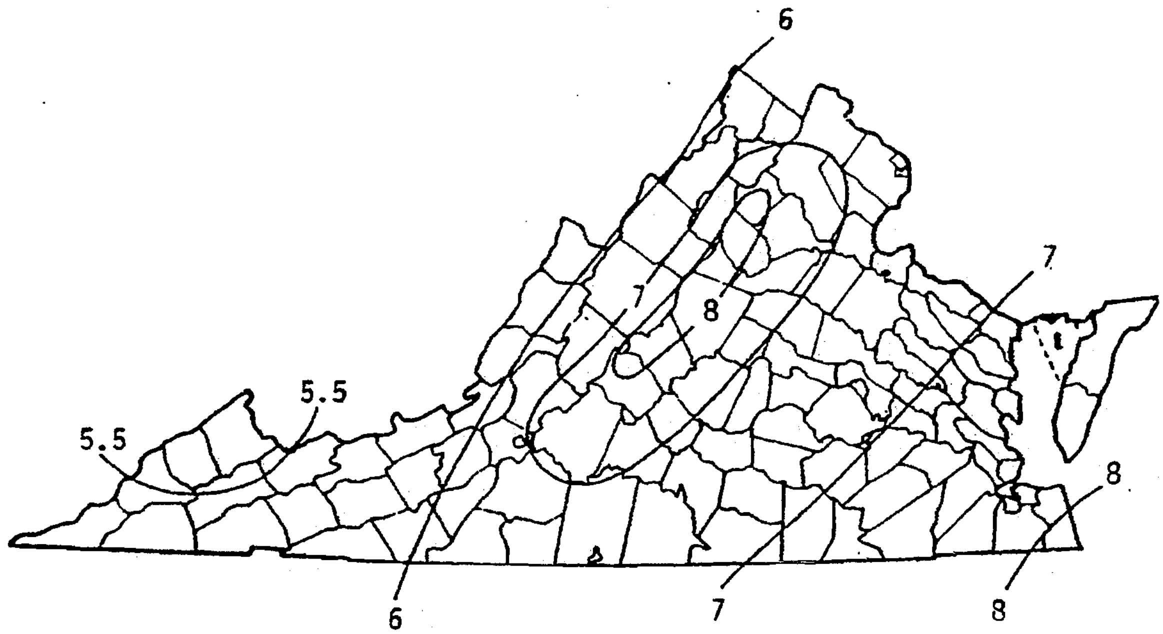


25-YEAR 24-HOUR RAINFALL (INCHES)

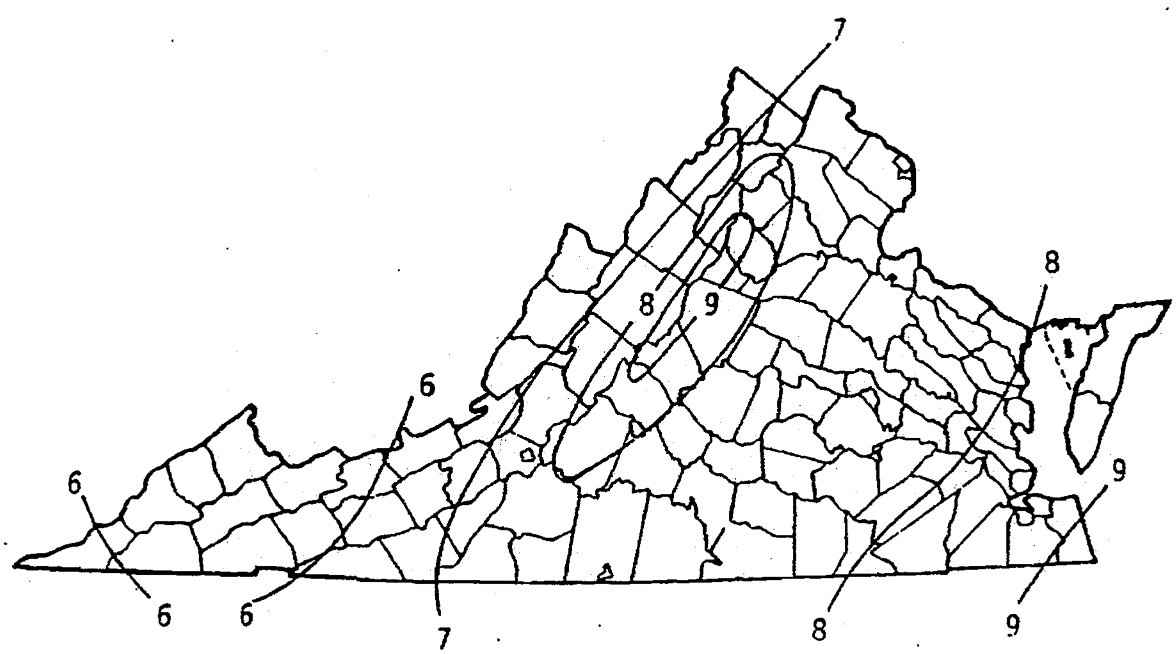
Source: USDA-SCS and U.S. Weather Bureau

Plate 5-20

RAINFALL DEPTHS FOR SELECTED DESIGN STORMS (continued)



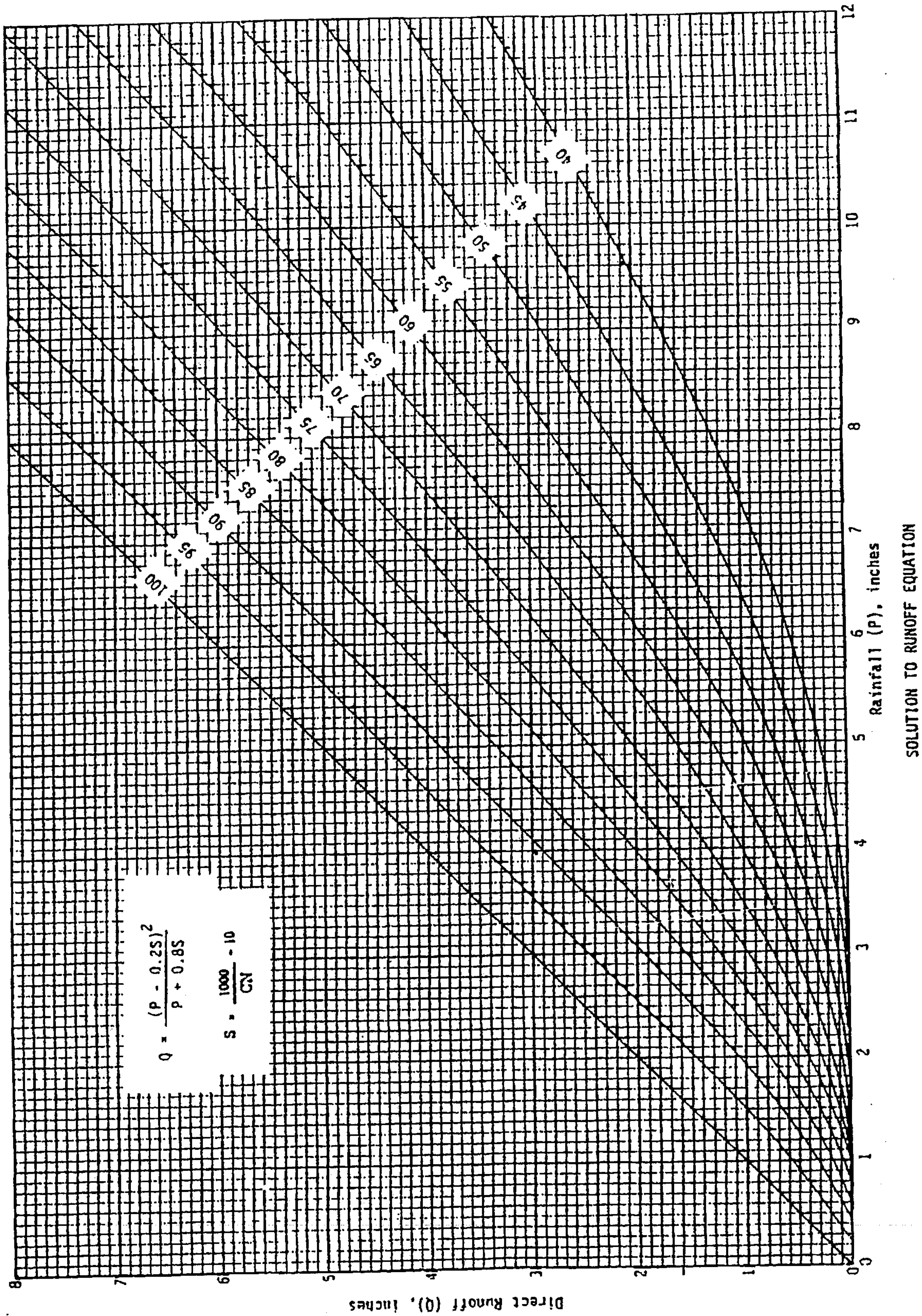
50-YEAR 24-HOUR RAINFALL (INCHES)



100-YEAR 24-HOUR RAINFALL (INCHES)

Source: USDA-SCS and U.S. Weather Bureau

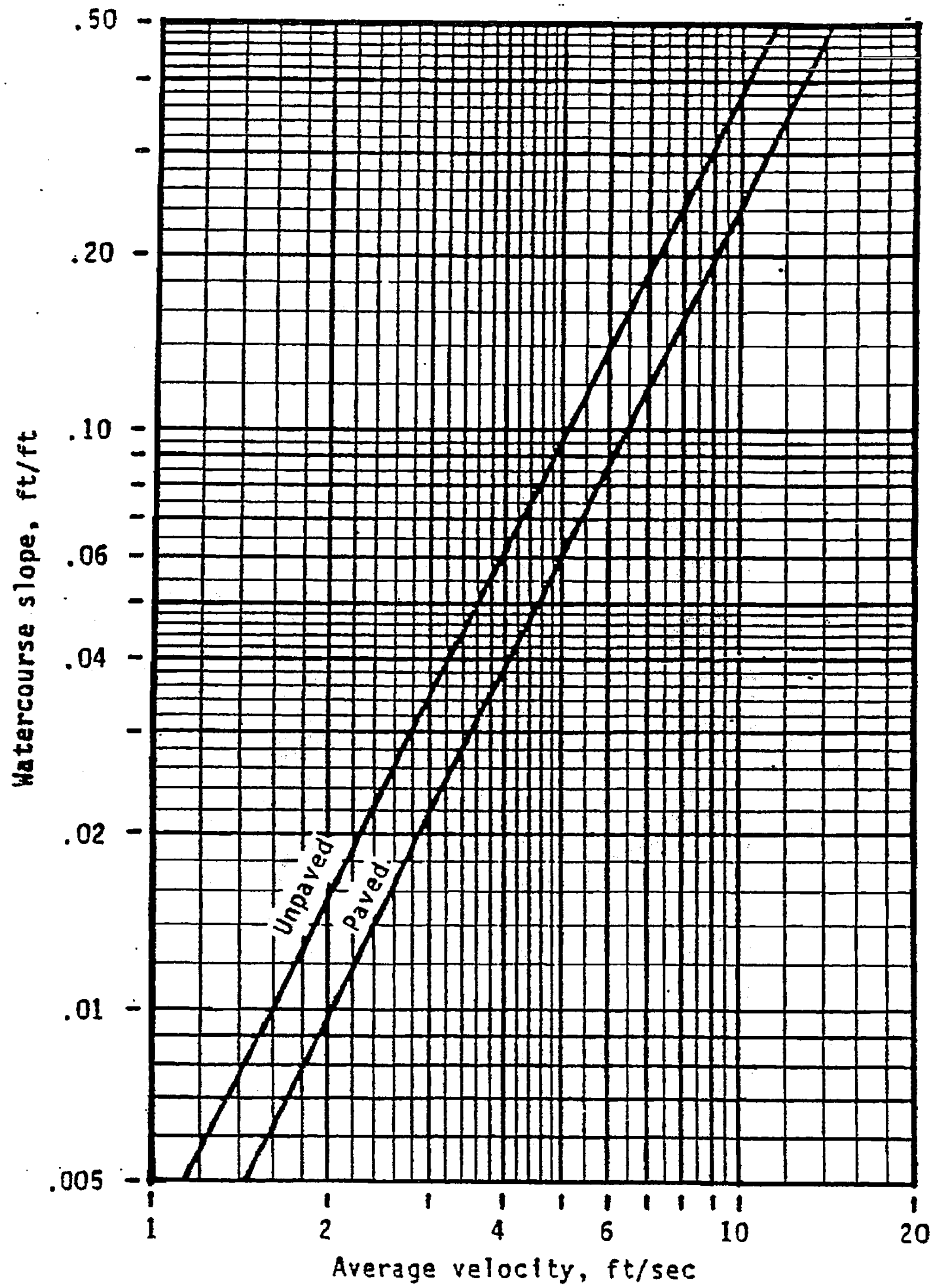
Plate 5-21



Source: USDA-SCS

Plate 5-22

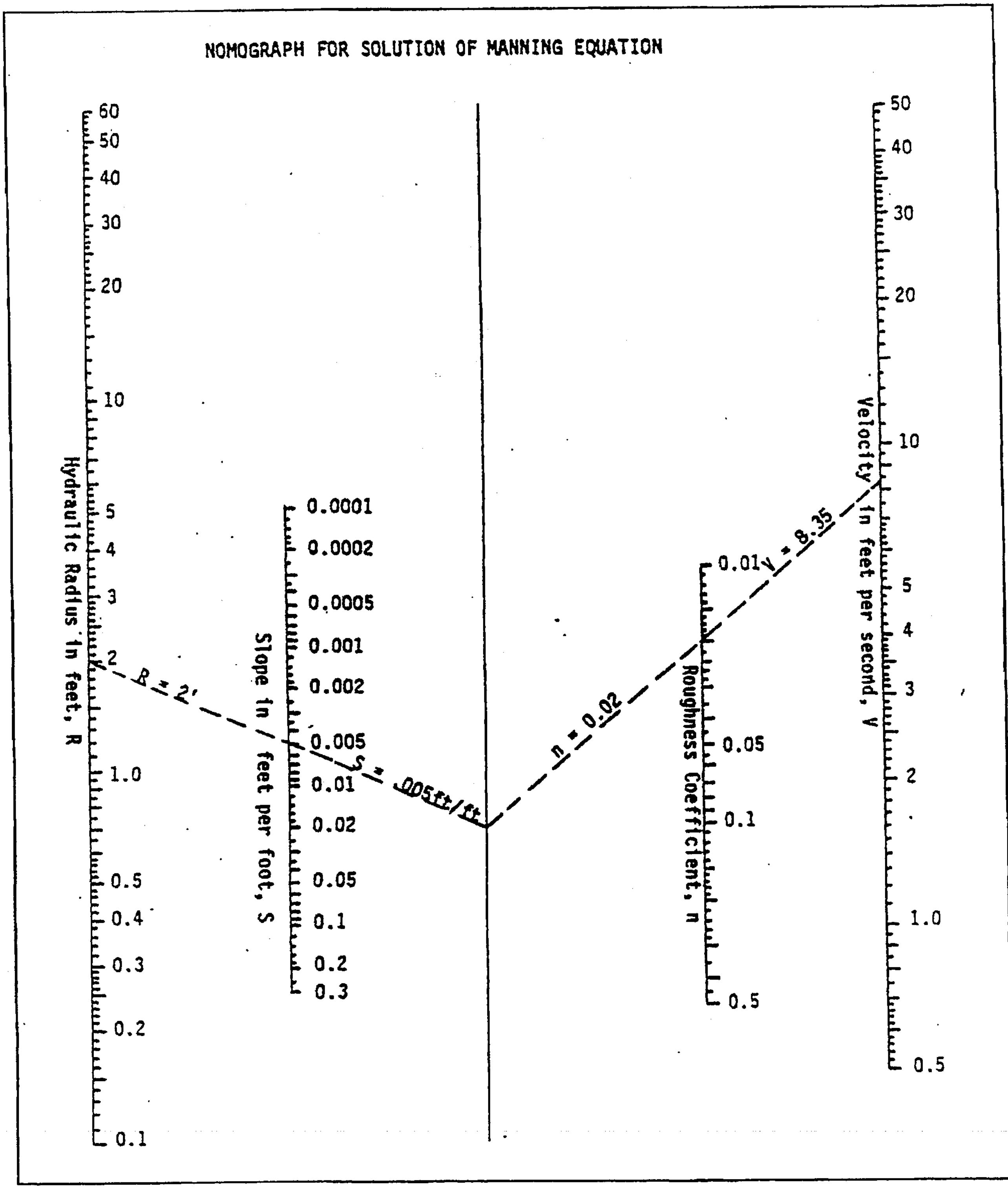
AVERAGE VELOCITIES FOR ESTIMATING TRAVEL TIME FOR SHALLOW CONCENTRATED FLOW



Source: USDA-SCS

Plate 5-23

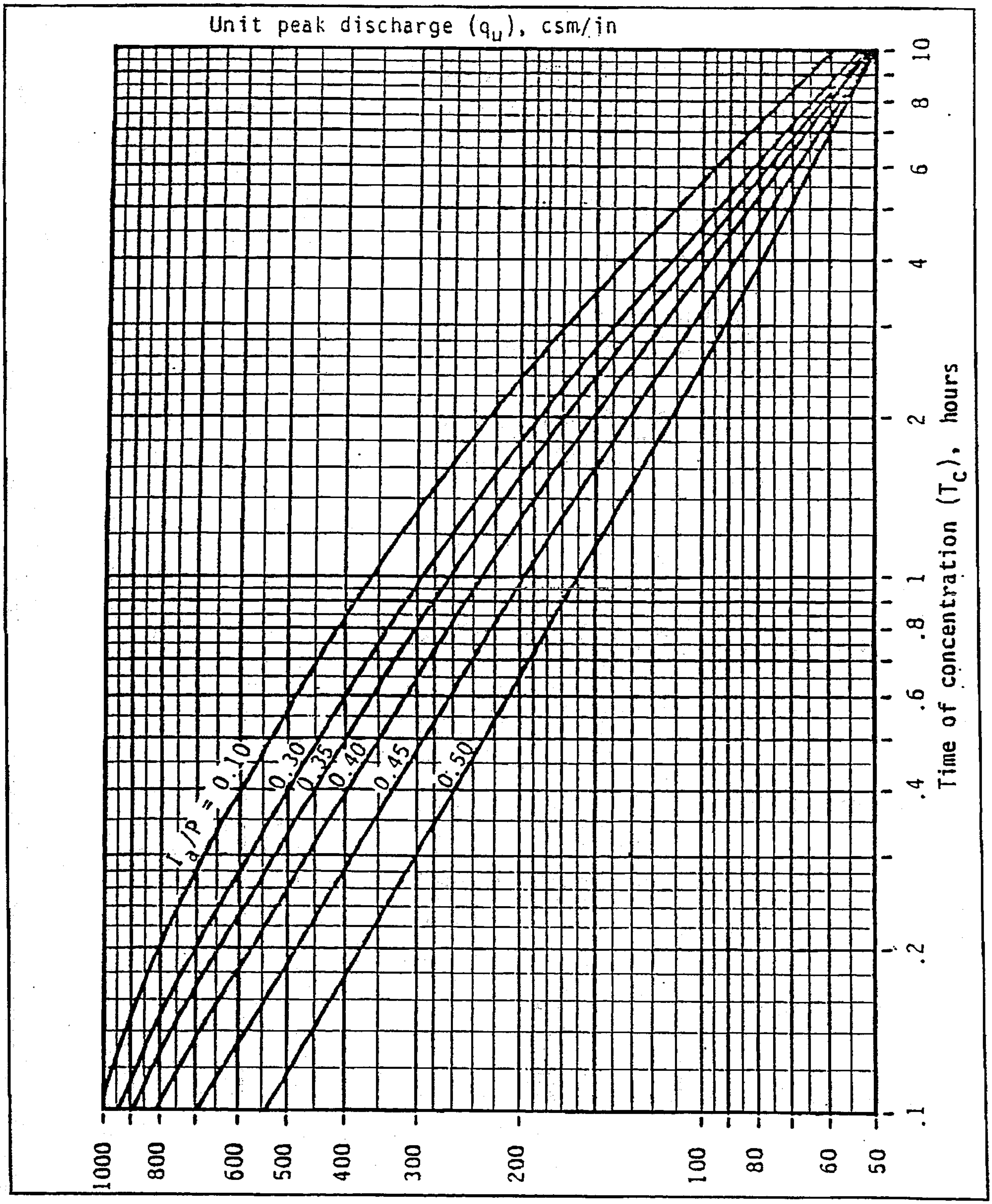
NOMOGRAPH FOR SOLUTION OF MANNING EQUATION



Source: VDOT

Plate 5-24

UNIT PEAK DISCHARGE (q_u) FOR SCS TYPE II RAINFALL DISTRIBUTION



Source: USDA-SCS

Plate 5-25

TABLE 5-5*

RUNOFF CURVE NUMBERS
FOR GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION			HYDROLOGIC SOIL GROUP A	B	C	D
Fully Developed Urban Areas (Vegetation Established)						
Open Space (lawns, parks, etc.)	Poor Condition; Grass		68	79	86	89
	Fair Condition; Grass 50 - 75% cover		49	69	79	84
	Good Condition; Grass > 75% cover		39	61	74	80
Impervious Areas	Paved parking lots, roofs, driveways		98	98	98	98
Streets and Roads	Paved; curbs and storm sewers		98	98	98	98
	Paved; open ditches (w/right-of-way)		83	89	92	93
	Gravel (with right-of-way)		76	85	89	91
	Dirt (with right-of-way)		72	82	87	89
Urban Districts		Average % Impervious				
	Commercial and Business	85	89	92	94	95
	Industrial	72	81	88	91	93

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information on selecting the runoff curve number.

Source: USDA-SCS

**TABLE 5-5* (continued)
RUNOFF CURVE NUMBERS FOR
GRAPHICAL PEAK DISCHARGE METHOD**

COVER DESCRIPTION			HYDROLOGIC SOIL GROUP			
			A	**B**	**C**	**D**
Residential Districts (by average lot size)		Average % Impervious				
	1/8 acre (town house)	65	77	85	90	92
	1/4 acre	38	61	75	83	87
	1/3 acre	30	57	72	81	86
	1/2 acre	25	54	70	80	85
	1 acre	20	51	68	79	84
	2 acres	12	46	65	77	82
Urban Areas - Development Underway, No Vegetation Established						
Newly graded area			81	89	93	95
Pavement and Roofs, Commercial & Business Areas			98	98	98	98
Row Houses, Town Houses and Residential w/lot sizes:	1/8 acre or less		93	96	97	98
	1/4 acre		88	93	95	97
	1/2 acre		85	91	94	96
	1 acre		82	90	93	95
	2 acres		81	89	92	94
Cultivated Agricultural Lands						
Fallow:	Bare Soil		77	86	91	94
	Crop Residue (CR) poor		76	85	90	93
	Crop Residue (CR) good		74	83	88	90

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information on selecting the runoff curve number.

TABLE 5-5* (continued)

RUNOFF CURVE NUMBERS FOR
GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION		HYDROLOGIC SOIL GROUP A	B	C	D
Cultivated Agricultural Lands (continued)					
Row Crops:	Straight row (SR) poor	72	81	88	91
	Straight row (SR) good	67	78	85	89
	Contoured (C) poor	70	79	84	88
	Contoured (C) good	65	75	82	86
	Contoured and Terraced (C&T) poor	66	74	80	82
	Contoured and Terraced (C&T) good	62	71	78	81
Other Agricultural Lands					
Pasture, grassland or range	poor	68	79	86	89
	fair	49	69	79	84
	good	39	61	74	80
Meadow		30	58	71	78
Brush - brush, weed, grass mix	poor	48	67	77	83
	fair	35	56	70	77
	good	30	48	65	73
Woods - grass combination	poor	57	73	82	86
	fair	43	65	76	82
	good	32	58	72	79

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information selecting the runoff curve number.

TABLE 5-5* (continued)

RUNOFF CURVE NUMBERS FOR GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION		HYDROLOGIC SOIL GROUP			
		A	B	C	D
Other Agricultural Lands (continued)					
Woods	poor	45	66	77	83
	fair	36	60	73	79
	good	30	55	70	77
Porous Pavement**					
	Gravel Subbase Thickness (inches)				
Porous Pavement (Properly Maintained)	10	57	66	69	75
	18	53	61	64	69
	24	52	58	61	66
	36	47	52	55	58
Porous Pavement (Not Properly Maintained)	10 - 36	98	98	98	98

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information on selecting runoff curve number.

** This information is not intended for design purposes.

TABLE 5-6
RUNOFF DEPTH FOR SELECTED CN's AND RAINFALL AMOUNTS[1]

	Runoff depth for curve number of ____												
Rainfall	40	45	50	55	60	65	70	75	80	85	90	95	98
							inches						
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

[1] Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Source: USDA-SCS

TABLE 5-7
ROUGHNESS COEFFICIENTS
(MANNING'S "n") FOR SHEET FLOW

Surface Description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods[3]:	
Light underbrush	0.40
Dense underbrush	0.80

[1] The "n" values are a composite of information compiled by Engman (1986).

[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[3] When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Source: USDA-SCS

TABLE 5-8

MANNING'S "n" VALUES

Surface	Best	Good	Fair	Bad
Uncoated cast-iron pipe	0.012	0.013	0.014	0.015
Coated cast-iron pipe	0.011	0.012*	0.013*	
Commercial wrought-iron pipe, black	0.012	0.013	0.014	0.015
Commercial wrought-iron pipe, galvanized	0.013	0.014	0.015	0.017
Riveted and spiral steel pipe	0.013	0.015*	0.017*	
Common clay drainage tile	0.011	0.012*	0.014*	0.017
Neat cement surfaces	0.010	0.011	0.012	0.013
Cement mortar surfaces	0.011	0.012	0.013*	0.015
Concrete pipe	0.012	0.013	0.015*	0.016
Concrete-lined channels	0.012	0.014*	0.016*	0.018
Cement-rubble surface	0.017	0.020	0.025	0.030
Dry-rubble surface	0.025	0.030	0.033	0.035
<u>Canals and ditches</u>:				
Earth, straight and uniform	0.017	0.020	0.0225*	0.025
Rock cuts, smooth and uniform	0.025	0.030	0.033	0.035
Rock cuts, jagged and irregular	0.035	0.040	0.045	
Winding sluggish canals	0.0225	0.025*	0.0275	0.030
Dredged earth channels	0.025	0.0275*	0.030	0.033
Canals with rough stony beds, weeds on earth banks	0.025	0.030	0.035*	0.040
Earth bottom, rubble sides	0.028	0.030*	0.033*	0.035

* Values commonly used in designing.

Source: King

TABLE 5-8 (continued)

MANNING'S "n" VALUES

Surface	Best	Good	Fair	Bad
Natural Stream Channels:				
1. Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.030	0.033
2. Same as #1, but some weeds and stones	0.030	0.033	0.035	0.040
3. Winding, some pools and shoals, clean	0.033	0.035	0.040	0.045
4. Same as #3, lower stages, more ineffective slope and sections	0.040	0.045	0.050	0.055
5. Same as #3, some weeds and stones	0.035	0.040	0.045	0.050
6. Same as #4, stony sections	0.045	0.050	0.055	0.060
7. Sluggish river reaches, rather weedy or with very deep pools	0.050	0.060	0.070	0.080
8. Very weedy reaches	0.075	0.100	0.125	0.150

* Values commonly used in designing.

Source: King

TABLE 5-9

I_a VALUES FOR RUNOFF CURVE NUMBERS

Curve Number	I_a (inches)	Curve Number	I_a (inches)	Curve Number	I_a (inches)
40	3.000	60	1.333	80	0.500
41	2.878	61	1.279	81	0.469
42	2.762	62	1.226	82	0.439
43	2.651	63	1.175	83	0.410
44	2.545	64	1.125	84	0.381
45	2.444	65	1.077	85	0.353
46	2.348	66	1.030	86	0.326
47	2.255	67	0.985	87	0.299
48	2.167	68	0.941	88	0.273
49	2.082	69	0.899	89	0.247
50	2.000	70	0.857	90	0.222
51	1.922	71	0.817	91	0.198
52	1.846	72	0.778	92	0.174
53	1.774	73	0.740	93	0.151
54	1.704	74	0.703	94	0.128
55	1.636	75	0.667	95	0.105
56	1.571	76	0.632	96	0.083
57	1.509	77	0.597	97	0.062
58	1.448	78	0.564	98	0.041
59	1.390	79	0.532		

Source: USDA-SCS

TABLE 5-10

ADJUSTMENT FACTOR (F_p) FOR POND AND SWAMP AREAS SPREAD THROUGHOUT THE WATERSHED

Percentage of pond and swamp areas	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Source: USDA-SCS

Tabular Method

The Tabular Method of runoff calculation is also described in TR-55 Urban Hydrology for Small Watersheds (62). This method may be used to develop a runoff hydrograph that shows the rate of runoff from the watershed with respect to time for a selected design storm.

The Tabular Method can be used when hydrographs are needed to measure runoff from watersheds which are divided into sub-areas. It is especially applicable for measuring the effects of changed landuse in a part of the watershed. It can also be used to determine the effects of structures and combinations of structures, including channel modifications, at different locations in a watershed. In this procedure, timing of the flow from the different sub-areas becomes very important.

The accuracy of the Tabular Method decreases as the complexity of the watershed increases. Drainage areas of individual sub-areas should not differ by a factor of five (5) or more. For most watershed conditions, however, this procedure is adequate to determine the effects of urbanization on peak rates of discharge for drainage areas up to approximately 20 square miles in size.

It is recommended that the user become familiar with the Peak Discharge Method before attempting the Tabular Method. The user is encouraged to refer to TR-55 for a complete presentation of the Tabular Method.

The basic data needed to use the Tabular Method include:

1. The drainage area of each sub-area.
2. The time of concentration (T_c) for each sub-area.
3. The travel time (T_t) for each routing reach.
4. The runoff curve number (CN) for each sub-area.
5. The 24-hour rainfall for the selected frequency design storm.
6. The runoff depth (in inches) from each sub-area.
7. The initial abstraction (I_a) for each sub-area.

Tables in Exhibit 5-II contain the tabular discharge values for the Type II rainfall distribution used in Example 5-6. Tabular discharges, in terms of CSM (cubic feet per second per square mile) per inch of runoff, are given for a range of T_c values from 0.1 to 2.0 hours and T_t values from 0 to 3.0 hours. (Tables for Type I, IA, and III distributions can be found in SCS-TR-55 but are not included here.)

The general procedure for generating a composite hydrograph using the Tabular Method is as follows:

Step 1 - Prepare worksheet 5a, as in example 5-6, which provides a summary of all basic data needed for the tabular hydrograph. The following basic information is needed for the worksheet:

a. Define the drainage areas and determine the area of each sub-area in square miles (A_m). Also define the main channel reaches that drain each sub-area.

b. Determine the time of concentration (T_c) for each sub-area (e.g., the time of flow from the most remote point in the sub-area to the outlet of sub-area, in hours).

c. Determine a runoff curve number (CN) for each sub-area. (See step 2 of the graphical peak discharge method.)

d. List rainfall (P) from Plates 5-19 through 5-21 and determine the runoff depth (in inches) for each sub-area. (See step 3a and 3b of the graphical peak discharge method.)

e. Determine the travel time (T_t) in the main channel reaches of sub-areas through which runoff from other sub-areas is routed.

f. Determine I_a from Table 5-9 and divide by rainfall (P) for each sub-area.

Step 2 - On worksheet 5b, place the basic watershed data used by rounding T_c, T_t, and I_a/P values to the nearest Table values in Exhibit 5-II. Use the value that is closest to the sum of the actual values of the sum of T_c and T_t. I_a/P can be the nearest Table value or unit discharge (CSM/in) interpolation between I_a/P values.

Step 3 - Develop individual hydrographs for each sub-area at the point of interest by multiplying the tabular value by the drainage area (A_m) and the runoff (Q). (A_mQ were previously determined on worksheet 5a, so all that remains is to multiply A_mQ by each tabular value under each time selected on Worksheet 5b.)

<u>Note</u>: Time values should be selected from Exhibit 5-II that will produce the composite hydrograph peak. **The composite hydrograph peak does not necessarily coincide with the peak of the individual sub-area at the point of interest in the watershed.**

Step 4 - The composite hydrograph is the summation of the individual hydrographs for each sub-area that have been routed to the point of interest in the watershed. Develop the composite hydrograph by summation of each column on worksheet 5b.

<u>Example 5-6</u>

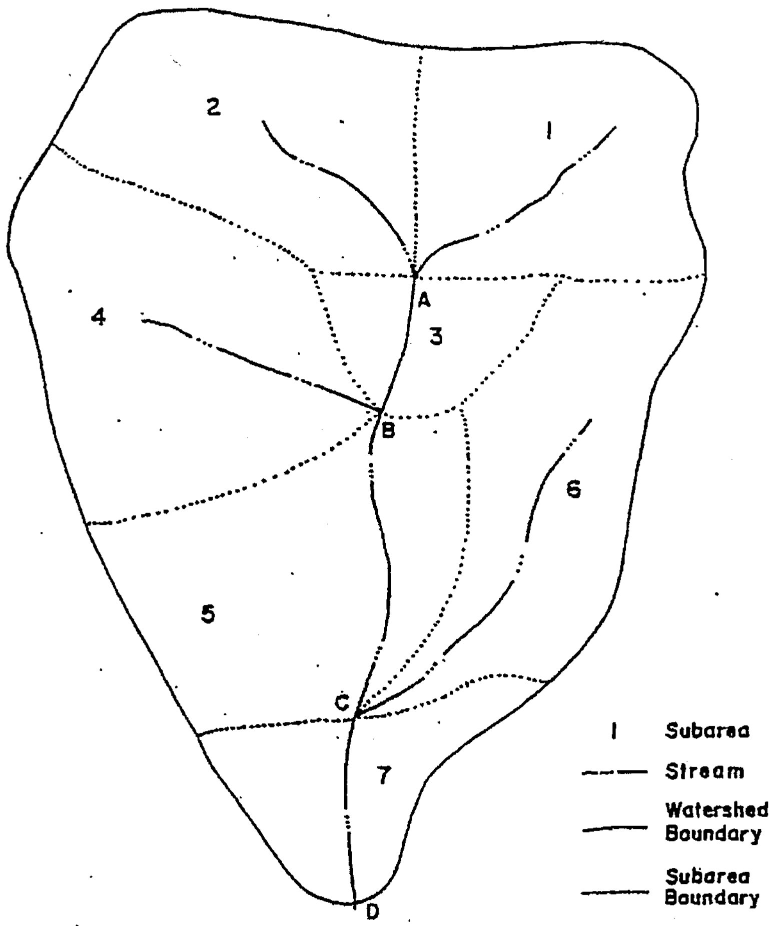
The 1.65 square mile watershed (shown below) is to be developed according to a pre-

conceived landuse plan. The current proposal is to develop sub-areas 5,6 and 7. The development includes a variety of landuses ranging from single-family dwellings and industrial parks.

Find: The effect of the development would have on the 2-year discharge at the lower end of sub-area 7.

EXAMPLE 5-6

The 1.65-square-mile watershed below is to be developed according to a pre-conceived land use plan. Proposed land use ranges from one-half acre residential lots in sub-area 1 to an industrial district in sub-area 7. Determine what effect the development would have on the 2-year discharge at the lower end of sub-area 7.



In solving example 5-6, the following information should be noted:

1. Information required in steps 1a-f was determined for both the "present" condition and the "developed" condition of the watershed for the 2-year frequency design storm. The data was measured from the map and derived from a landuse plan for the watershed and is summarized on worksheet 5a. Separate worksheets are used for "present" and "developed" conditions.

2. Drainage areas (A_m) were multiplied by runoff (Q) and placed on Worksheet 5a and later transferred to Worksheet 5b.

3. Sub-area T_c and ΣT_t used were the computed values as no rounding was necessary to fit the values in the Tables. I_a/P values were rounded to the nearest values in the Tables.

4. The appropriate sheet from Exhibit 5-II was selected for each sub-area based on T_c listed in the middle of that sheet. The I_a/P value was then selected and a straight edge placed on the line for the appropriate travel time (ΣT_t) on the left edge of the sheet.

5. Hydrograph time values were selected to best define the composite hydrograph from the top of the sheet and placed at the top of Worksheet 5b.

6. Unit discharge values (CSM/in) for each time value were selected at the straight edge and multiplied by the A_mQ value determined in 2 above. This process was followed for each sub-area.

7. The columns under each hydrograph time were added to produce the composite hydrograph at the lower end of sub-area 7.

Worksheet 5a: Basic watershed data

Project Sugar Hill Location Campbell County, Va. By EC Date 2-5-91

Circle one: (Present) Developed ______ Frequency (yr) 2 Checked SM Date 2-6-91

Subarea name	Drainage area A_m (mi^2)	Time of concentration T_c (hr)	Travel time through subarea T_t (hr)	Downstream subarea names	Travel time summation to outlet ΣT_t (hr)	24-hr Rainfall P (in)	Runoff curve number CN	Runoff Q (in)	A_mQ (mi^2-in)	Initial abstraction I_a (in)	I_a/P
1	0.30	1.50	--	3, 5, 7	2.50	3.5	65	0.75	0.23	1.077	0.31
2	0.20	1.25	--	3, 5, 7	2.50	3.5	70	1.01	0.20	0.857	0.24
3	0.10	0.50	0.50	5, 7	2.00	3.5	75	1.30	0.13	0.667	0.19
4	0.25	0.75	--	5, 7	2.00	3.5	70	1.01	0.25	0.857	0.24
5	0.20	1.50	1.25	7	0.75	3.5	75	1.30	0.26	0.667	0.19
6	0.40	1.50	--	7	0.75	3.5	70	1.01	0.40	0.857	0.24
7	0.20	1.25	0.75	--	0	3.5	75	1.30	0.26	0.667	0.19
		From worksheet 3	From worksheet 3				From worksheet 2	From worksheet 2		From table 5-7	

Worksheet 5b: Tabular hydrograph discharge summary

Project Sugar Hill Location Campbell County, Va. By EC Date 2-5-91

Circle one: Present Developed Frequency (yr) 2 Checked SM Date 2-6-91

Subarea name	Basic watershed data used 1/				Select and enter hydrograph times in hours from exhibit 5-II 2/											
	Subarea T_c (hr)	ΣT_t to outlet (hr)	I_a/P	A_mQ (mi^2-in)	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5
					Discharges at selected hydrograph times 3/ (cfs)											
1	1.50	2.50	0.3	0.23	0	0	0	0	0	0	0	0	2	7	20	37
2	1.25	2.50	0.3	0.20	0	0	0	0	0	0	0	1	3	9	24	37
3	0.50	2.00	0.1	0.13	2	2	2	3	5	8	16	26	39	36	24	11
4	0.75	2.00	0.3	0.25	0	0	0	0	1	3	10	21	44	57	50	32
5	1.50	0.75	0.1	0.26	8	11	20	33	47	58	62	61	50	38	27	17
6	1.50	0.75	0.3	0.40	2	4	16	27	46	64	76	79	72	59	44	32
7	1.25	0	0.1	0.26	67	74	81	69	55	42	34	27	20	16	12	10
Composite hydrograph at outlet					79	91	119	132	154	175	198	215	230	222	201	176

1/ Worksheet 5a. Rounded as needed for use with exhibit 5-II

2/ Enter rainfall distribution type used.

3/ Hydrograph discharge for selected times is A_mQ multiplied by tabular discharge from appropriate exhibit 5-II

Worksheet 5a: Basic watershed data

Project Sugar Hill Location Campbell County, Va. By EC Date 2-5-91

Circle one: Present Developed Frequency (yr) 2 Checked SM Date 2-6-91

Subarea name	Drainage area A_m (mi^2)	Time of concentration T_c (hr)	Travel time through subarea T_t (hr)	Downstream subarea names	Travel time summation to outlet ΣT_t (hr)	24-hr Rainfall P (in)	Runoff curve number CN	Runoff Q (in)	$A_m Q$ (mi^2-in)	Initial abstraction I_a (in)	I_a/P
1	0.30	1.50	--	3,5,7	2.00	3.5	65	0.75	0.23	1.077	.31
2	0.20	1.25	--	3,5,7	2.00	3.5	70	1.01	0.20	0.357	.24
3	0.10	0.50	0.50	5,7	1.50	3.5	75	1.30	0.13	0.667	.19
4	0.25	0.75	--	5,7	1.50	3.5	70	1.01	0.25	0.857	.24
5	0.20	1.50	1.00	7	0.50	3.5	85	2.02	0.40	0.353	.10
6	0.40	1.00	--	7	0.50	3.5	75	1.30	0.52	0.667	.19
7	0.20	0.75	0.50	--	0	3.5	90	2.45	0.49	0.198	.06

From worksheet 3 (Tc, Tt) From worksheet 2 (CN, Q) From table 5-7 (Ia)

Worksheet 5b: Tabular hydrograph discharge summary

Project Sugar Hill Location Campbell County, Va. By EC Date 2-5-91

Circle one: Present **(Developed)** [1]Frequency (yr) 2 Checked SM Date 2-6-91

Subarea name	Basic watershed data used 1/				Select and enter hydrograph times in hours from exhibit 5-II 2/											
	Subarea T_c (hr)	ΣT_t to outlet (hr)	I_a/P	A_mQ (mi^2-in)	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5
					Discharges at selected hydrograph times 3/ (cfs)											
1	1.50	2.00	0.3	0.23	0	0	0	0	0	0	1	3	10	22	37	41
2	1.25	2.00	0.3	0.20	0	0	0	0	0	0	1	4	13	26	39	35
3	0.50	1.50	0.1	0.13	3	4	6	12	23	35	42	40	29	18	10	6
4	0.75	1.50	0.3	0.25		0	0	2	9	23	41	55	60	49	33	21
5	1.50	0.50	0.1	0.40	24	32	54	78	95	100	94	82	62	46	32	22
6	1.00	0.50	0.1	0.52	59	83	132	162	156	131	101	77	53	38	28	21
7	0.75	0	0.1	0.49	201	181	123	84	60	46	36	30	24	20	17	15
Composite hydrograph at outlet					287	300	315	338	343	335	316	291	251	219	196	161

1/ Worksheet 5a. Rounded as needed for use with exhibit 5.
2/ Enter rainfall distribution type used.
3/ Hydrograph discharge for selected times is A_mQ multiplied by tabular discharge from appropriate exhibit 5.

Source: USDA-SCS

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Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =0.1 HR * * *																		
0.0	24	34	53	334	647	1010	623	217	147	123	104	86	76	66	57	51	46	42	38	34	32	29	26	23	21	20	19	18	15	13	12	0
.10	21	29	43	134	267	520	847	701	378	224	157	122	98	75	64	56	50	45	41	36	33	30	27	24	21	20	19	18	16	13	12	0
.20	18	25	35	61	110	215	418	704	702	486	312	209	151	94	73	62	54	49	44	38	34	31	28	25	22	21	19	18	16	14	12	0
.30	17	23	33	56	92	174	337	582	662	545	389	269	190	109	79	65	56	50	45	39	35	32	29	25	22	21	20	18	16	14	12	0
.40	15	20	28	41	51	78	142	272	478	601	563	447	328	172	104	76	63	55	49	42	37	33	29	26	23	21	20	19	17	14	12	0
.50	14	19	26	39	47	69	117	220	392	531	553	482	380	209	121	84	67	57	51	43	38	33	30	27	23	21	20	19	17	14	12	0
.75	12	15	21	29	33	38	49	73	126	224	343	432	464	385	252	156	103	76	62	50	43	36	31	28	25	22	21	19	17	15	12	0
1.0	9	12	15	21	23	26	29	33	40	55	86	148	238	406	434	317	205	130	89	62	50	41	34	30	27	24	22	20	18	16	12	0
1.5	7	8	10	14	15	16	18	20	22	25	29	34	45	101	220	339	373	320	234	131	80	53	40	34	30	27	24	21	19	17	12	2
2.0	4	6	7	9	9	10	11	12	13	15	16	18	20	25	37	72	150	252	336	312	216	109	58	42	34	30	27	24	20	18	13	8
2.5	3	4	5	6	7	7	8	8	9	10	11	12	13	16	19	25	39	75	142	262	303	229	108	58	41	34	30	27	22	19	14	11
3.0	1	2	3	4	4	5	5	6	6	7	7	8	8	10	12	14	17	22	31	76	169	288	236	122	64	43	35	30	24	20	16	11
IA/P = 0.30														* * * TC =0.1 HR * * *																		
0.0	0	0	0	154	568	936	524	217	172	149	126	107	97	86	76	69	63	58	53	48	46	42	38	34	31	30	28	27	24	20	19	0
.10	0	0	0	19	109	415	762	603	346	230	176	143	119	96	84	74	68	62	57	50	47	44	40	35	32	30	29	27	24	21	19	0
.20	0	0	0	0	13	77	302	609	605	432	297	217	167	115	94	81	73	66	60	53	48	45	41	37	33	31	29	28	25	21	19	0
.30	0	0	0	0	9	54	219	479	563	476	357	263	199	129	99	85	75	68	62	54	49	45	41	37	33	31	29	28	25	21	19	0
.40	0	0	0	0	0	6	38	159	372	500	484	399	309	183	123	96	82	73	66	58	51	46	42	38	34	31	30	28	25	22	19	0
.50	0	0	0	0	0	4	27	115	287	429	465	421	346	213	138	103	86	76	68	59	52	47	43	39	34	32	30	29	25	22	19	0
.75	0	0	0	0	0	0	1	10	46	132	246	338	381	341	243	165	119	94	80	67	58	50	45	41	37	33	31	29	26	23	19	0
1.0	0	0	0	0	0	0	0	1	4	22	69	149	241	357	331	246	170	122	96	76	64	54	47	42	38	34	32	30	27	24	19	0
1.5	0	0	0	0	0	0	0	0	0	0	0	1	4	41	142	258	310	285	224	142	97	71	55	47	43	39	35	32	29	25	20	4
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	49	130	221	279	255	182	108	70	55	47	42	38	34	30	27	20	11
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	14	52	119	224	256	193	107	70	55	47	42	38	32	28	22	17
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	52	141	240	199	117	74	56	48	43	35	30	24	18
IA/P = 0.50														* * * TC =0.1 HR * * *																		
0.0	0	0	0	0	70	539	377	196	171	154	134	117	108	99	89	83	77	72	67	61	59	56	51	46	43	42	40	38	34	30	28	0
.10	0	0	0	0	47	375	376	256	199	169	146	126	114	102	92	85	79	73	68	62	59	56	52	47	43	42	40	38	34	30	28	0
.20	0	0	0	0	0	31	260	338	283	227	189	160	138	112	99	90	83	77	72	64	60	57	53	48	44	42	41	39	35	30	28	0
.30	0	0	0	0	0	0	21	180	285	284	246	208	176	131	110	97	88	82	76	68	62	59	54	50	45	43	41	39	36	31	28	0
.40	0	0	0	0	0	0	14	125	232	266	253	223	192	142	115	100	91	83	77	69	63	59	55	50	45	43	41	40	36	31	28	0
.50	0	0	0	0	0	0	9	86	183	239	248	231	205	154	122	104	93	85	79	71	64	59	55	51	46	43	41	40	36	32	28	0
.75	0	0	0	0	0	0	3	31	87	147	190	211	213	184	147	121	103	92	84	75	67	61	57	52	47	44	42	40	37	32	28	0
1.0	0	0	0	0	0	0	0	0	1	13	45	92	141	205	197	165	134	112	98	84	75	65	57	55	50	46	43	41	38	34	28	0
1.5	0	0	0	0	0	0	0	0	0	0	0	2	9	51	118	170	183	167	143	111	92	77	65	59	54	50	45	43	39	35	28	2
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	15	51	103	148	168	156	127	96	76	65	58	54	49	45	41	37	29	12
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	31	69	131	159	140	101	78	66	59	54	50	43	39	31	24
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	46	101	151	134	99	77	65	59	54	45	41	33	26

RAINFALL TYPE = II

* * * TC = 0.1 HR * * *

SHEET 1 OF 10

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =0.2 HR * * *														IA/P = 0.10				
0.0	23	31	47	209	403	739	800	481	250	166	128	102	86	70	61	54	49	44	40	35	33	30	27	24	21	20	19	18	16	13	12	0
.10	19	26	39	86	168	325	601	733	565	355	229	161	122	83	69	59	53	47	43	37	34	31	28	25	22	21	19	18	16	14	12	0
.20	17	23	32	49	74	136	262	488	652	594	435	298	207	115	81	67	58	51	46	40	35	32	29	26	23	21	20	19	16	14	12	0
.30	16	22	30	46	64	112	212	396	566	585	485	360	258	139	90	71	60	53	48	41	36	32	29	26	23	21	20	19	16	14	12	0
.40	14	19	25	37	43	57	94	173	322	485	551	507	409	227	129	87	68	58	52	44	38	33	30	27	24	21	20	19	17	14	12	0
.50	13	18	24	35	40	52	80	142	262	410	504	506	441	269	153	98	73	61	53	45	39	34	30	27	24	22	20	19	17	15	12	0
.75	10	13	17	23	26	30	34	40	55	86	150	247	349	438	360	240	151	101	75	57	47	39	33	29	26	23	21	20	18	15	12	0
1.0	9	11	14	19	21	24	26	30	35	44	62	101	167	337	413	353	245	157	104	68	53	42	35	31	28	24	22	20	18	16	12	0
1.5	6	8	10	13	14	15	17	19	21	23	26	30	37	73	166	288	356	337	264	154	91	57	42	35	30	27	24	22	19	17	13	3
2.0	4	5	7	8	9	10	10	11	12	14	15	16	18	23	31	55	114	206	291	324	239	125	63	44	35	31	28	24	20	18	14	9
2.5	3	4	5	6	6	7	7	8	9	9	10	11	12	15	18	22	32	58	111	227	298	246	122	63	43	35	31	27	22	19	15	11
3.0	1	2	3	4	4	4	5	5	6	6	7	7	8	9	11	13	16	19	27	59	138	280	248	137	70	46	36	31	25	21	16	11
IA/P = 0.30														* * * TC =0.2 HR * * *														IA/P = 0.30				
0.0	0	0	0	39	180	545	697	497	276	198	158	130	110	93	81	73	67	61	56	49	46	43	39	35	32	30	29	27	24	21	19	0
.10	0	0	0	2	27	129	407	600	532	361	252	190	150	108	90	79	71	65	59	52	48	44	41	36	32	31	29	28	25	21	19	0
.20	0	0	0	2	19	92	302	501	521	415	306	228	176	119	95	82	73	67	61	53	48	45	41	37	33	31	29	28	25	21	19	0
.30	0	0	0	0	1	13	66	223	408	484	438	350	269	163	114	93	80	72	65	57	51	46	42	38	34	31	30	28	25	22	19	0
.40	0	0	0	0	1	9	47	164	327	431	436	379	306	189	127	98	83	74	67	58	52	47	43	38	34	31	30	28	25	22	19	0
.50	0	0	0	0	0	0	6	33	120	258	374	415	391	271	173	121	95	81	72	62	55	48	44	40	35	32	30	29	26	22	19	0
.75	0	0	0	0	0	0	2	13	50	126	221	302	348	323	240	167	121	96	81	68	59	50	45	41	37	33	31	29	26	23	19	0
1.0	0	0	0	0	0	0	0	0	1	6	24	69	139	285	331	280	204	145	109	82	68	56	48	43	39	35	32	30	27	24	19	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	16	79	186	271	288	247	165	110	76	58	49	44	40	35	32	29	26	20	5
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	24	80	163	235	262	202	123	76	58	49	43	39	35	30	27	21	13
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	28	77	179	242	207	120	75	57	48	43	39	32	29	22	17
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	30	101	207	227	130	80	59	49	44	35	30	24	18
IA/P = 0.50														* * * TC =0.2 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	7	98	371	322	221	182	158	137	120	104	94	86	80	74	69	62	60	57	52	47	44	42	40	39	35	30	28	0
.10	0	0	0	0	4	67	270	305	249	204	174	149	130	108	97	88	82	76	71	64	60	57	53	48	44	42	41	39	35	30	28	0
.20	0	0	0	0	0	3	45	195	268	255	221	189	163	125	106	95	87	80	75	67	62	58	54	49	45	43	41	39	35	31	28	0
.30	0	0	0	0	0	2	31	140	226	245	229	203	176	134	111	98	89	82	76	68	62	59	55	50	45	43	41	39	36	31	28	0
.40	0	0	0	0	0	1	21	101	184	225	228	211	188	144	117	101	91	84	78	69	63	59	55	50	45	43	41	40	36	31	28	0
.50	0	0	0	0	0	0	1	14	72	146	199	218	213	175	137	113	99	89	82	73	66	60	56	52	47	43	42	40	36	32	28	0
.75	0	0	0	0	0	0	0	5	28	71	121	162	186	193	161	133	112	98	88	78	70	62	57	53	48	44	42	41	37	33	28	0
1.0	0	0	0	0	0	0	0	0	0	2	13	38	77	154	186	174	147	122	105	89	78	68	60	56	51	46	43	42	38	34	28	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	2	22	71	129	163	168	150	120	98	80	67	60	55	51	46	43	40	36	28	4
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	25	65	112	146	157	134	103	79	67	60	55	50	46	41	38	29	14
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	26	60	117	148	136	101	79	66	59	54	50	43	39	31	24
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9	40	90	142	130	99	78	66	59	54	45	41	33	26

RAINFALL TYPE = II * * * TC = 0.2 HR * * * SHEET 2 OF 10

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =0.3 HR * * *														IA/P = 0.10				
0.0	20	28	41	118	235	447	676	676	459	283	196	146	114	80	66	57	51	46	42	37	33	31	28	24	22	20	19	18	16	13	12	0
.10	19	26	39	99	189	361	571	641	520	362	251	181	136	89	70	60	53	48	43	37	34	31	28	25	22	21	19	18	16	14	12	0
.20	17	23	32	53	83	154	292	478	587	542	422	308	223	127	86	68	58	52	46	40	35	32	29	26	23	21	20	19	16	14	12	0
.30	16	22	30	49	72	127	237	398	524	536	460	359	268	151	97	73	61	53	48	41	36	32	29	26	23	21	20	19	16	14	12	0
.40	14	19	25	37	45	63	105	193	330	459	510	477	398	237	139	92	70	59	52	44	38	34	30	27	24	21	20	19	17	14	12	0
.50	13	18	24	35	42	56	89	158	272	397	472	475	424	274	163	104	76	62	54	46	39	34	30	27	24	22	20	19	17	15	12	0
.75	11	14	19	26	30	34	42	59	95	160	250	339	417	398	299	196	128	89	69	54	45	37	32	29	26	23	21	20	17	15	12	0
1.0	9	11	14	19	21	24	27	30	36	46	68	109	174	328	396	346	248	163	109	70	54	43	35	31	28	24	22	20	18	16	12	0
1.5	6	8	10	13	14	15	17	19	21	23	26	31	38	77	169	282	347	330	264	158	94	58	42	35	31	27	24	22	19	17	13	3
2.0	4	5	7	8	9	10	10	11	12	14	15	16	18	23	32	57	116	205	285	317	239	128	64	44	36	31	28	25	20	18	14	9
2.5	2	4	5	6	6	7	7	8	9	9	10	11	12	15	18	23	33	60	113	223	293	245	125	65	44	35	31	27	22	19	15	11
3.0	1	2	3	4	4	4	5	5	6	6	7	7	8	9	11	13	16	20	27	61	138	275	246	139	72	46	36	31	25	21	16	11
IA/P = 0.30														* * * TC =0.3 HR * * *														IA/P = 0.30				
0.0	0	0	0	11	64	251	525	574	454	303	221	173	140	104	88	77	70	64	58	51	47	44	40	36	32	31	29	28	24	21	19	0
.10	0	0	0	0	7	45	183	411	520	476	360	268	205	133	101	85	76	69	62	55	49	45	41	37	33	31	30	28	25	21	19	0
.20	0	0	0	0	5	32	132	318	452	468	396	310	240	151	109	90	78	70	64	56	50	46	42	38	33	31	30	28	25	22	19	0
.30	0	0	0	0	0	3	22	96	244	383	440	411	344	217	142	105	87	76	69	60	53	47	43	39	35	32	30	29	26	22	19	0
.40	0	0	0	0	0	2	16	69	186	317	399	407	365	246	160	115	92	79	71	61	54	48	43	39	35	32	30	29	26	22	19	0
.50	0	0	0	0	0	0	2	11	50	140	258	352	389	327	223	149	110	89	77	66	57	50	45	41	36	33	31	29	26	23	19	0
.75	0	0	0	0	0	0	1	4	20	63	135	219	290	335	281	205	146	110	89	72	62	52	46	42	38	34	31	30	27	23	19	0
1.0	0	0	0	0	0	0	0	0	0	2	9	32	78	216	320	306	243	176	128	90	72	59	49	44	40	36	33	31	28	24	19	1
1.5	0	0	0	0	0	0	0	0	0	0	0	0	2	20	84	185	264	281	246	168	112	77	58	49	44	40	36	32	29	26	20	5
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	50	121	200	257	224	141	83	61	50	44	40	36	31	28	21	14
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	16	51	145	239	223	137	82	60	50	44	40	33	29	22	17
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	19	74	184	224	146	89	63	51	45	36	31	24	18
IA/P = 0.50														* * * TC =0.3 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	1	25	151	299	277	219	187	162	141	113	100	90	84	78	72	65	61	58	53	48	44	42	41	39	35	31	28	0
.10	0	0	0	0	1	17	106	235	263	234	202	175	152	120	104	93	85	79	73	66	61	58	54	49	44	42	41	39	35	31	28	0
.20	0	0	0	0	0	0	12	75	182	236	234	213	188	144	116	101	91	84	78	70	63	59	55	50	45	43	41	40	36	31	28	0
.30	0	0	0	0	0	0	8	52	138	203	224	217	197	154	123	105	94	86	79	71	64	59	55	51	46	43	42	40	36	32	28	0
.40	0	0	0	0	0	0	5	37	105	170	206	213	203	164	131	110	97	88	81	72	65	60	56	51	46	43	42	40	36	32	28	0
.50	0	0	0	0	0	0	0	4	26	78	140	184	203	191	155	126	107	95	86	76	69	62	57	53	48	44	42	41	37	33	28	0
.75	0	0	0	0	0	0	0	1	10	34	73	117	153	184	173	146	122	105	94	82	73	64	58	54	49	45	43	41	37	33	28	0
1.0	0	0	0	0	0	0	0	0	0	0	4	17	42	114	168	178	159	134	114	94	82	70	61	57	52	47	44	42	39	35	28	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	10	44	98	144	163	157	130	105	84	69	61	56	52	47	44	40	36	29	6
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	14	44	87	127	153	141	110	83	69	61	56	51	47	42	38	30	17
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	16	42	97	138	145	107	82	68	60	55	51	43	40	32	25
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	27	71	127	139	105	81	68	60	55	46	41	33	27

RAINFALL TYPE = II   * * * TC = 0.3 HR * * *   SHEET 3 OF 10

Source: USDA-SCS

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =0.4 HR * * *														IA/P = 0.10				
0.0	18	25	36	77	141	271	468	592	574	431	298	216	163	104	77	63	55	49	44	38	34	31	28	25	22	21	20	18	16	14	12	0
.10	18	24	34	67	116	219	385	523	557	473	357	263	196	119	84	67	57	51	46	39	35	32	29	25	22	21	20	19	16	14	12	0
.20	15	20	28	44	59	97	179	316	454	523	489	401	309	178	112	81	65	56	49	42	37	33	30	26	23	21	20	19	17	14	12	0
.30	15	20	27	41	53	82	147	260	389	478	486	429	349	210	129	89	69	58	51	43	38	33	30	27	24	21	20	19	17	14	12	0
.40	13	17	23	33	38	48	71	121	214	331	429	467	442	308	189	120	85	66	56	47	41	35	31	28	24	22	20	19	17	15	12	0
.50	12	16	22	31	36	44	62	102	176	279	379	438	440	339	218	137	94	71	59	49	42	35	31	28	25	22	21	19	17	15	12	0
.75	10	13	17	24	26	30	35	45	65	106	170	251	326	393	341	245	164	112	81	59	48	39	33	30	26	23	21	20	18	15	12	0
1.0	8	10	13	17	19	21	24	27	31	37	50	75	118	251	360	376	292	205	138	83	60	45	36	32	28	25	22	21	18	16	12	1
1.5	6	7	9	12	13	14	15	17	19	21	23	26	31	56	121	224	311	333	293	192	115	66	45	36	31	28	25	22	19	17	13	4
2.0	4	5	6	8	8	9	10	10	11	12	14	15	16	20	27	43	85	159	243	306	264	154	74	47	37	32	28	25	21	18	14	9
2.5	2	3	4	5	6	6	7	7	8	9	9	10	11	13	16	20	27	46	85	184	285	262	147	74	47	37	32	28	22	19	15	11
3.0	1	2	2	3	4	4	4	5	5	6	6	7	7	8	10	12	14	17	23	47	109	227	268	160	83	50	38	32	25	21	16	11
IA/P = 0.30														* * * TC =0.4 HR * * *														IA/P = 0.30				
0.0	0	0	0	4	26	113	296	480	495	413	306	234	186	127	100	84	74	67	61	54	49	45	41	37	33	31	29	28	25	21	19	0
.10	0	0	0	0	2	18	81	224	395	462	430	347	272	172	121	96	82	73	66	57	51	46	42	38	34	31	30	28	25	22	19	0
.20	0	0	0	0	2	13	59	169	320	414	424	373	305	196	134	103	85	75	67	59	52	47	43	39	34	32	30	29	25	22	19	0
.30	0	0	0	0	0	1	9	42	127	255	361	403	383	274	181	127	99	83	73	63	55	48	44	40	36	32	30	29	26	23	19	0
.40	0	0	0	0	0	1	6	30	94	202	308	372	379	298	203	141	106	87	76	65	56	49	44	40	36	32	31	29	26	23	19	0
.50	0	0	0	0	0	0	0	4	21	70	158	258	334	364	270	187	133	102	85	70	60	51	46	41	37	33	31	30	26	23	19	0
.75	0	0	0	0	0	0	0	2	8	30	76	145	219	321	305	241	177	130	102	78	65	55	47	43	38	34	32	30	27	24	19	0
1.0	0	0	0	0	0	0	0	0	0	1	4	15	42	150	267	308	272	209	154	103	79	62	51	45	41	37	33	31	28	25	19	1
1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	10	51	136	226	274	263	195	131	85	62	51	45	41	36	33	29	26	20	6
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	31	86	162	252	239	162	93	64	52	45	41	37	31	28	21	15
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	33	112	202	235	155	92	64	52	45	41	33	29	23	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	21	76	182	221	148	90	63	51	45	36	31	24	13
IA/P = 0.50														* * * TC =0.4 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	7	59	168	245	257	213	186	163	128	109	96	88	81	75	67	62	58	54	50	45	43	41	39	35	31	28	0
.10	0	0	0	0	0	0	5	41	125	205	240	222	198	154	123	106	94	86	79	71	64	60	56	51	46	43	42	40	36	32	28	0
.20	0	0	0	0	0	0	3	28	93	168	216	220	205	164	131	110	97	88	81	72	65	60	56	51	46	43	42	40	36	32	28	0
.30	0	0	0	0	0	0	0	2	20	69	135	189	209	192	155	126	107	95	86	77	69	62	57	53	48	44	42	41	37	33	28	0
.40	0	0	0	0	0	0	0	1	14	50	106	161	193	202	163	133	112	98	89	78	70	62	58	53	48	44	42	41	37	33	28	0
.50	0	0	0	0	0	0	0	1	9	37	83	135	174	194	171	140	117	102	91	80	71	63	58	54	49	45	43	41	37	33	28	0
.75	0	0	0	0	0	0	0	0	0	3	15	40	76	147	177	169	146	124	107	90	79	68	60	56	51	47	43	42	38	34	28	0
1.0	0	0	0	0	0	0	0	0	0	0	1	7	21	78	141	173	167	146	125	101	86	73	63	58	53	48	45	42	39	35	28	1
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	26	71	121	153	159	139	113	89	72	63	57	53	48	44	40	37	29	7
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	16	45	86	138	150	125	93	74	64	58	53	48	42	39	31	20
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	17	59	112	143	121	91	73	63	57	53	45	40	32	26
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11	40	101	138	117	90	73	63	57	48	42	34	27

RAINFALL TYPE = II * * * TC = 0.4 HR * * * SHEET 4 OF 10

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =0.5 HR * * *														IA/P = 0.10				
0.0	17	23	32	57	94	170	308	467	529	507	402	297	226	140	96	74	61	53	47	41	36	32	29	26	23	21	20	19	16	14	12	0
.10	16	22	30	51	80	140	252	395	484	499	434	343	265	162	108	80	65	55	49	42	36	33	29	26	23	21	20	19	16	14	12	0
.20	14	19	25	38	47	69	116	207	332	434	477	449	378	238	149	101	77	62	53	45	39	34	30	27	24	22	20	19	17	14	12	0
.30	13	18	24	35	43	60	97	170	278	382	446	448	401	270	171	114	83	66	56	46	40	34	31	27	24	22	20	19	17	15	12	0
.40	12	15	21	29	33	40	53	83	141	233	332	408	434	361	243	157	107	79	64	51	43	36	32	28	25	22	21	20	17	15	12	0
.50	11	15	20	28	31	37	48	71	118	194	286	367	412	378	271	178	119	86	68	53	44	37	32	29	25	23	21	20	17	15	12	0
.75	9	11	14	19	21	24	27	31	37	49	74	118	182	319	374	328	244	169	117	76	56	43	35	31	28	25	22	21	18	16	12	1
1.0	7	9	12	16	17	19	21	24	27	32	40	55	83	188	309	359	322	245	172	102	68	49	38	32	29	26	23	21	19	16	12	1
1.5	5	7	8	11	12	13	14	15	17	19	21	23	27	43	89	175	269	322	309	225	140	77	49	38	32	29	25	23	20	17	13	5
2.0	3	4	6	7	8	8	9	10	10	11	12	14	15	18	23	35	65	123	202	297	280	181	88	52	39	33	29	26	21	19	14	10
2.5	2	3	4	5	5	6	6	7	7	8	9	[illegible]	10	12	15	18	24	36	66	150	244	278	171	87	52	39	33	29	23	20	15	11
3.0	1	1	2	3	3	4	4	4	5	5	6	6	7	8	9	11	13	16	20	37	86	198	263	182	96	56	40	33	26	21	16	11
IA/P = 0.30														* * * TC =0.5 HR * * *														IA/P = 0.30				
0.0	0	0	0	1	9	53	157	314	433	439	379	299	237	159	118	95	81	71	65	56	50	46	42	38	34	31	30	28	25	22	19	0
.10	0	0	0	0	1	6	37	117	248	372	416	391	330	218	150	113	92	79	70	60	53	47	43	39	35	32	30	29	26	22	19	0
.20	0	0	0	0	1	4	26	87	194	313	382	388	349	244	167	122	97	82	72	62	54	48	43	39	35	32	30	29	26	22	19	0
.30	0	0	0	0	0	0	3	19	64	151	259	341	372	316	223	156	117	94	80	67	58	50	45	41	36	33	31	29	26	23	19	0
.40	0	0	0	0	0	0	2	13	47	116	211	298	354	328	245	172	127	100	83	69	59	51	45	41	37	33	31	29	26	23	19	0
.50	0	0	0	0	0	0	0	1	9	34	89	170	255	341	303	225	161	120	96	76	64	54	47	42	38	34	31	30	27	24	19	0
.75	0	0	0	0	0	0	0	1	4	14	41	89	152	270	305	268	207	155	118	87	70	57	48	44	39	35	32	30	27	24	19	0
1.0	0	0	0	0	0	0	0	0	0	0	2	7	22	98	212	295	285	237	181	120	88	67	53	46	42	38	34	31	28	25	19	2
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	30	95	183	249	265	217	152	96	66	53	46	41	37	34	30	26	20	8
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	18	59	125	221	245	182	105	69	54	47	42	38	32	28	22	16
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	21	84	174	230	172	103	69	54	46	42	34	30	23	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	13	56	157	217	163	101	68	53	46	37	31	25	18
IA/P = 0.50														* * * TC =0.5 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	2	26	89	170	217	229	200	179	144	119	104	93	85	78	70	64	59	55	51	46	43	41	40	36	32	28	0
.10	0	0	0	0	0	0	1	18	65	135	190	216	205	170	137	115	101	91	83	74	67	61	56	52	47	44	42	40	36	32	28	0
.20	0	0	0	0	0	0	1	12	47	106	162	198	203	178	145	121	105	94	85	76	68	61	57	52	48	44	42	40	37	32	28	0
.30	0	0	0	0	0	0	0	1	8	34	82	135	177	194	168	139	117	102	92	80	71	63	58	54	49	45	43	41	37	33	28	0
.40	0	0	0	0	0	0	0	0	6	25	63	111	155	189	174	146	122	106	94	82	73	64	58	54	50	45	43	41	37	33	28	0
.50	0	0	0	0	0	0	0	0	4	18	48	90	133	184	177	152	128	110	97	84	74	65	59	55	50	45	43	41	38	33	29	0
.75	0	0	0	0	0	0	0	0	1	7	22	47	80	142	169	164	144	124	108	91	79	68	61	56	51	47	44	42	38	34	28	2
1.0	0	0	0	0	0	0	0	0	0	0	1	3	11	51	112	155	166	154	134	109	91	76	65	59	54	49	45	43	39	35	28	2
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2	16	50	97	136	154	145	121	95	75	64	58	54	49	45	41	37	29	10
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	18	47	86	134	146	125	94	75	64	58	53	49	42	39	31	21
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	11	44	95	140	127	97	77	65	58	54	45	41	33	26
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	29	86	135	122	95	76	65	58	49	43	35	27

RAINFALL TYPE = II   * * * TC = 0.5 HR * * *   SHEET 5 OF 10

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =0.75 HR * * *														IA/P = 0.10				
0.0	13	18	24	36	46	68	115	194	294	380	424	410	369	252	172	123	93	74	61	49	41	35	31	27	24	22	20	19	17	15	12	0
.10	13	17	23	34	42	59	97	162	250	337	395	405	381	279	191	135	100	79	65	51	42	36	31	28	25	22	21	19	17	15	12	0
.20	11	15	20	28	32	39	52	82	135	211	295	362	391	351	255	178	127	95	75	57	46	38	32	29	26	23	21	20	17	15	12	0
.30	11	14	19	26	30	36	47	70	113	179	256	326	379	360	277	196	140	103	80	60	48	38	33	29	26	23	21	20	18	15	12	0
.40	10	12	16	22	25	28	33	42	61	96	151	221	291	367	336	255	182	131	98	69	54	42	34	30	27	24	22	20	18	16	12	0
.50	9	12	16	21	24	27	31	39	53	82	128	190	258	358	343	274	200	144	106	74	56	43	35	30	27	24	22	20	18	16	12	0
.75	8	10	13	17	18	21	23	26	31	39	55	82	122	230	314	329	281	217	161	104	72	51	38	33	29	26	23	21	19	16	12	1
1.0	6	8	10	13	14	15	17	19	21	23	27	32	42	89	177	272	319	303	249	163	105	66	45	36	31	27	24	22	19	17	13	3
1.5	4	6	7	9	10	10	11	12	14	15	16	18	20	27	46	90	163	241	295	275	204	119	66	45	35	31	27	24	20	18	13	7
2.0	3	4	5	6	7	7	8	9	9	10	11	12	13	16	20	28	48	89	151	245	274	213	115	65	44	35	30	27	22	19	14	10
2.5	1	2	3	4	4	5	5	6	6	7	7	8	8	10	12	14	17	24	37	86	170	260	219	127	71	47	36	31	24	20	16	11
3.0	1	1	2	3	3	3	4	4	4	5	5	5	6	7	8	10	11	14	17	30	64	157	247	205	122	70	46	36	27	22	17	12
IA/P = 0.30														* * * TC =0.75 HR * * *														IA/P = 0.30				
0.0	0	0	0	0	1	6	30	86	174	266	326	348	328	246	181	138	110	92	79	66	57	49	44	40	36	32	31	29	26	23	19	0
.10	0	0	0	0	0	1	4	22	65	137	223	292	329	303	228	170	131	106	89	73	61	52	46	41	37	33	31	29	26	23	19	0
.20	0	0	0	0	0	0	3	15	48	108	185	256	305	321	245	184	141	112	93	75	63	53	46	42	37	34	31	30	27	23	19	0
.30	0	0	0	0	0	0	2	11	36	84	151	221	277	308	260	199	152	120	98	78	65	54	47	42	38	34	31	30	27	23	19	0
.40	0	0	0	0	0	0	0	1	8	27	65	122	188	286	301	243	187	144	114	87	71	57	48	43	39	35	32	30	27	24	19	1
.50	0	0	0	0	0	0	0	1	6	20	50	98	158	263	292	254	200	155	122	91	74	59	49	44	40	35	32	30	27	24	19	1
.75	0	0	0	0	0	0	0	0	0	2	8	23	51	140	231	269	253	211	167	119	90	68	53	46	42	37	34	31	28	25	19	2
1.0	0	0	0	0	0	0	0	0	0	0	0	1	4	29	96	186	249	261	231	169	120	84	61	50	44	40	36	33	29	26	20	5
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	34	91	163	220	241	197	131	83	61	50	44	40	35	31	27	21	12
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	36	85	174	226	200	127	82	60	49	44	39	32	29	22	17
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	37	105	196	214	135	87	62	51	44	36	31	24	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	24	96	205	189	130	85	62	50	39	32	26	18
IA/P = 0.50														* * * TC =0.75 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	0	2	16	45	92	137	166	185	170	146	125	110	98	89	79	70	63	58	53	48	44	42	41	37	33	28	0
.10	0	0	0	0	0	0	0	1	11	34	73	115	149	180	163	141	122	107	96	84	74	65	59	54	50	45	43	41	38	33	28	0
.20	0	0	0	0	0	0	0	1	8	25	57	96	131	173	166	146	126	111	99	86	76	66	59	55	50	46	43	41	38	34	28	0
.30	0	0	0	0	0	0	0	0	1	5	18	44	79	143	170	160	141	122	108	92	81	69	61	56	52	47	44	42	38	34	28	1
.40	0	0	0	0	0	0	0	0	0	4	14	34	64	127	166	162	145	127	111	95	82	70	62	57	52	47	44	42	38	34	28	1
.50	0	0	0	0	0	0	0	0	0	0	2	10	26	82	138	162	157	140	123	103	88	75	64	58	53	49	45	43	39	35	28	2
.75	0	0	0	0	0	0	0	0	0	0	1	4	12	47	98	139	154	148	135	113	96	80	67	60	55	50	46	43	39	36	29	3
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	30	73	119	146	151	134	113	91	74	63	58	53	48	45	41	37	29	7
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	30	66	105	143	143	117	90	73	63	57	52	48	42	39	30	18
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	30	77	121	137	114	88	72	63	57	52	44	40	32	25
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	19	55	111	132	111	87	71	62	56	47	42	34	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	12	51	112	128	108	86	71	62	51	44	36	27

RAINFALL TYPE = II * * * TC = 0.75 HR * * * SHEET 6 OF 10

Source: USDA-SCS

1992

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

* * * TC =1.0 HR * * *

IA/P = 0.10

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	11	15	20	29	35	47	72	112	168	231	289	329	357	313	239	175	133	103	83	63	50	40	33	29	26	23	21	20	17	15	12	0
.10	10	13	17	24	27	33	42	62	95	144	202	260	306	340	293	222	165	126	98	72	56	43	35	30	27	24	22	20	18	15	12	0
.20	10	13	17	23	26	30	38	54	82	123	176	232	281	332	303	238	179	136	105	76	59	45	35	30	27	24	22	20	18	16	12	1
.30	9	12	16	22	24	28	35	48	70	105	152	205	256	323	310	254	193	146	113	81	61	46	36	31	27	24	22	20	18	16	12	1
.40	8	11	14	19	21	23	27	32	42	61	91	132	181	276	318	294	237	181	138	95	70	51	39	32	28	25	23	21	18	16	12	1
.50	8	10	13	18	20	22	25	30	38	53	78	114	159	253	311	300	251	195	149	102	74	53	40	33	29	25	23	21	18	16	12	1
.75	7	8	11	14	16	17	19	21	25	30	38	53	76	146	228	284	293	256	208	143	99	66	46	36	31	27	24	22	19	17	13	2
1.0	5	7	8	11	12	13	14	16	17	19	22	25	31	57	111	188	256	286	272	208	144	90	56	41	33	29	26	23	20	17	13	4
1.5	4	5	6	8	8	9	10	11	12	13	14	15	17	22	33	59	107	171	231	268	235	157	88	56	41	33	29	25	21	18	14	8
2.0	2	3	4	5	5	6	6	7	7	8	9	9	10	12	15	19	27	44	78	157	231	252	167	96	59	42	34	29	23	20	15	11
2.5	1	2	2	3	4	4	4	5	5	6	6	7	7	8	10	12	15	19	27	58	120	214	241	159	94	59	42	34	26	21	16	11
3.0	0	1	1	2	2	3	3	3	4	4	4	5	5	6	7	8	10	12	14	22	44	113	214	231	152	91	58	42	29	23	17	12

* * * TC =1.0 HR * * *

IA/P = 0.30

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	0	1	4	16	42	83	137	195	243	271	292	227	178	143	117	98	79	66	55	47	42	38	34	31	30	27	23	19	0
.10	0	0	0	0	0	0	3	12	32	66	113	168	218	279	260	213	169	136	113	88	72	59	49	43	39	35	32	30	27	24	19	1
.20	0	0	0	0	0	0	2	9	24	52	93	143	193	271	271	225	180	145	119	92	75	60	50	44	39	35	32	30	27	24	19	1
.30	0	0	0	0	0	0	1	6	18	41	75	120	169	246	264	234	191	153	125	96	78	62	51	44	40	36	33	31	27	24	19	1
.40	0	0	0	0	0	0	0	1	4	14	32	61	100	190	251	259	222	181	146	109	86	67	53	46	41	37	33	31	28	25	19	2
.50	0	0	0	0	0	0	0	1	3	10	24	49	83	168	237	254	230	191	155	115	90	69	54	47	42	37	34	31	28	25	19	2
.75	0	0	0	0	0	0	0	0	0	1	4	12	25	76	150	213	239	228	198	149	112	82	61	50	44	39	35	32	29	26	20	4
1.0	0	0	0	0	0	0	0	0	0	0	0	1	2	15	51	113	182	226	234	197	150	104	72	56	47	42	38	34	30	27	20	7
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	18	51	104	162	220	210	158	102	71	56	47	42	37	31	28	22	13
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	20	49	121	187	209	152	100	70	55	47	41	34	29	23	17
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	32	87	171	199	146	98	69	54	46	37	31	24	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	13	62	158	192	151	103	73	56	41	34	26	18

* * * TC =1.0 HR * * *

IA/P = 0.50

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	0	0	0	1	7	21	42	71	101	126	160	154	138	123	110	100	87	77	67	60	55	50	46	43	41	38	34	28	1
.10	0	0	0	0	0	0	0	1	5	15	33	58	87	134	156	149	134	120	108	93	82	71	62	57	52	47	44	42	38	34	28	1
.20	0	0	0	0	0	0	0	1	4	12	26	48	74	123	153	153	137	123	111	95	84	72	63	57	52	47	44	42	38	34	28	1
.30	0	0	0	0	0	0	0	0	3	9	20	38	62	111	143	150	140	127	114	98	86	73	63	58	53	48	45	42	39	35	28	1
.40	0	0	0	0	0	0	0	0	0	2	6	16	31	75	120	145	148	137	123	106	91	77	66	59	54	49	45	43	39	35	29	2
.50	0	0	0	0	0	0	0	0	0	1	5	12	25	64	109	139	146	139	127	108	94	79	67	60	55	50	46	43	39	36	29	3
.75	0	0	0	0	0	0	0	0	0	0	2	5	12	39	78	115	136	140	134	117	101	84	70	62	56	51	47	44	40	36	29	4
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	26	59	96	125	139	133	117	97	78	66	59	54	49	46	41	37	29	8
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9	26	54	86	123	133	119	95	77	66	59	54	49	43	39	31	17
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	25	64	104	129	116	93	76	65	58	53	45	41	33	24
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10	34	84	125	117	96	78	66	59	49	43	35	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	32	89	122	114	94	77	66	53	45	37	27

* * * TC = 1.0 HR * * *

RAINFALL TYPE = II

SHEET 7 OF 10

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =1.25 HR * * *															IA/P = 0.10			
0.0	10	13	18	25	29	38	54	81	118	163	213	256	284	311	266	212	163	129	104	78	61	47	37	31	27	24	22	20	18	16	12	1
.10	10	13	17	23	27	34	47	69	102	143	189	234	267	297	274	226	175	138	111	82	64	48	38	31	27	24	22	20	18	16	12	1
.20	9	11	15	20	22	26	31	42	60	88	124	168	212	280	292	261	212	166	131	95	72	53	40	33	28	25	23	21	18	16	12	1
.30	8	11	14	19	21	24	29	38	53	76	108	148	190	263	288	268	224	177	140	101	76	55	41	34	29	25	23	21	18	16	12	2
.40	8	10	13	18	20	23	27	34	46	66	94	130	170	245	282	273	235	188	149	107	80	58	42	34	29	26	23	21	19	16	12	2
.50	7	9	12	16	17	19	22	25	31	41	58	82	114	190	256	279	262	222	178	127	93	65	46	36	31	27	24	22	19	17	13	2
.75	6	8	10	14	15	17	19	21	25	31	41	56	78	139	207	254	265	245	208	152	110	75	51	39	32	28	25	22	19	17	13	3
1.0	5	6	8	10	11	13	14	15	17	19	22	26	33	60	109	173	230	261	255	208	153	100	64	46	36	30	26	24	20	18	13	5
1.5	3	4	5	7	7	8	9	9	10	11	12	13	15	19	27	45	79	130	186	247	239	180	108	68	48	37	31	27	22	19	14	10
2.0	2	3	4	5	6	6	7	7	8	8	9	10	11	13	16	22	35	59	98	171	236	236	156	95	62	44	35	30	23	20	15	11
2.5	1	2	2	3	4	4	4	5	5	5	6	6	7	8	10	12	14	19	28	58	114	197	226	163	102	65	46	36	26	21	16	11
3.0	0	1	1	2	2	2	2	3	3	3	4	4	4	5	6	7	9	10	13	19	35	88	184	218	169	109	70	49	31	24	18	12
IA/P = 0.30														* * * TC =1.25 HR * * *															IA/P = 0,30			
0.0	0	0	0	0	0	2	9	25	50	86	130	174	208	253	235	201	164	136	115	92	76	61	51	44	39	35	32	30	27	24	19	1
.10	0	0	0	0	0	0	1	6	19	40	71	110	153	217	247	227	191	157	131	103	84	66	53	46	41	36	33	31	28	24	19	2
.20	0	0	0	0	0	0	1	4	14	31	58	93	133	202	239	231	199	165	138	108	87	68	55	47	41	37	33	31	28	25	19	2
.30	0	0	0	0	0	0	0	1	3	10	24	46	77	152	210	236	222	190	158	122	97	74	58	49	43	38	34	32	28	25	20	3
.40	0	0	0	0	0	0	0	0	2	8	19	37	64	134	196	232	225	198	166	127	101	77	59	50	43	38	35	32	28	25	20	3
.50	0	0	0	0	0	0	0	0	0	2	6	14	30	82	151	206	228	217	189	146	113	85	64	52	45	40	36	33	29	26	20	5
.75	0	0	0	0	0	0	0	0	0	1	2	7	15	49	105	164	205	218	205	166	129	95	69	55	47	41	37	33	29	26	20	6
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	32	77	134	185	214	203	166	120	83	63	52	45	39	35	30	27	21	10
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	33	72	121	184	203	171	117	82	62	51	44	39	32	29	22	15
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	21	67	132	194	174	123	86	64	52	45	35	31	24	18
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	13	46	121	187	166	119	84	63	52	39	32	25	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	44	129	180	160	116	83	63	44	35	27	18
IA/P = 0.50														* * * TC =1.25 HR * * *															IA/P = 0.50			
0.0	0	0	0	0	0	0	1	5	13	26	44	68	91	125	142	142	128	117	107	94	83	72	63	57	52	47	44	42	38	34	28	2
.10	0	0	0	0	0	0	0	0	3	10	20	36	57	100	129	140	136	125	114	100	88	76	65	59	54	49	45	43	39	35	29	3
.20	0	0	0	0	0	0	0	0	2	7	16	30	48	90	122	139	139	127	117	102	90	77	66	60	54	49	45	43	39	35	29	3
.30	0	0	0	0	0	0	0	0	0	2	5	12	24	59	98	126	137	134	125	109	96	82	69	61	56	51	46	44	40	36	29	4
.40	0	0	0	0	0	0	0	0	0	1	4	10	19	51	89	119	134	136	127	112	98	83	70	62	56	51	47	44	40	36	29	5
.50	0	0	0	0	0	0	0	0	0	1	3	7	15	43	79	112	131	135	129	114	100	85	71	63	57	52	47	44	40	36	29	6
.75	0	0	0	0	0	0	0	0	0	0	0	1	3	15	39	71	102	123	130	125	112	94	78	67	60	54	49	46	41	37	29	9
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	17	40	71	101	121	129	121	103	84	71	62	56	51	47	42	38	30	13
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	26	51	92	119	125	105	86	72	63	57	52	44	40	32	23
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	11	35	72	112	122	103	85	71	63	56	47	42	34	26
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	24	66	111	119	101	83	71	62	51	44	36	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	23	71	110	116	99	82	70	55	46	37	27

RAINFALL TYPE = II * * * TC = 1.25 HR * * * SHEET 8 OF 10

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =1.5 HR * * *														IA/P = 0.10				
0.0	9	11	15	21	25	31	41	58	82	112	147	184	216	255	275	236	198	159	129	98	76	57	43	35	30	25	23	21	18	16	12	1
.10	8	10	13	18	20	23	28	37	51	72	98	131	166	226	265	254	226	187	151	113	86	63	46	37	31	26	23	21	19	16	13	2
.20	8	10	13	17	19	22	26	33	45	63	87	116	149	212	259	259	233	197	160	119	90	66	48	38	32	27	24	22	19	17	13	2
.30	7	9	12	16	18	21	24	30	40	55	76	103	134	197	244	255	238	206	169	125	95	68	49	38	32	27	24	22	19	17	13	2
.40	7	8	11	14	15	17	19	23	28	36	49	67	91	151	208	247	252	230	196	146	109	77	54	41	34	29	25	22	19	17	13	3
.50	6	8	10	13	15	16	18	21	26	33	43	59	80	136	194	238	249	235	204	154	115	81	56	42	34	29	25	23	20	17	13	3
.75	5	7	8	11	12	13	14	16	18	21	25	32	42	76	125	179	222	240	233	193	148	102	67	48	38	32	27	24	20	18	13	5
1.0	4	5	7	8	9	10	11	12	13	14	16	18	22	34	59	101	152	201	236	230	193	135	86	59	44	35	30	26	21	18	14	7
1.5	3	4	5	6	6	7	8	8	9	10	11	12	13	16	22	34	58	95	141	203	226	197	131	84	58	43	35	29	23	20	15	10
2.0	1	2	3	4	4	5	5	6	6	7	7	8	9	10	12	16	22	34	56	110	172	218	187	126	82	57	43	34	25	21	16	11
2.5	1	1	2	2	3	3	3	4	4	4	5	5	6	7	8	9	11	14	18	34	69	141	210	190	133	87	60	44	30	23	17	12
3.0	0	0	1	1	2	2	2	2	3	3	3	3	4	5	5	6	8	9	11	16	27	66	149	204	181	128	85	58	35	25	18	12
IA/P = 0.30														* * * TC =1.5 HR * * *														IA/P = 0.30				
0.0	0	0	0	0	0	1	6	15	31	53	80	112	144	193	225	208	186	157	134	108	89	70	56	48	42	37	34	31	28	25	20	2
.10	0	0	0	0	0	0	1	4	12	25	43	68	97	157	198	219	203	178	151	120	98	77	60	50	44	38	35	32	28	25	20	3
.20	0	0	0	0	0	0	0	1	3	9	19	35	57	114	168	201	213	196	171	135	108	84	64	53	46	40	36	33	29	26	20	4
.30	0	0	0	0	0	0	0	1	2	7	15	29	48	100	155	193	210	200	177	140	113	87	66	54	46	41	36	33	29	26	20	5
.40	0	0	0	0	0	0	0	0	2	5	12	23	39	87	141	184	207	202	182	146	117	89	68	55	47	41	36	33	29	26	20	5
.50	0	0	0	0	0	0	0	0	0	1	4	9	18	51	101	153	190	205	197	164	131	99	73	58	49	43	38	34	30	26	20	7
.75	0	0	0	0	0	0	0	0	0	0	2	4	9	30	68	116	160	189	197	179	147	110	80	62	52	45	39	35	30	27	21	8
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	20	49	92	138	175	195	178	137	97	72	57	48	42	37	31	28	21	12
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	21	47	95	145	187	178	133	95	71	57	48	42	34	29	23	16
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	13	45	97	162	180	138	99	74	58	49	38	32	25	18
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	31	89	161	174	133	97	72	58	42	34	26	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	29	98	160	169	129	95	71	48	37	28	19
IA/P = 0.50														* * * TC =1.5 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	0	0	3	8	16	27	42	59	92	116	128	130	121	112	100	90	78	67	60	55	50	46	43	39	35	29	4
.10	0	0	0	0	0	0	0	2	6	12	22	35	51	84	110	125	128	123	114	102	91	79	68	61	55	50	46	43	39	35	29	4
.20	0	0	0	0	0	0	0	0	1	4	10	18	29	60	91	114	126	128	120	108	97	83	71	63	57	52	47	44	40	36	29	5
.30	0	0	0	0	0	0	0	0	1	3	8	14	24	52	83	108	123	126	122	110	98	85	72	63	57	52	48	44	40	36	29	6
.40	0	0	0	0	0	0	0	0	0	1	2	6	12	31	60	90	112	124	126	116	104	90	75	66	59	54	49	45	41	37	29	8
.50	0	0	0	0	0	0	0	0	0	0	2	4	9	26	53	83	106	121	125	118	106	91	77	67	60	54	49	46	41	37	29	8
.75	0	0	0	0	0	0	0	0	0	0	1	2	5	16	36	62	88	108	119	122	112	97	81	69	62	56	51	47	42	38	30	11
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	26	49	75	98	118	121	108	90	76	66	59	54	49	43	39	31	16
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	11	25	45	80	107	118	106	89	75	65	59	53	45	41	32	23
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	11	32	63	100	115	104	87	74	65	58	48	42	34	26
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	16	48	94	113	105	89	76	66	53	45	36	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	15	54	96	111	103	88	75	58	48	38	28

RAINFALL TYPE = II   * * * TC = 1.5 HR * * *   SHEET 9 OF 10

Exhibit 5-II, continued: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

TRVL TIME (HR) / HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC =2.0 HR * * *														IA/P = 0.10				
0.0	7	9	12	16	18	21	27	36	49	64	82	104	127	171	201	226	208	193	171	132	105	79	58	45	36	30	26	23	20	17	13	3
.10	6	8	10	14	15	17	20	25	33	43	57	74	94	139	179	204	218	205	188	150	118	88	63	48	38	32	27	24	20	17	13	4
.20	6	8	10	13	14	16	19	23	29	39	51	66	84	128	169	198	213	207	192	157	123	91	65	49	39	33	28	24	20	17	13	4
.30	6	7	9	12	14	15	18	21	27	35	45	59	76	117	159	191	211	208	196	163	128	95	68	51	40	33	28	25	20	18	13	4
.40	5	6	8	11	12	13	15	17	20	24	31	41	53	87	128	167	197	209	205	180	145	106	75	55	43	35	30	26	21	18	14	5
.50	5	6	8	10	11	13	14	16	18	22	28	37	48	78	118	158	190	208	208	185	151	111	77	57	44	36	30	26	21	18	14	5
.75	4	6	7	9	10	11	12	13	15	18	22	27	35	58	91	129	164	191	202	194	167	125	87	63	48	38	32	27	22	18	14	6
1.0	3	4	6	7	8	8	9	10	11	12	14	16	18	28	46	74	110	147	178	201	193	156	108	76	56	43	35	30	23	19	14	8
1.5	2	3	3	5	5	5	6	6	7	8	8	9	10	12	16	23	36	57	86	137	178	195	160	113	79	58	45	36	26	21	16	11
2.0	1	2	2	3	3	4	4	4	5	5	6	6	7	8	10	12	16	23	35	67	112	169	190	154	110	78	57	44	30	23	17	11
2.5	0	1	1	2	2	2	3	3	3	4	4	4	5	6	7	8	9	12	16	28	52	105	170	185	149	107	76	56	35	26	18	12
3.0	0	0	1	1	1	1	1	2	2	2	2	3	3	3	4	5	6	7	8	12	18	41	99	161	180	152	112	80	45	30	19	12
IA/P = 0.30														* * * TC =2.0 HR * * *														IA/P = 0.30				
0.0	0	0	0	0	0	1	3	8	15	25	38	54	74	115	148	168	185	170	159	131	110	89	70	57	49	42	38	34	29	26	20	5
.10	0	0	0	0	0	0	0	2	6	12	21	32	47	85	124	153	169	180	168	145	120	96	75	60	51	44	39	35	30	26	20	6
.20	0	0	0	0	0	0	0	2	4	10	17	27	41	75	114	146	165	175	170	149	124	99	76	62	52	45	39	35	30	27	21	6
.30	0	0	0	0	0	0	0	0	1	3	7	14	23	49	86	122	151	170	174	160	136	107	82	66	54	47	41	37	31	27	21	8
.40	0	0	0	0	0	0	0	0	1	2	6	11	19	43	77	113	144	165	173	163	140	111	85	67	55	47	41	37	31	27	21	8
.50	0	0	0	0	0	0	0	0	1	2	4	9	16	37	68	104	136	160	171	165	144	114	87	69	56	48	42	37	31	27	21	9
.75	0	0	0	0	0	0	0	0	0	0	1	2	5	15	34	62	96	127	152	167	160	132	100	77	62	52	45	40	32	28	22	11
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	24	48	79	111	150	166	153	118	90	71	58	49	43	34	29	23	14
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	10	24	45	88	130	161	148	115	88	70	57	48	37	31	24	17
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	10	32	68	122	157	143	113	87	68	56	42	34	26	18
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	16	51	114	153	144	116	89	70	49	38	27	19
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	15	59	118	150	140	113	88	57	42	29	19
IA/P = 0.50														* * * TC =2.0 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	0	0	1	4	8	13	20	28	51	73	92	104	111	112	106	97	86	75	66	60	54	49	46	41	37	30	7
.10	0	0	0	0	0	0	0	1	3	6	11	17	24	45	68	87	101	109	112	107	98	88	76	67	60	55	50	46	41	37	30	8
.20	0	0	0	0	0	0	0	1	2	5	9	14	21	40	62	82	98	107	111	108	100	89	77	68	61	55	50	47	41	37	30	8
.30	0	0	0	0	0	0	0	0	0	2	4	7	12	26	46	67	86	100	108	111	104	93	80	70	63	57	52	48	42	38	30	10
.40	0	0	0	0	0	0	0	0	0	1	3	6	10	22	41	62	81	96	106	110	105	94	81	71	63	57	52	48	42	38	30	11
.50	0	0	0	0	0	0	0	0	0	0	1	2	4	13	27	46	67	85	99	110	108	98	85	74	66	59	54	49	43	39	31	13
.75	0	0	0	0	0	0	0	0	0	0	0	1	2	7	18	33	52	71	88	104	108	102	89	77	68	61	55	50	44	39	31	15
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	13	25	43	62	87	103	108	97	84	73	65	59	53	45	41	32	20
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	12	24	48	74	99	106	95	83	72	64	58	48	43	34	25
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	17	37	69	99	104	94	82	72	64	52	45	36	27
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	27	65	95	102	95	83	73	58	49	38	28
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	32	68	95	101	93	82	64	52	40	28

RAINFALL TYPE = II * * * TC = 2.0 HR * * * SHEET 10 OF 10

PART II

STORMWATER DETENTION

Flow Routing

A stormwater detention basin acts as a constriction in the stream. When the capacity of the outlet structure is exceeded, a portion of the flow backs up and is temporarily stored. Flow routing (or flood routing) is the procedure used to determine the volume of water that will be stored behind the detention structure during a rainfall event. In order to design a detention basin, a flow routing procedure must be used to determine the required storage volume for the selected design storm and the allowable release rate.

Storage-Indication Method

One of the most widely used methods of determining the required storage volume in detention basins is the Storage-Indication Method. This mathematical flow routing procedure consists of a trial and error process based upon the Continuity Equation. The basic premise is that the volume of water entering the basin minus the volume of water leaving the basin (over a given time interval) equals the required storage volume. The design procedure for implementing the Storage-Indication Method can be quite lengthy and time consuming when done manually.

Rather than present an in-depth explanation or an over-simplified version of the subject of flood routing in this handbook, the reader is referred to the Soil Conservation Service National Engineering Handbook, Section 4, Chapter 17 (68). That reference provides a good explanation of flood routing along with design procedures for the Storage-Indication Method and other acceptable techniques of calculating detention storage volumes.

Graphical Storage Method

A simpler, but less accurate method of estimating detention storage volume is the Graphical Storage Method. This method was developed by the Soil Conservation Service and is explained fully in the SCS Technical Release No. 55 (62). It involves the use of one graph which was developed based upon average storage and routing effects of many structures using the Storage-Indication Method of flood routing.

The primary advantages of this method are its simplicity and its compatibility with SCS runoff calculation procedures described in Part I of this chapter. It is particularly suited for small detention basin design and for estimating the required size of basins during the project planning phase.

A design procedure for the Graphical Storage Method is presented here; however, its use is subject to the following limitations:

1. Failure of the structure must not endanger or result in loss of life or major property damage.

2. An error in calculated storage volume of +/- 25% must be tolerable.

3. This method may be used for single- and multiple- stage outflow devices providing: (a) each stage requires a design storm and a computation of the related storage; (b) the discharge of the upper stage(s) includes the discharge of the lower stage(s).

The following design procedure will only determine the required storage volume of the basin. The design of an appropriate discharge structure, which will maintain the allowable release rate at the design storage elevation, should be done by a qualified engineer.

DESIGN PROCEDURE - GRAPHICAL STORAGE METHOD

Step 1: Determine the allowable peak release rate (Q_o) for the basin in CFS or CSM.

The most common procedure in determining Q_o is to limit the downstream discharge rate to the 2-year pre-developed discharge rate. (See Chapter 4 for a more detailed discussion of the runoff criteria of the E&S Regulations.)

Step 2: Calculate the peak inflow rate (Q_i) for the "developed" conditions.

Step 3: Calculate the ratio Q_o/Q_i of design release rate (Q_o) to the inflow rate (Q_i) in the same units.

Step 4: Using Graph (Plate 5-27), enter the graph with Q_o/Q_i; move vertically to intersect the curve; then move horizontally to read the value for the ratio V_s/V_r.

Step 5: Calculate the required storage volume (V_s) in watershed inches by multiplying the V_s/V_r ratio by the volume of runoff (V_r) in inches for the "developed" condition.

Step 6: Convert V_s from watershed inches to acre-ft. by multiplying V_s (inches) by the watershed area (acres) and dividing by 12 in./ft.

Step 7: Proportion the storage basin and design the discharge structure so that the allowable release rate is not exceeded and the maximum water storage elevation is known.

Design Examples

The following examples represent three typical design problems. Example 5-7 and 5-8 require the use of the graph (Plate 5-27) to design a single-site detention basin. Example 5-9 requires the use of the same graph for a multi-site design in a watershed with seven sub-areas. In the following examples, the required storage volumes are determined, but the actual basin sizing and discharge structure design are beyond the scope of this text and are not included.

Example 5-7

A developer proposes to develop a 75-acre tract of woodland into a residential subdivision. The 75-acre tract is the entire drainage area of a main channel which intersects a natural stream at the property boundary. The developer is required to detain stormwater in a basin to be constructed on the main channel below the development so that the peak rate of runoff entering the natural stream after development does not exceed the pre-development peak runoff rate for a 2-year frequency design storm. This example uses the Type II storm distribution since the project is located in south-central Virginia.

Find: The required storage volume of the basin.

Step 1: Determine the allowable release rate, Q_o.

The peak discharge method was used to calculate the pre-development and post-development peak flow rates and runoff depths for a 2-year storm. The results are as follows:

Pre-development			Post-development		
Q_{peak}	=	35 cfs	Q_{peak}	=	90 cfs
V_r	=	1 inch	V_r	=	2 inches

Therefore,

Q_o = 35 cfs $\qquad$ Q_i = 90 cfs

Step 2: Determine the post-development peak discharge, Q_i.

In this example, Q_i is given. $\qquad$ Q_i = 90 cfs

Step 3: Determine $\frac{Q_0}{Q_i}$.

$$\frac{Q_0}{Q_i} = \frac{35\ cfs}{90\ cfs} = 0.389$$

Step 4: From the graph (Plate 5-27), determine, $\frac{V_s}{V_r}$.

Entering the graph with $\frac{Q_0}{Q_i} = 0.389$ and intersecting the curve,

$$\frac{V_s}{V_r} = 0.326$$

Step 5: Calculate the required storage volume, V_s.

$$\frac{V_s}{V_r} = 0.326\ \ and\ \ V_r = 2\ inches$$

$$V_s = (V_r)\left(\frac{V_s}{V_r}\right) = (2\ inches)\ (.326)$$

$$V_s = .652\ inches$$

Step 6: Convert V_s to acre-feet.

$$V_s = (.652\ inches)\left(\frac{75\ acres}{12\ in./ft.}\right) = 4.1\ acre\text{-}feet$$

Note: The next step would require the development of an elevation-storage curve for the basin, and an elevation-discharge curve for the proposed outlet structures. The objective would be to select an outlet structure which will discharge at the allowable release rate when the water reaches the maximum storage elevation. This step is beyond the scope of this text and, therefore, is not included.

Example 5-8

The developer is required to detain the stormwater runoff calculated in example 5-4 so that the peak rate of runoff after development does not exceed the peak pre-development rate of runoff for a 2-year frequency design storm.

Examples 5-4 and 5-5 use the graphical peak discharge method to determine the following:

Pre-development	Post-development
Q_{peak} = 102 cfs	Q_{peak} = 202 cfs
V_r = 0.9 in.	V_r = 1.36 in.

Therefore,

Q_o = 102 cfs	Q_i = 202 cfs

Find: The required storage volume of the basin.

Step 1: Determine Q_o

In this example, Q_o is given. Q_o = 102 cfs.

Step 2: Determine Q_i

Again, this value is given. Q_i = 202 cfs.

Step 3: Determine $\frac{Q_o}{Q_i}$.

$$\frac{Q_o}{Q_i} = \frac{102\ cfs}{202\ cfs} = 0.50$$

Step 4: From the graph (Plate 5-27), determine $\frac{V_s}{V_r}$.

Entering the graph with $\frac{Q_o}{Q_i}$ = 0.50 and intersecting the curve,

$$\frac{V_s}{V_r} = 0.278$$

Step 5: Calculate the required storage volume V_s.

$$\frac{V_s}{V_r} = 0.278 \quad \text{and } V_r = 1.36 \text{ inches}$$

$$V_s = (V_r)\left(\frac{V_s}{V_r}\right) = (1.36 \text{ in.})\ (0.278)$$

$$V_s = 0.378 \text{ inches}$$

Step 6: Convert V_s to acre-feet.

$$V_s = (0.378 \text{ in.})(0.39 \text{ sq.mi.})\left(\frac{53.33 \text{ ac.ft.}}{\text{in.-sq.mi.}}\right)$$

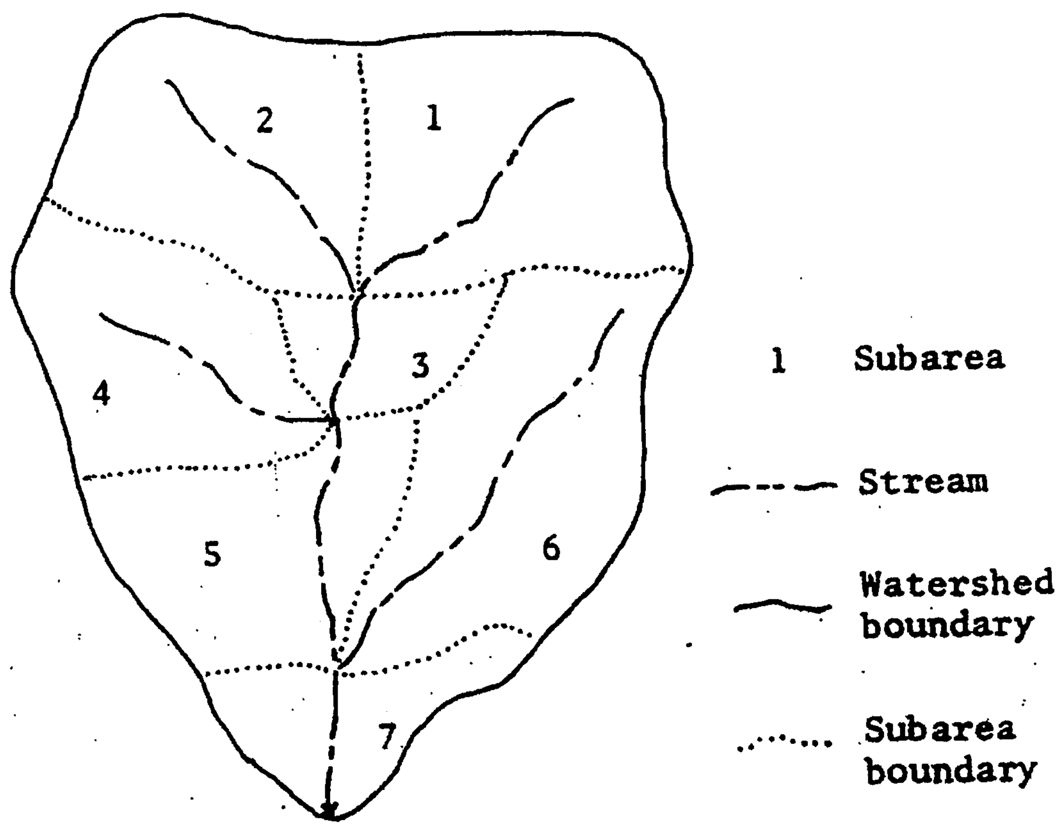
$$V_s = 7.86 \text{ acre-feet}$$

Note: This step would require the development of an elevation-storage curve for the detention basin, and an elevation-discharge curve for the proposed outlet structures. The objective would be to select an outlet structure which would discharge at the allowable release rate when the water reaches the maximum storage elevation. This step is beyond the scope of this handbook and, therefore, is not included.

Example 5-9

The watershed illustrated below is to be developed according to a predetermined plan. The tabular method was used in Example 5-6 to develop the tabular hydrographs shown on Worksheet 5b for both the present and future watershed conditions.

Find: Determine the peak release rates and required storage volumes for stormwater detention basins located at the outlets of sub-areas 4 and 6 so that the composite peak discharge rate at the outlet of sub-area 7 will not increase after development for the selected design storm.



In order to determine the allowable release rates for the detention basins in this example, an analysis of the appropriate tabular hydrographs is necessary. The future flow condition contributions by sub-areas 4 and 6 are subtracted from the future composite hydrograph as follows:

(SUB) AREA NAME	Time (in hours)				
	13.2	13.4	13.6	13.8	14.0
	Discharges (cfs)				
Composite Discharge	338	343	335	316	291
Sub-Area 4 Discharge	2	9	23	41	55
Sub-Area 6 Discharge	162	156	131	101	77
Composite minus sub-areas 4 & 6:	174	178	**181**	174	159

The partial composite peak discharge is 181 cfs. From Worksheet 5B in example 5-6, the present condition composite hydrograph shows an allowable peak release rate of 230 cfs. Therefore, the allowable release rate from sub-areas 4 and 6 combined is:

230 cfs - 181 cfs = <u>49 cfs</u>.

It is now necessary to decide the distribution of the 49 cfs release rate between the two detention basins. For a first trial, assume the basin at the outlet of sub-area 6 (structure 6A) to have a 30 cfs release rate, and the basin at the outlet of sub-area 4 (structure 4A) to have a 19 cfs release rate.

<u>DETERMINE STORAGE REQUIRED IN STRUCTURE 6A</u>

1. $Q_o = 30 \text{ cfs} = \dfrac{30 \text{ cfs}}{0.4 \text{ mi}^2} = 75 \text{ CSM}$

2. Q_i must be determined for sub-area 6. Do not use the peak rate of 162 cfs shown on the tabular hydrograph (Worksheet 5b for developed conditions), because that discharge represents only the sub-area contribution at the outlet of sub-area 7, not the peak discharge at the sub-area 6.

   Go to Exhibit 5-II for Type II rainfall, T_c = 1.00 hr. and T_t = 0. Interpolate between Ia/p values to obtain Q_i for Ia/p = 0.19, read Q_i = 318 CSM per inch of runoff.

   Therefore, $Q_i = 318 \dfrac{\text{CSM}}{\text{in.}} (V_r) = 318 \dfrac{\text{CSM}}{\text{in.}} (1.3 \text{ in.}) = 413 \text{ CSM}.$

3. $$\frac{Q_o}{Q_i} = \frac{75\ CSM}{413\ CSM} = 0.18$$

4. From the Graph (Plate 5-27, Type II rainfall distribution)

$$\frac{V_s}{V_r} = 0.47$$

5. Since the future condition runoff volume V_r = 1.30 in. (from Worksheet 5a for developed conditions):

$$V_s = (V_r)\left(\frac{V_s}{V_r}\right) = 1.30\ (0.47) = 0.61\ in.$$

6. $$V_s = \frac{0.61\ in.\ (640\ acre/mi.^2)(0.40\ mi.^2)}{12\ in./ft.}$$

$$V_s = 13.0\ acre\text{-}feet$$

DETERMINE STORAGE REQUIRED IN STRUCTURE 4A

1. $Q_o = 19\text{ cfs} = \dfrac{19\text{ cfs}}{0.25\text{ mi}^2} = 76\text{ CSM}$

2. Find Q_i by using Exhibit 5-II for Type II rainfall, T_c = 0.75 and T_t = 0. Interpolate between Ia/p values to obtain Q_i for Ia/p = 0.24. Read Q_i = 367 CSM per inch of runoff.

Therefore, $Q_i = 367\ \dfrac{\text{CSM}}{\text{in.}}\ (V_r) = 367\ \dfrac{\text{CSM}}{\text{in.}}\ (1.01\text{ in.}) = 371\text{ CSM}$

3. $$\frac{Q_o}{Q_i} = \frac{76\ CSM}{371\ CSM} = 0.2$$

4. From the Graph (Plate 5-27)

$$\frac{V_s}{V_r} = 0.455$$

5. Since V_r = 1.01 (From Worksheet 5a for developed conditions)

$$V_s = 1.01(0.455) = 0.46 \text{ in.}$$

6. $$V_s = \frac{0.46\ in.\ (640\ acre/mi.^2)(0.25\ mi.^2)}{12\ in./ft.}$$

$$V_s = 6.1\ acre\text{-}feet$$

SUMMARY

Structure	Drainage Area	Q_o	Storage Volume
4A	0.25 mi.^{2}	19 cfs	6.1 acre-ft.
6A	0.40 mi.^{2}	30 cfs	13.0 acre-ft.
Total		49 cfs	19.1 acre-ft.

The structures may now be designed using elevation storage curves for the impoundment sites and elevation-discharge curves for the selected discharge structures.

Other trial calculations can be made, if desired, to determine the most economical allocation of storage between the two detention basins that still maintain a combined release rate of 49 cfs.

* Note: Curve for types I and IA is not applicable in the State of Virginia.

APPROXIMATE GEOGRAPHIC BOUNDARIES FOR SCS RAINFALL DISTRIBUTION

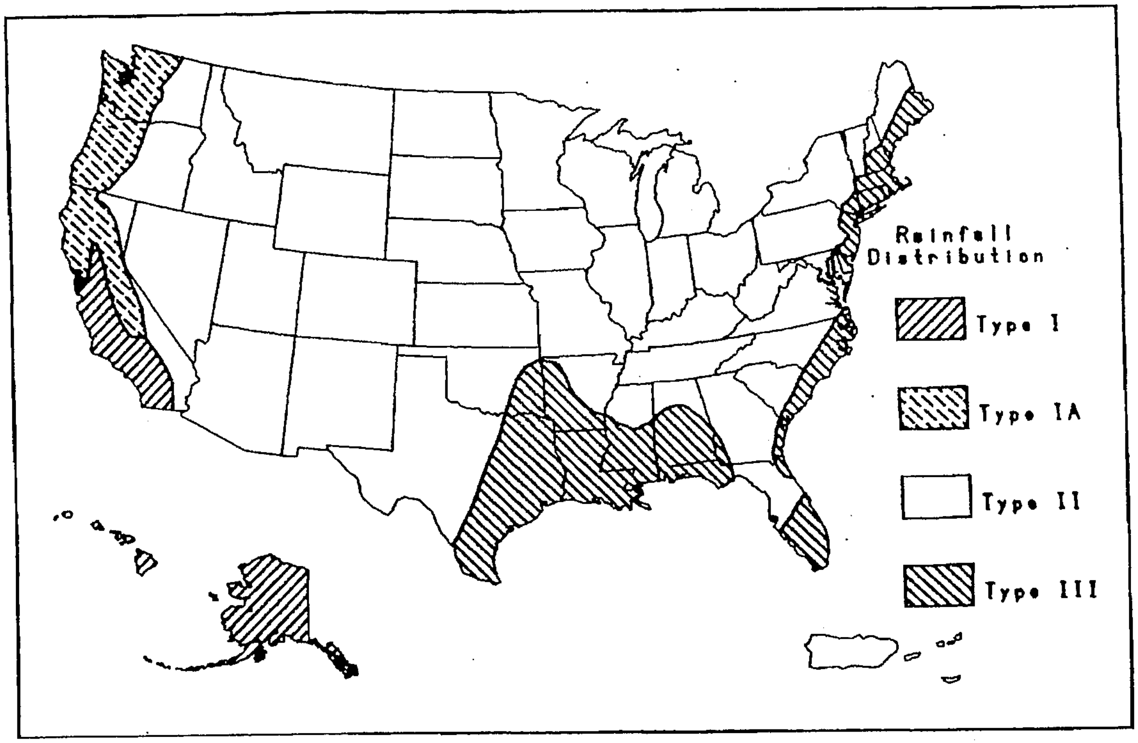
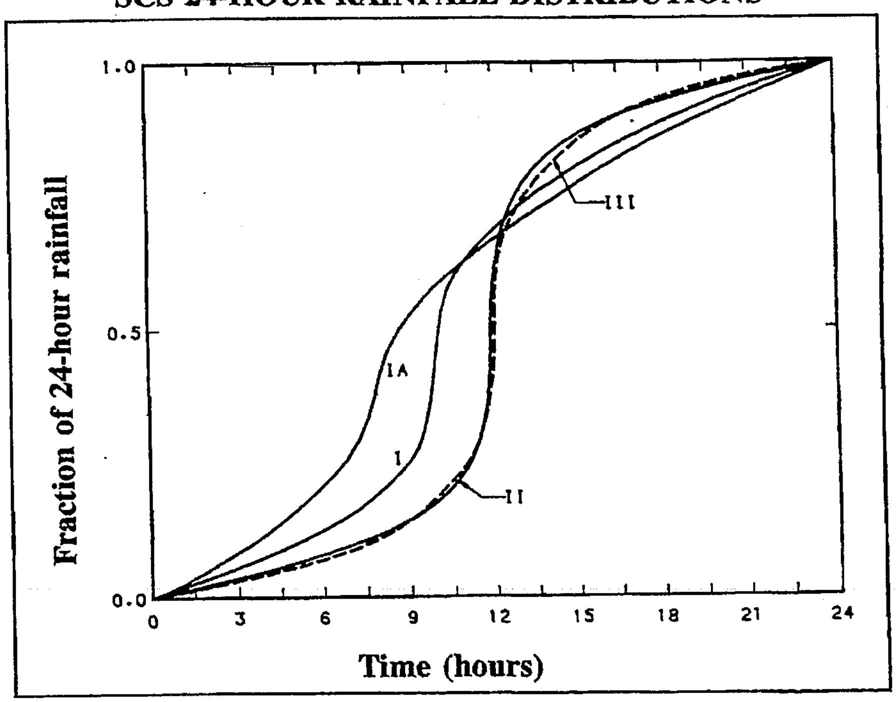


Plate 5-26A

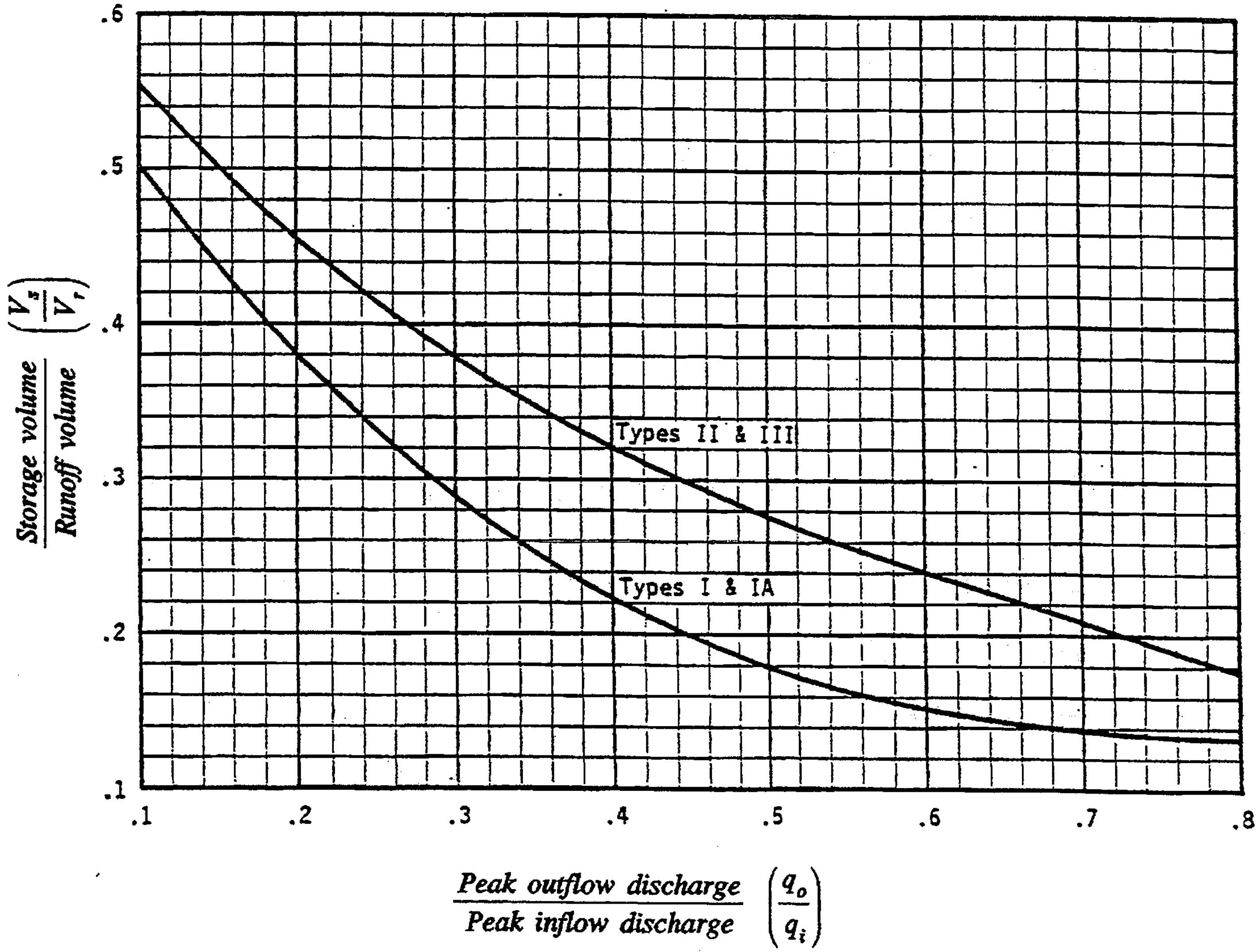
SCS 24-HOUR RAINFALL DISTRIBUTIONS



Source: USDA-SCS, TR-55

Plate 5-26B

APPROXIMATE DETENTION BASIN ROUTING FOR RAINFALL TYPES I, IA, II, AND III



Source: USDA-SCS, TR-55

Plate 5-27

PART III

OPEN CHANNEL FLOW

INTRODUCTION V-97

* Design Criteria for Constructed Channels
* Channel Slope
* Channel Cross-Section
* Channel Lining

DESIGNING A STORMWATER CONVEYANCE CHANNEL V-98

* Calculation of Channel Capacity and Velocity
* Channel Lining Design
* Channel Design Procedure

DETERMINATION OF AN ADEQUATE CHANNEL V-122

INTRODUCTION

Discussion of open channel flow has been divided into two sections. The first section, Constructed Stormwater Conveyance Channels, deals with the design of new stormwater conveyance channels in accordance with the Virginia Erosion and Sediment Control Handbook. The second section, Natural Channels, deals with undisturbed natural stream channels. Both of these sections provide information to allow the determination of an adequate channel as required by the Erosion and Sediment Control Regulations, Minimum Standard #19.

In order to simplify the hydraulic calculations, it is assumed that the channel can be divided into segments in which uniform flow exists. Uniform flow describes a condition where the depth of flow, area, velocity and discharge at every section of the channel segment are constant. In reality, these conditions are seldom met. The channel can, however, be divided into segments which have similar cross-sections and slope, and the flow can be considered at one point in time, such as the peak flow, when the quantity of flow would be more or less constant.

The two methods of analyzing the erosion resistance of a channel are the Maximum Permissible Velocity method and the Tractive Force method. An explanation of the Maximum Permissible Velocity method is given in the following pages of this chapter.

The following information is based on the assumption that the reader has some basic knowledge of hydraulic engineering principles and terms.

Design Criteria for Constructed Channels

The Virginia Erosion and Sediment Control Regulations (VESCR) contain two primary requirements for the design of man-made channels. First, the channel must have sufficient capacity to convey the peak flow expected from the 10-year frequency storm. Second, the channel lining must be resistant to erosion for the velocity of flow expected from the 2-year storm. These are statewide minimum requirements. The designer should investigate the specific drainage area to determine if more stringent design criteria are required.

Both the capacity of the channel and the velocity of flow are functions of the channel lining, cross-sectional area and slope. The channel must have a cross-section and lining that will provide sufficient capacity, erosion resistance, and stability to convey the runoff.

Channel Slope

The slope of the channel is generally fixed by the topography and proposed route of the channel. Often, there is little a designer can do to alter the slope. A field survey can provide accurate information on slope.

Channel Cross-Section

The most commonly used channel cross-sections are vee, parabolic, and trapezoidal shapes. Chapter 3 (Std. & Spec. 3.17) contains guidelines for selecting an appropriate shape based upon size, intended use, and lining of the channel. Selection of the proper channel design is a trial and error process by which the designer attempts to accommodate the flow without exceeding the maximum permissible velocity for the lining.

Channel Lining

There are a number of possible channel linings from which to choose. Commonly used channel linings include grass, riprap and concrete.

For design purposes, erosion resistance of a particular lining is stated in terms of the maximum velocity that the lining can withstand without experiencing erosion problems. Other factors should also be considered such as the duration of flow, impact of extreme storm events, flooding problems, etc.

Concrete and similar structural linings generally do not erode and the design is not restricted by maximum permissible flow velocities. However, riprap and grass-lined channels do have maximum permissible velocities above which erosion will occur.

For grass lined channels, the maximum permissible velocity is usually based upon the erosion resistance of a mature stand of vegetation. Newly seeded areas or areas with immature vegetation are very susceptible to erosion damage. Therefore, it is recommended that a temporary channel lining should be used to prevent channel erosion until the vegetation is established. When used properly, temporary lining materials can greatly increase the success in achieving an adequate stand of vegetation. (See Chapter 3 for more information on temporary lining materials.)

DESIGNING A STORMWATER CONVEYANCE CHANNEL

CALCULATION OF CHANNEL CAPACITY AND VELOCITY

In this section, the following two equations are used to calculate flow and velocity in open channels:

(A) Manning's Equation

$$V = \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

where,

V = the average velocity in the channel (ft./sec.)
n = Manning's roughness coefficient, based on channel lining
R = the hydraulic radius (feet) = A/P
S = the slope of the channel (feet/foot).

(B) Continuity Equation - Initial estimates of the required cross-sectional area of the channel can be made by manipulating this equation.

$$Q = VA$$

where,

Q	=	Flow rate (ft.^{3}/sec.) in the channel
V	=	Average velocity in the channel (ft./sec.) from Manning's equation
A	=	Cross-sectional area of the channel (ft.^{2}). See Plate 5-28 for formulas used to calculate cross-sectional area and hydraulic radius.

Additional design aids have also been placed at the end of this section for channel velocity calculation, and calculation of flow capacities based on various channel linings and configurations.

Manning's "n"

Manning's "n" value is a dimensionless number used to assign a value to the roughness of a channel. The Manning "n" value is dependent on a number of variables, the most important of which is the channel roughness, or hydraulic resistance of the material forming the channel side walls and bed. For some smooth channel lining materials such as concrete, the Manning "n" is taken to be a constant value based only on the estimated surface roughness. For bed materials such as rock riprap, the Manning "n" varies with the average size of the rock exposed to the flow. Grass and other vegetative linings produce a very complex relationship between Manning "n" and a variety of factors because the vegetation behaves in various ways depending on the type and height of the vegetation and the velocity of flow.

In addition to the bed roughness, the Manning "n" also tends to vary slightly with channel size. While this variation can normally be neglected, it should be kept in mind that the Manning "n" for small channels, such as street gutters, is larger than the Manning "n" for larger drainage ditches lined with similar material. Similarly, the Manning "n" for small drainage ditches is larger than the "n" for very large ditches. For determination of the "n" factor used in solving the Manning Equation, see the Channel Lining Design unit.

CHANNEL LINING DESIGN

Channel linings are used to help stabilize channels, thus preventing erosion and sedimentation damages. Linings may be installed in either natural or man-made channels, and can be utilized either in the initial design of the channel or as a remedy to an existing erosion problem.

Channel linings may be classified generally as either rigid (concrete or asphalt) or flexible (rock riprap or vegetation). Each of these lining types has certain advantages and disadvantages. Some of these are outlined in the following table.

TABLE 5-11

ADVANTAGES AND DISADVANTAGES OF RIGID AND FLEXIBLE CHANNEL LININGS

Type of Channel Lining	Advantages	Disadvantages
Rigid	Good capacity Low flow resistance Can be used for steep channels Can be used when width is restricted Underlying soil is completely protected	High velocities at outlet Unnatural appearance Prevent infiltration Hydrostatic pressure failure May be destroyed by undercutting
Flexible	Generally less expensive Safer for roadsides Self-healing Permit infiltration and exfiltration Filter contaminants Provide energy dissipation (higher Manning "n") Lower velocity at outlet Natural appearance	Higher depth of flow Require wider right-of-way Lower flow capacity Some erosion damage may occur during high floods

Source: Va. DSWC

Determination of "n" Values

Ranges of values for Mannings "n" have been determined for various types of channel linings. The lower the Manning value, the more hydraulically efficient the lining is. For example, the range of values for formed concrete is between .013 and .017. Therefore, .013 represents the best attainable "n" value and the most hydraulically efficient value for formed concrete, while .017 represents the least hydraulically efficient.

It is good practice to use a higher "n" value within the range of a lining material in order to achieve a conservative design. It is usually unacceptable to use the lowest value since some minor imperfections in the channel lining are likely and the lining will become somewhat less hydraulically efficient over time.

Rigid Channel Linings

Table 5-12 lists the Mannings "n" values for many of the commonly used channel linings.

Flexible Channel Linings

Riprap:

The Manning "n" value varies with mean stone size, as follows:

$$n = 0.0395\ (d_{50})^{1/6}$$

where,

d_{50} = the median size (feet) of the stone riprap.

Thus, the following "n" values apply for common stone sizes:

d_{50} (ft.)	n
0.25	0.0314
0.50	0.0352
0.75	0.0377
1.00	0.0395
1.50	0.0423

Vegetative Linings:

Manning "n" values vary with hydraulic radius, velocity, as well as roughness. While usually not considered important for moderate size rigid-lined channels, the effect of velocity on Manning "n" values is considered especially significant when related to vegetative linings. Accordingly, curves have been developed to represent the interaction between hydraulic radius, velocity and roughness coefficient as related to various vegetative retardances. (See Plate 5-29 and Table 5-13.)

For grass-lined channels, Mannings "n" value can be determined by the following procedure:

1. Determine the maximum permissible velocity (V) for the grass to be used. (See Table 5-14 and Plate 5-30.)

2. Calculate the hydraulic radius (R) of the channel. (See Plate 5-28.)

3. From Table 5-13, determine the retardance class of the grass to be used. When calculating channel capacity, the highest retardance class of the grass should be used (e.g., long condition). When calculating velocity, the lowest retardance class should be used (e.g., mowed condition).

4. Enter Plate 5-29 with the product of: V x R. Move vertically until the correct retardance curve is intersected. Read "n" on the left axis.

Determination of Maximum Permissible Velocity

Once Mannings "n" has been selected and the average velocity has been determined, the velocity is compared with the maximum permissible velocity for the selected channel lining. If the velocity is less than the permissible velocity, then the channel design is considered to be acceptable with respect to erosion resistance.

When properly constructed, rigid channel linings can resist very high velocities without erosion damage or failure. Therefore, hydraulic capacity is usually the primary design consideration. However, the overall design should include measures to prevent erosion damage to the receiving channel due to excessive discharge velocities. (See Chapter 3 for details on outlet protection.)

For channels with flexible channel linings, selection of the proper channel lining is critical. Both the hydraulic capacity of the channel and its erosion resistance (the maximum permissible velocity) are directly related to the channel lining. Because of the variability of conditions within the watershed, it is good design practice to maintain a safety margin between the maximum permissible velocity of the channel lining and the calculated channel velocity.

Flexible Channel Linings

The method described below is adapted from Hydraulic Engineering Circular No. 15 of the Federal Highway Administration. It is applicable to both straight and curved sections of channel where the flow is parallel to the bank of the channel.

For Straight Sections of Channel:

This design method determines a stable rock size for straight and curved sections of channels. It is assumed that the shape, depth of flow, and slope of channel are known. A stone size is chosen based on the maximum depth of flow. If the sides of the channel are steeper than 3:1, the stone size must be modified accordingly. The final design size will be stable on both the sides and bottom of the channel.

1. Enter Plate 5-31 with the maximum depth of flow (feet) and channel slope (feet/foot). Where the two lines intersect, choose the d_{50} size of stone. (Select the d_{50} for the diagonal line above the point of intersection.)

2. If channel side slopes are steeper than 3:1, continue with step 3; if not, the procedure is complete.

3. Enter Plate 5-32 with the side slope and the base width to maximum depth ratio (B/d). Where the two lines intersect, move horizontally left to read K_1.

4. Determine from Plate 5-33 the angle of repose for the d_{50} size of stone. (Use 42° for d_{50} greater than 1.0 feet ±.) Do not use riprap on slopes steeper than the angle of repose for the size of stone.

5. Enter Plate 5-34 with the side slope of the channel and the angle of repose for the d_{50} size of stone. Where the two lines intersect, move vertically down to read K_2.

6. Compute $d_{50} \times K_1/K_2 = d'_{50}$. to determine the correct size stone for the bottom and side slopes of straight sections of channel.

For Curved Sections of Channel:

1. Compute the radius of the curve (Ro) measured at the outside edge of the bottom.

2. Compute the ratio of the top width of water surface (Bs) to the radius of the curve (Ro), Bs/Ro.

3. Enter Plate 5-35 with the ratio Bs/Ro. Move vertically until the curve is intersected. Move horizontally left to read K_3.

4. Compute $d'_{50} \times K_3 = d_{50c}$ to determine the correct size stone for bottom and side slopes of curved sections of channel.

<u>Other Design Considerations</u>

1. <u>Adjustment for average channel depth</u>. When other conditions are the same, a deep channel can convey water at a higher mean velocity, without erosion, than a shallow one. Thus, a correction for flow depth should be applied to the permissible velocity. Plate 5-30 shows the suggested correction factors.

2. <u>Side Slopes</u>. When riprap-lined channels have side slopes steeper than 3:1 or the channel is curved (or is sinuous), the rock size must be adjusted accordingly. (Follow the procedure outlined in the <u>Flexible Lining Section</u>.) Minimum side slopes for channels excavated in various materials are shown in Table 5-15.

3. <u>Freeboard and Height of Bank</u>. For lined channels (other than vegetative linings), the channel lining should extend above the expected surface water

elevation. The recommended height of the channel lining above the water surface depends on several factors related to the particular watershed under consideration. The channel should be designed to convey a larger (or less frequent) storm event if the 10-year storm design is not adequate to prevent flooding or property damage during these events.

CHANNEL DESIGN PROCEDURE

Rigid Linings

For rigid channel linings, the design procedure is as follows:

Step 1 - Determine the flow into the channel. Perform hydrologic computations for peak Q_{10} and Q_2 flows.

Step 2 - Determine the slope of the existing or proposed channel.

$$\frac{Rise\ (ft.)}{Run\ (ft.)} = Slope\ \frac{feet}{foot}$$

Step 3 - Determine the minimum side slope necessary to maintain channel stability (from Table 5-15 in subsection titled "Other Design Considerations").

Step 4 - Choose a channel shape from Plate 5-28 (e.g., vee, parabolic, or trapezoidal). If vee or trapezoidal configuration, choose the angle of the channel wall side slope.

Step 5 - Select a channel lining, then determine the Mannings "n" value (from subsection titled "Determination of "n" Values for Use in the Mannings Equation").

Step 6 - Choose a desirable design depth.

Step 7 - For the channel slope, geometry and depth of flow, calculate the channel capacity by using a combination of the Mannings/Continuity Equation.

Determine by trial and error that the cross-sectional channel is adequate to carry the peak Q_{10} flow. Compare each calculated cross-sectional area to the area required to provide adequate Q_{10} capacity.

$$\frac{Q_{10}\ n}{1.49\ s^{1/2}} = A\ R^{2/3}$$

Note: At a minimum, man-made channels must convey the flow from the 10-year frequency storm without overtopping its banks. If the channel capacity is less than the peak 10-year runoff flow, increase the width and/or depth, and recheck the capacity. Repeat until the channel capacity is adequate.

Step 8 - Check to ensure that recommended freeboard, if necessary, exists above Q_{10} water surface elevation. Make channel adjustment as necessary.

Step 9 - Using the 2-year frequency storm velocity, verify that the designed channel will not erode.

$$V_2 = \frac{Q_2}{A_2}$$

(A_2 is also determined by trial and error.)

Also, if outlet velocity exceeds the maximum permissible velocity of the receiving stream, outlet protection must be used in accordance with Chapter 3, Section 3.18.

Flexible Linings

The following procedure can be used for the design of flexible channel linings:

Step 1 - Determine the flow into the channel. Perform hydrologic computations for the peak Q_{10} and Q_2 flows.

Step 2 - Determine the slope of the existing or proposed channel:

$$\frac{Rise\ (ft.)}{Run\ (ft.)} = Slope\ \frac{feet}{foot}$$

Step 3 - Determine the minimum side slope necessary to maintain channel stability from Table 5-15 in subsection titled "Other Design Considerations."

Step 4 - Choose a channel shape from Plate 5-28 (e.g., vee, parabolic or trapezoidal).

Step 5 - Select a channel lining and determine maximum permissible velocity of the lining.

Step 6 - Make an initial estimate of the cross-sectional area that is required to carry the Q_{10} flow by using the Continuity Equation:

$$A = \frac{Q}{V}$$

where,

Q	=	flow into channel
V	=	M.P.V. of lining selected in Step 5.

Step 7 - Select initial channel dimensions that will provide the cross-sectional area estimated in Step 6.

Step 8 - Calculate Hydraulic Radius (R) of the channel from the formulas listed on Plate 5-28.

Step 9 - Multiply the maximum permissible velocity (of the selected lining) by the hydraulic radius.

Step 10 - Determine the roughness coefficient "n" for the lining to be used (from the subsection titled "Determination of "n" Values for Use in Mannings Equation").

<u>Note</u>: If a vegetated lining is used, assume a retardance (from Table 5-13) for an unmowed or uncut condition to calculate capacity and retardance for a mowed or cut condition to check velocity.

Step 11 - Check Q_{10} capacity using the combined equations: Manning/ Continuity.

$$Q = \frac{1.49}{n} R^{2/3} S^{1/2} A$$

where,

A	=	cross-sectional area required to carry Q_{10} flow (from Step 6).

Step 12 - Check velocity (for the 2-year storm) by using the Manning Equation: (Use the hydraulic radius for the flow depth of the 2-year storm.)

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

Compare velocity to maximum permissible velocity of the selected channel lining.

Step 13 - If capacity is adequate and the velocity does not exceed the maximum permissible velocity, proceed to Step 14. If capacity or lining is not adequate, make the appropriate design modifications and repeat the procedure.

Step 14 - Check to ensure the recommended freeboard, if necessary, exists above Q_{10} water surface elevation. Make channel adjustments as necessary.

Note: The solution to the following problems are provided for illustrative purposes. There may be numerous designs which would solve these problems.)

Example 5-10: Rigid linings

Given: Peak Q_{10} flow = 255 cfs. Peak Q_2 flow = 200 cfs. Slope of the proposed channel = 1% or .01 ft./ft.

Find: An adequate channel design to convey the 10-year storm flow.

Solution:

Step 1 - Choose channel shape from Plate 5-28. Trapezoidal configuration with 2:1 side slopes was selected.

Step 2 - Select a channel lining and determine "n" value. Concrete ("n" = .014) was selected.

Step 3 - Determine depth of flow. Use 1.5 depth.

Step 4 - Using the Manning/Continuity Equation, determine by trial and error the bottom width (B) required to convey the Q_{10} flow.

$$\frac{Qn}{1.49\ S^{1/2}} = AR^{2/3}$$

where,

Q = 255 cfs
n = 0.014 (Float Finish Concrete)
S = 0.010 ft./ft.
A = $Bd + Zd^2 = B(1.5) + 2(1.5)^2 = 1.5B + 4.5$ (formula from Plate 5-28 for determining cross-sectional area of trapezoidal section).
R = A/P
P = $B + 2(Z^2 + 1)^{1/2}$ (d)
= $B + 2(2^2 + 1)^{1/2}$ (1.5)
= B + 6.7

$$\frac{Qn}{1.49\ S^{1/2}} = \frac{255\ (.014)}{1.49\ (.010)^{1/2}} = 24.0$$

Trial	B	$A = 1.5B + 4.5$	$P = B + 6.7$	$R = A/P$	$R^{2/3}$	$AR^{2/3}$
1	11	21	17.7	1.19	1.12	$23.5 < 24.0$ cross-section insufficient
2	12	22.5	18.7	1.20	1.13	$25.4 > 24.0$ cross-section too large
3	11.5	21.75	18.2	1.20	1.13	$24.5 \approx 24.0$ cross-section adequate

Therefore, a trapezoidal channel with an 11.5 ft. bottom width and 2:1 side slope will be adequate to convey 255 cfs with a depth of 1.5 ft. No check for erosion resistance capability is necessary, since rigid channel linings are not subject to scour at velocities up to about 20 feet per second.

Step 5 - Check velocity in the channel. Note that it is rather high ($A_2 = 18.2$; $V = Q_2/A_2 = 200/18.2 = 11.0$ fps.) and that a scour-control device will probably be necessary to re-adjust the flow at the downstream end of the proposed channel.

<u>Example 5-11: Flexible Lining</u>

Given: A trapezoidal channel: 3-feet deep, 8-feet bottom, 2:1 side slopes, and a 2% slope.

Find: Riprap size for the bottom and side slopes of channel.

Solution:

Step 1 - From Plate 5-31, for a 3-foot deep channel on a 2% grade, $d_{50} = 0.75$ feet or 9 inches.

Step 2 - Since the side slopes are steeper than 3:1, continue with Step 3.

Step 3 - From Plate 5-32, $B/d = 8/3 = 2.67$; $Z = 2$; $K_1 = 0.82$.

Step 4 - From Plate 5-33, for $d_{50} = 9$ inches, $o = 41°$.

Step 5 - From Plate 5-34, for Z = 2 and o = 41°, K_2 = 0.73.

Step 6 - $d_{50} \times K_1/K_2 = d'_{50} = 0.75 \times 0.82/0.73 = .84$ feet.

$$0.84\ ft.\ x\ \frac{12\ inches}{1\ foot} = 10.08 \quad (Use\ d_{50} = 10\ inches.)$$

Given: The preceding channel has a curved section with a radius of 50 feet.

Find: A stable riprap size for the bottom and side slopes of the curved section of channel.

Solution:

Step 1 - Ro = 50 feet

Step 2 - Bs/Ro = 20/50 = 0.40.

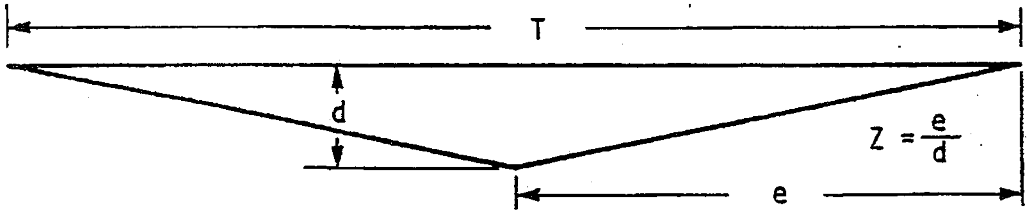
Step 3 - From Plate 5-35, for Bs/Ro = 0.40, K_3 = 1.1.

Step 4 - $d'_{50} \times K_3 = d_{50c} = 0.84 \times 1.1 = 0.92$ ft.

$$0.92\ ft.\ x\ \frac{12\ inches}{1\ foot} = 11.0\ inches$$

CHANNEL GEOMETRY

V - Shape

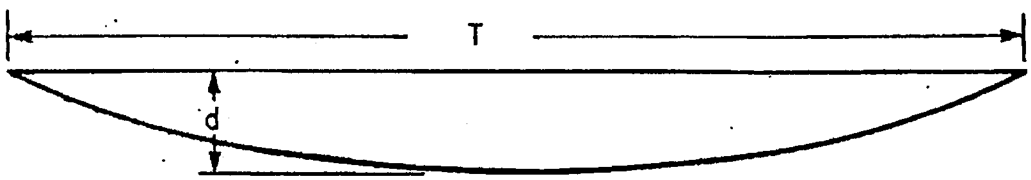


Cross-Sectional Area (A) = Zd^2

Top Width (T) = 2dZ

Hydraulic Radius (R) = $\dfrac{Zd}{2\sqrt{Z^2 + 1}}$

Parabolic Shape

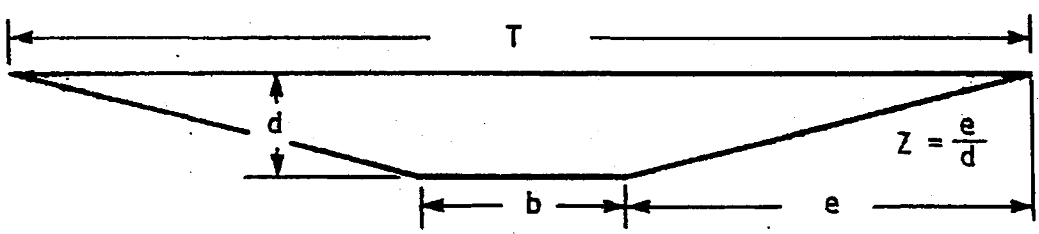


Cross-Sectional Area (A) = $\frac{2}{3}$ Td

Top Width (T) = $\dfrac{1.5\ A}{d}$

Hydraulic Radius = $\dfrac{T^2 d}{1.5T^2 + 4d^2}$

Trapezoidal Shape



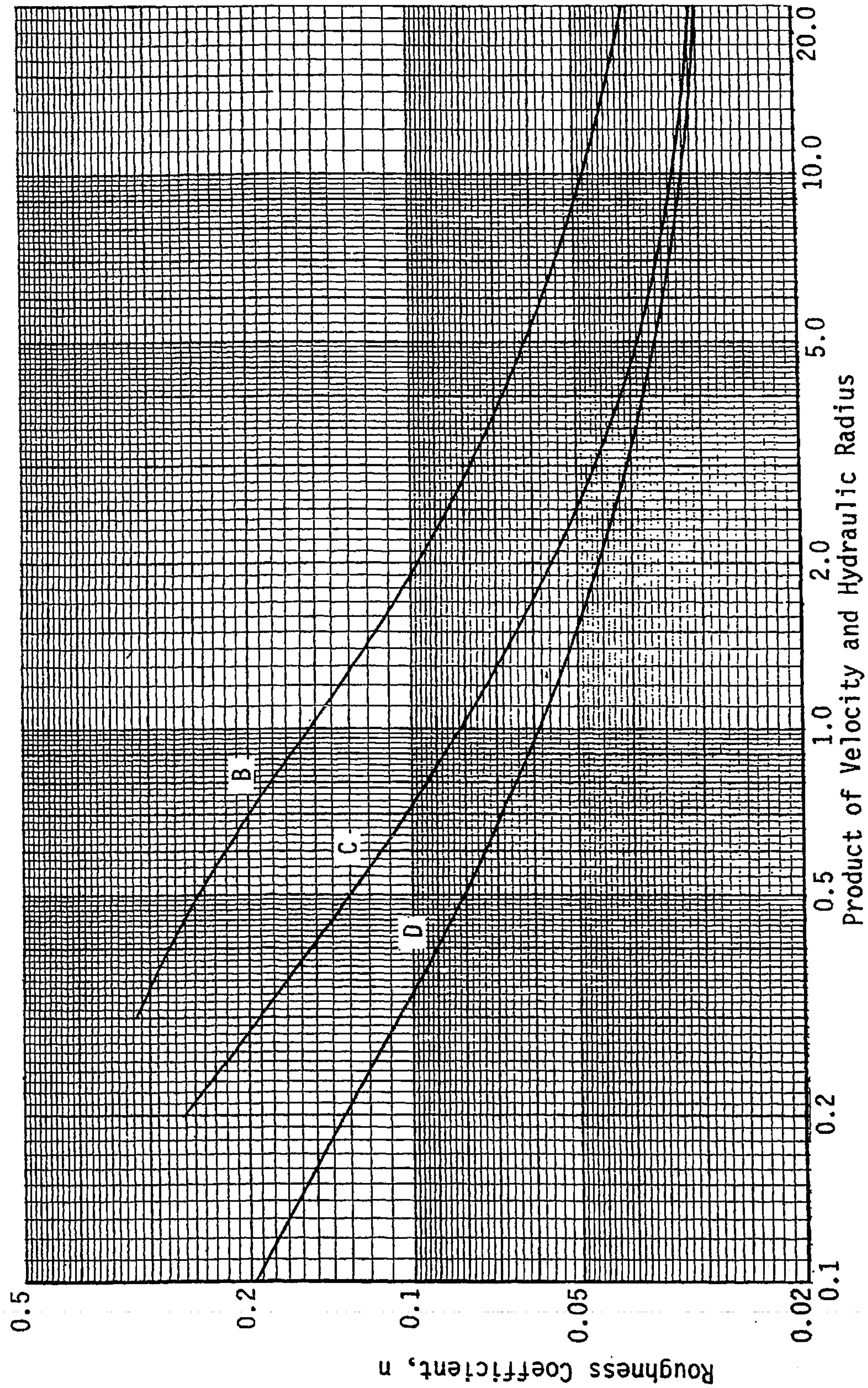
Cross-Sectional Area (A) = $bd + Zd^2$

Top Width (T) = b + 2dZ

Hydraulic Radius = $\dfrac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}}$

Source: USDA-SCS

Plate 5-28



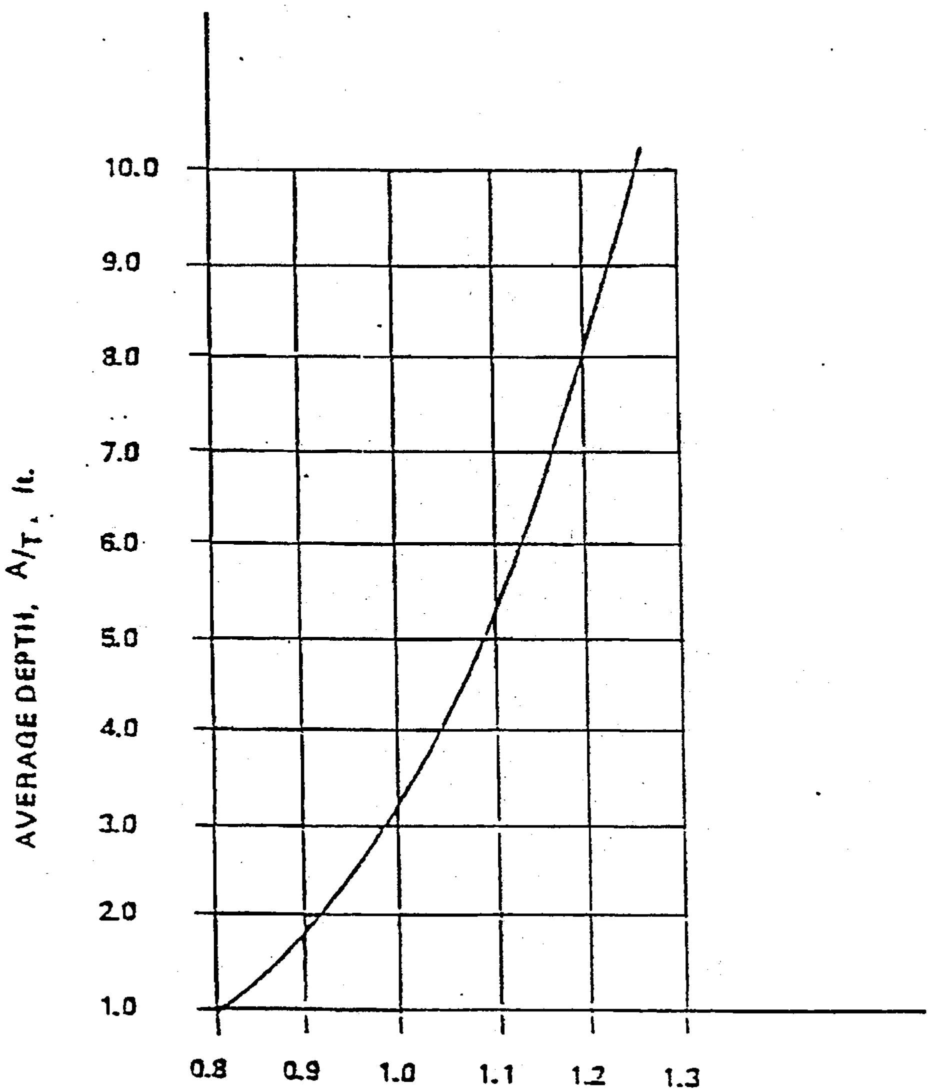
ROUGHNESS COEFFICIENT AS A FUNCTION OF v x R FOR VARIOUS RETARDANCE CLASSES

Source: USDA-SCS

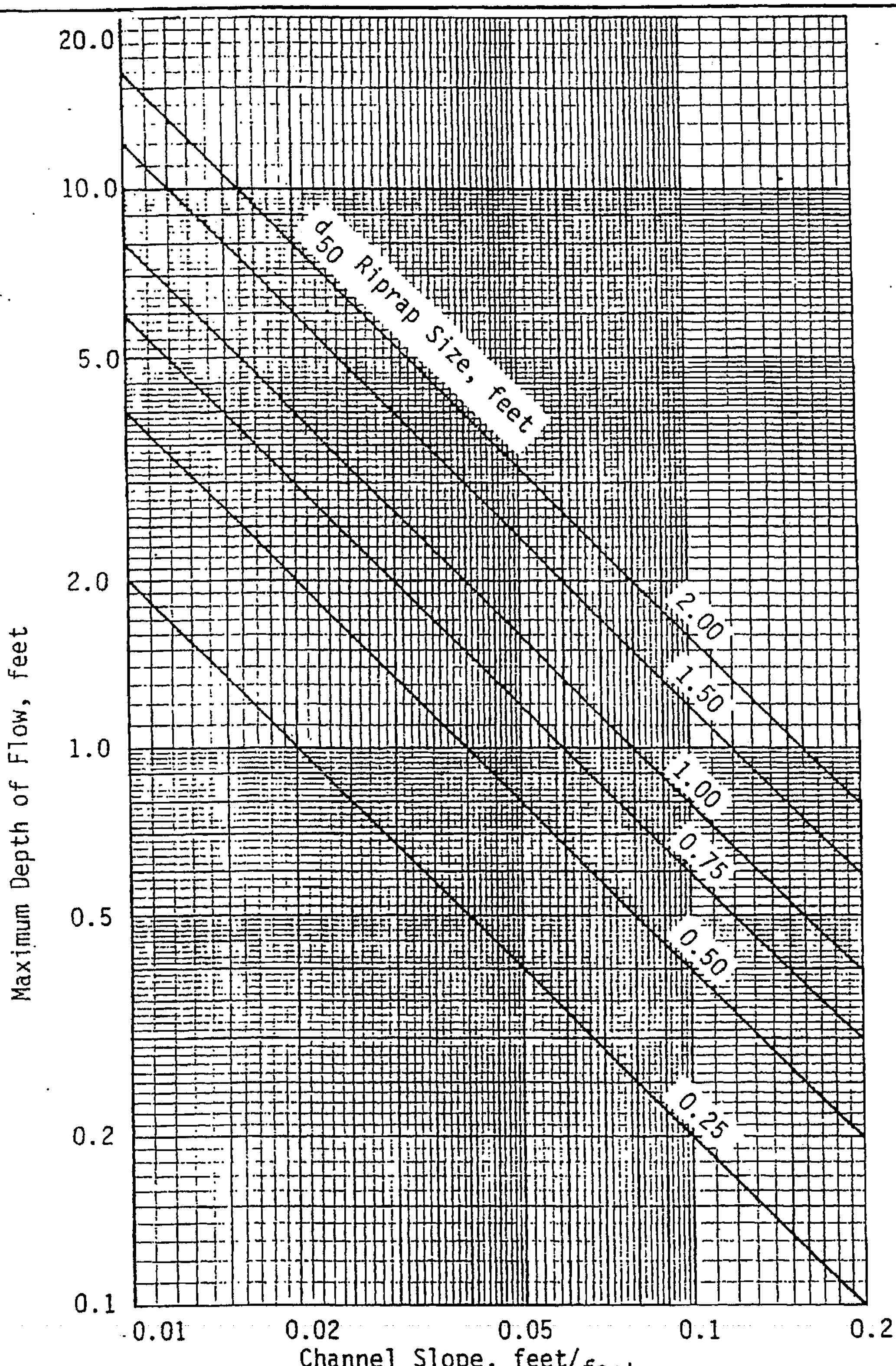
Plate 5-29

PLATE 5-30

CORRECTION FACTORS BASED FOR PERMISSIBLE VELOCITY BASED ON AVERAGE DEPTH OF FLOW



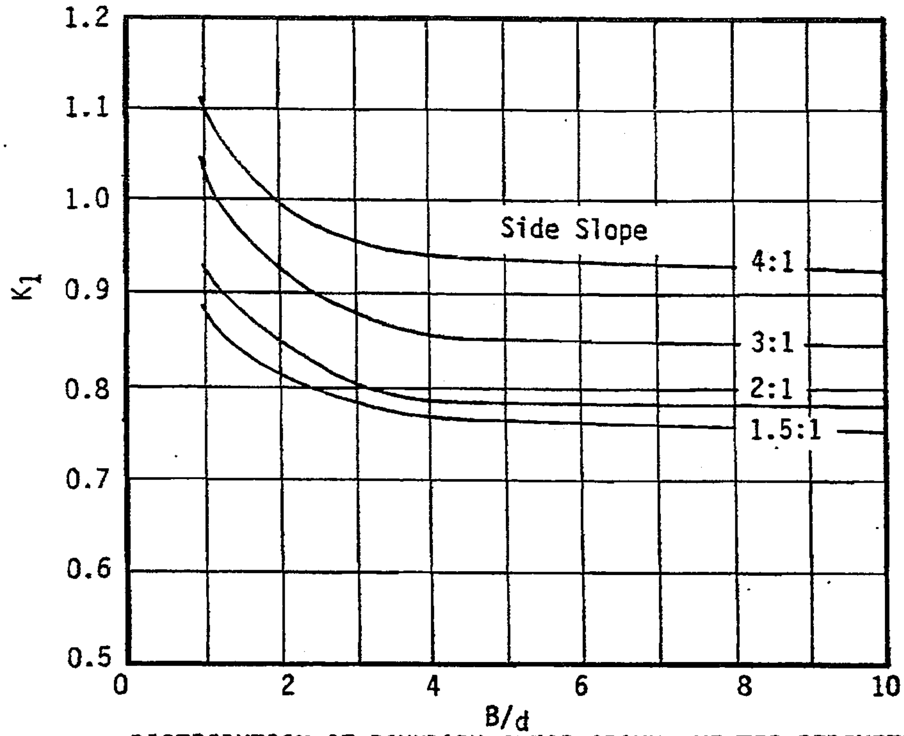
Source: Va. DSWC



MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

Source: VDOT Drainage Manual

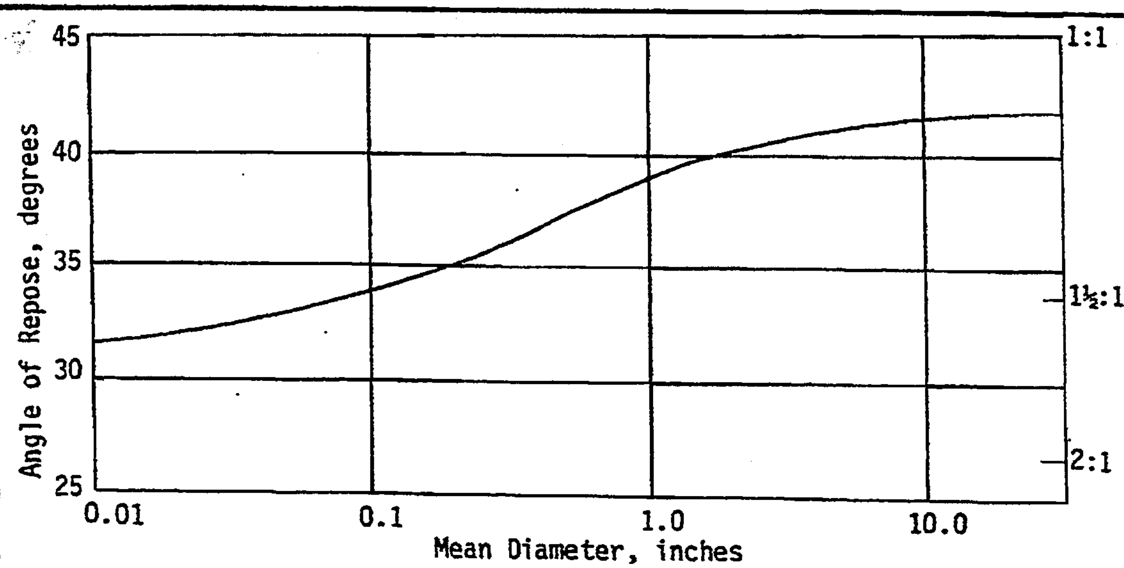
Plate 5-31



DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPEZOIDAL CHANNEL

Source: VDOT Drainage Manual

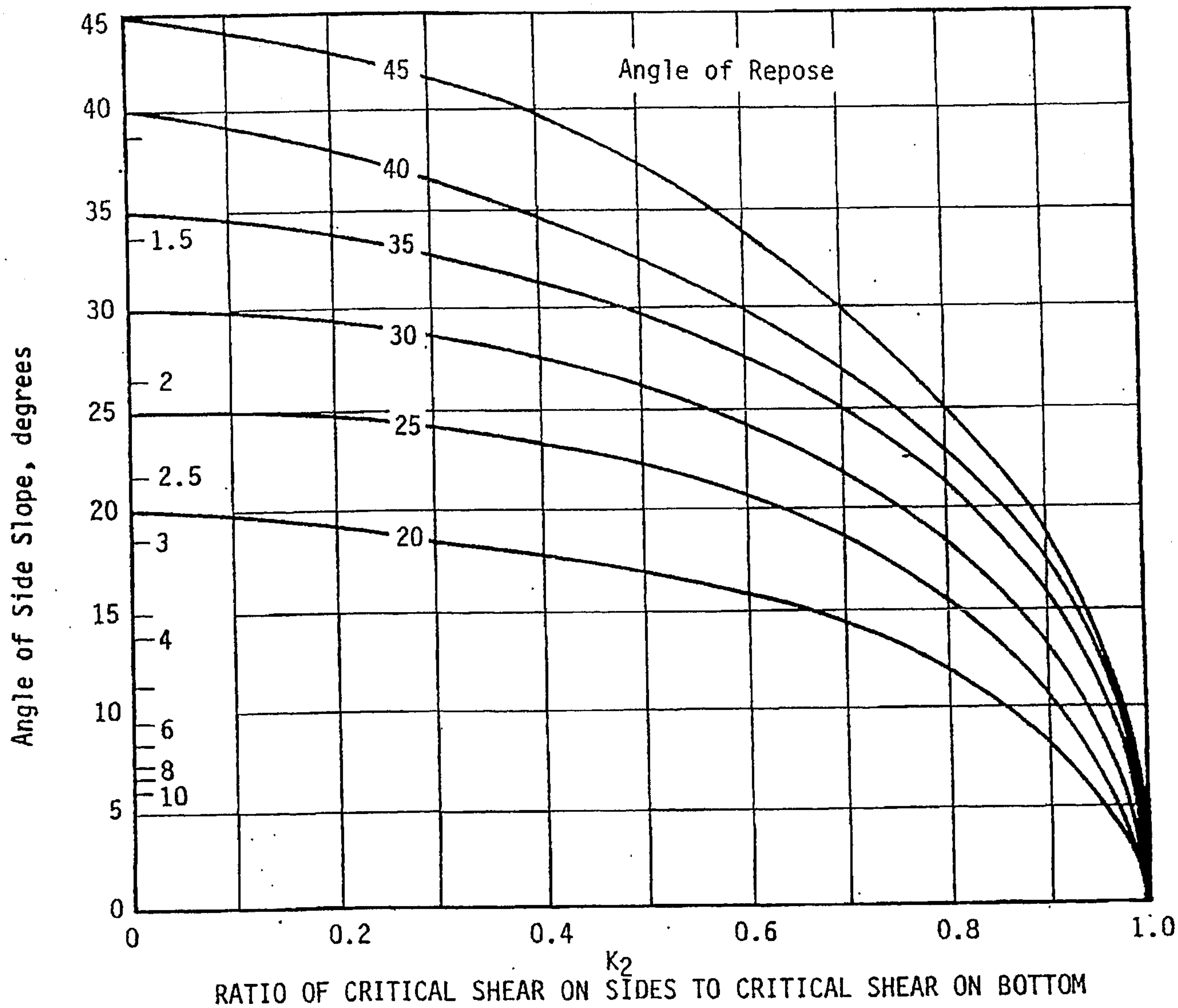
Plate 5-32



ANGLE OF REPOSE FOR RIPRAP STONES

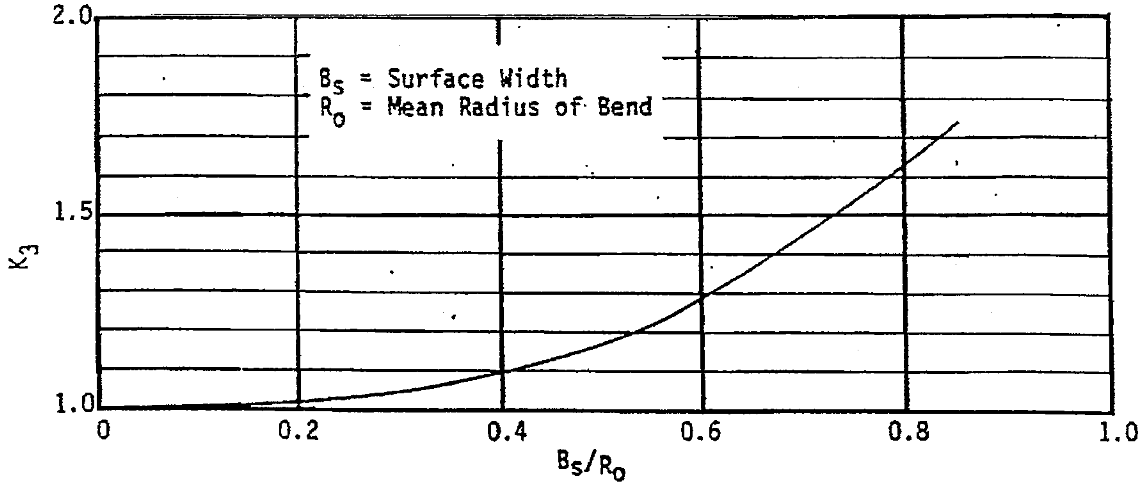
Source: VDOT Drainage Manual

Plate 5-33



Source: VDOT Drainage Manual

Plate 5-34



RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACHES

Source: VDOT Drainage Manual

Plate 5-35

TABLE 5-12

MANNING "n" VALUES FOR SELECTED CHANNEL LINING MATERIALS

Material	Range of "n" Values
Concrete	
- Formed	0.013 - 0.017
- Trowel Finish	0.012 - 0.014
- Float Finish	0.013 - 0.015
- Gunite	0.016 - 0.022
Gravel Bed, Formed Concrete Sides	0.017 - 0.020
Asphalt Concrete	
- Smooth	0.013
- Rough	0.016
Corrugated Metal	
- 2-2/3" x 1/2" Corrugations	0.024
- 6" x 2" Corrugations	0.032
Concrete Pipe	0.011 - 0.013

Source: Va. DSWC

TABLE 5-13

RETARDANCE CLASSIFICATIONS
FOR VEGETATIVE CHANNEL LININGS

Retardance		Stand	Condition
B	Tall fescue	Good	Unmowed - 18"
	Sericea lespedeza	Good	Unmowed - 18"
	Grass-legume mixture	Good	Unmowed - 20"
	Small grains, mature	Good	Uncut - 19"
	Bermudagrass	Good	Tall - 12"
	Reed Canarygrass	Good	Mowed - 14"
C	Bermudagrass	Good	Mowed - 6"
	Redtop	Good	Headed - 18"
	Grass-legume mix., summer	Good	Unmowed - 7"
	Kentucky bluegrass	Good	Headed - 9"
	Small grains, mature	Poor	Uncut - 19"
	Tall fescue	Good	Mowed - 6"
D	Bermudagrass	Good	Mowed - 2.5"
	Red fescue	Good	Headed - 15"
	Grass-legume mixture, spring and fall	Good	Unmowed - 5"
	Sericea lespedeza	Good	Mowed - 2"

Source: USDA-SCS

TABLE 5-14

PERMISSIBLE VELOCITIES FOR GRASS-LINED CHANNELS

Channel Slope	Lining	Velocity* (ft./sec.)
0 - 5%	Bermudagrass	6
	Reed canarygrass Tall fescue Kentucky bluegrass	5
	Grass-legume mixture	4
	Red fescue Redtop Sericea lespedeza Annual lespedeza Small grains Temporary vegetation	2.5
5 - 10%	Bermudagrass	5
	Reed canarygrass Tall fescue Kentucky bluegrass	4
	Grass-legume mixture	3
Greater than 10%	Bermudagrass	4
	Reed canarygrass Tall fescue Kentucky bluegrass	3

* For highly erodible soils, decrease permissible velocities by 25%.

Source: Soil and Water Conservation Engineering, Schwab, et. al. and American Society of Civil Engineers.

TABLE 5-15

MINIMUM SIDE SLOPES FOR CHANNELS EXCAVATED IN VARIOUS MATERIALS

Material	Side Slope
Rock	Nearly vertical
Earth w/stone riprap lining	2:1
Firm clay or earth w/vegetative lining	2:1
Loose sandy earth, sandy loam or porous clay w/vegetative lining	3:1
Earth w/concrete lining extending to top of channel banks	1½:1

DETERMINATION OF AN "ADEQUATE CHANNEL"

The Virginia Erosion and Sediment Control Regulations (Minimum Standard #19) require that runoff from new development must be discharged into an "adequate channel." An adequate channel is defined as a watercourse that will convey a chosen frequency storm event without overtopping its banks or causing erosive damage to the bed, banks and overbanks sections of the channel.

Determination of flow capacity and velocity in a natural channel involves considerable judgement. The results cannot be determined with as great a certainty as for a man-made channel. Variations in cross-section, alignment and roughness in the channel, and the changing quantities of flowing water make the determination of capacity and velocity an approximation, at best.

The following procedure involves the use of the Manning's Equation, the Continuity Equation and the Maximum Permissible Velocity method of calculation. The procedure is not exact and will yield only capacity and velocity estimates for each channel reach without regard to backwater effects due to channel constrictions such as culverts or bridges. If the purpose of the channel investigation is to determine a flood plain or profile, a more sophisticated analysis should be undertaken. However, to determine channel capacity and stability, which is the primary objective here, this procedure will be considered adequate.

Survey of the Stream Channel

A survey must first be made of each channel segment (called a reach) to determine the relevant channel characteristics (e.g., slope, cross section, roughness, etc.). This data is then utilized in a design procedure to check the adequacy of the stream channel. Following are recommended elements of such a survey:

Survey Procedure

1. Develop a profile of the channel bottom along the centerline of the stream. Such a profile can be developed from a good topographic map, if available, or from a field level run, if necessary.

2. Control points should be selected along the centerline to define independent stream channel reaches to be tested. Good control points would include points of entry of major tributaries, points of significant change in grade or cross-section, or bridges or culverts which obstruct the design flow.

3. Obtain sufficient cross-sections, at right angles to the centerline in each reach, to determine the average channel cross-section. This portion of the survey should be done in the field, not from a map.

4. Note the relevant physical characteristics of the stream channel between control

points (including significance of meanders, the material comprising the channel bed and banks, vegetation, obstructions and other factors needed to determine a roughness coefficient "n"). This information must also be obtained in the field.

Note that an "n" factor for each stream channel reach must be determined. If the channel is man-made, "n" can be determined by one of the methods described in the section for design of constructed stormwater conveyance channels. If the channel is natural, the following procedure should be used.

This procedure assumes that "n" is influenced by several factors. Each of these factors should be evaluated independently without regard to each other. The roughness coefficient "n" can be computed as follows:

A. Selection of a basic "n" value, (n_1): Select a basic "n" value from Table 5-16 for a straight, uniform, smooth channel cut into the natural material involved. The channel of each reach should be visualized as straight and uniform in cross-section, with smooth sides and bottom, and cut into the natural material of the channel.

B. Selection of modifying values for surface irregularity, (n_2): Select a modifying value from Table 5-17. Consider surface irregularity, first, in relation to the degree of smoothness attainable in the natural materials involved and, second, in relation to the depths of flow under consideration. A value of zero would correspond to the best surface attainable in the materials involved.

C. Selection of modifying values for variations in the and shape of cross-section, (n_3): Select the modifying value from Table 5-18. The effect of changes in size may be best visualized by considering, primarily, the frequency with which large and small sections alternate and, secondarily, on the magnitude of the changes. Shape variations depend upon the degree to which the changes cause the greatest depth of flow to shift from one side of the channel to the other in the shortest distance.

D. Selection of modifying values for obstructions, (n_4): (Select modifying values from Table 5-19). Care should be taken not to re-evaluate effects already considered in Steps B and C (above). The obstruction should be judged by:

   1. The degree to which the obstructions occupy or reduce the average cross-sectional area.

   2. The character of the obstructions. (Sharp-edged or angular objects induce greater turbulence than curved, smooth-surfaced objects.)

   3. The position and spacing of obstructions laterally and longitudinally in the reach under consideration.

E. Selection of modifying values for vegetation, (n_5): (Select modifying values from

Table 5-20). The retarding effect of vegetation should be judged by the following criteria:

1. Height in relation to depth of flow.
2. Capacity to resist bending.
3. The degree to which the cross-section is occupied or blocked out.
4. The lateral and longitudinal distribution of different types of vegetation.
5. The density and height of vegetation in the reach considered.

F. Selection of a modifying value for the degree meandering, (n_6): Select the appropriate value from Table 5-21. Calculate the ratio of meandering length to straight length in the reach considered.

G. Sum the values found in Steps A-E. Multiply the sum by the value found in Step F. Add this to the sum of Steps A-E to compute the composite "n" for the reach.

$$n = (n_1 + n_2 + n_3 + n_4 + n_5) \quad x \quad (n_6) + (n_1 + n_2 + n_3 + n_4 + n_5)$$

Design Procedure

After the channel has been divided into reaches, the following procedure may be used to determine adequacy. The procedure should be applied to each reach, beginning at the outlet of the development site, and progressing downstream until the total drainage area is at least 100 times greater than the area of the development site under consideration. (See Chapter 8 for a discussion of Minimum Standard #19.)

Step 1 - Determine the peak runoff rate for the stream channel using the 2-year storm. Calculate runoff from the entire contributing drainage area (including the proposed development site) at the bottom end (outlet) of the reach. (See Part 1 of this chapter for appropriate method(s) of calculating peak runoff rates.)

Step 2 - Determine the average bankfull cross-sectional area, hydraulic radius, slope and permissible velocity in the channel reach. (See survey procedure, Steps 1 through 3, for determining slope and average cross-section.)

Use Plate 5-16 for calculation of cross-sectional area and hydraulic radius.

The permissible velocity in natural channels should be determined for the most erodible condition along the reach, (e.g., exposed soil). Table 5-22 gives permissible velocities for channels cut into different types of soil.

Use Table 5-23 to determine if a reduction in permissible velocity is required due to channel sinuosity.

Note: Even though a channel may be fairly straight, it is recommended to assume slight sinuosity and use a 5% reduction in the permissible velocity.

Plate 5-39 is used to determine adjustment in permissible velocity based on average depth of flow.

Step 3 - Determine the roughness coefficient (n) for the reach. (See Survey Procedure, Step 4.)

Step 4 - Calculate bankfull velocity (V) and capacity (Q) using the Manning and Continuity Equations. These equations are explained in the section "Constructed Stormwater Conveyance Channels."

Step 5 - Compare actual channel capacity (Q) with the peak rate of runoff (from Step 1); and compare the actual flow velocity (V) with the permissible velocity (from Step 2). If the capacity of the channel is greater than the peak runoff rate from a 2-year storm, the velocity (V) should be computed using the actual depth of the 2-year storm flow.

If the existing channel is adequate with respect to both capacity and erosion resistance, the channel can be considered adequate to convey the increased discharge. If not, on-site measures and/or channel improvements must be incorporated into the site design.

Stream Channel Improvements (Modifications)

A. Design/Construction Requirements

1. If channel improvements are to be used, then MS #19 requires that:

    (a) the channel be capable of containing the 10-year frequency design storm within its banks; and

    (b) a 2-year frequency storm will not cause erosion to the channel bed or bank.

2. Improvement of the channel shall continue downstream until channel adequacy can be demonstrated, or to the point where the total drainage area above the improved channel section is 100 times greater than the contributing drainage area of the project-area watershed.

3. Prior written permission of all property owners is required prior to

constructing any channel improvements or modifications.

4. Evidence of approval from all applicable regulatory agencies to undertake channel improvements is required. Approval may require the acquisition of permits to complete the proposed work.

B. <u>Channel Modification (Practices and Restrictions)</u>

VEGETATIVE STREAMBANK STABILIZATION (Std. & Spec. 3.22) and/or STRUCTURAL STREAMBANK STABILIZATION (Std. & Spec. 3.23) may be used to reduce or eliminate erosion potential. Stable rock sizes for riprap linings can be determined from procedures outlined in the section titled "Designing a Stormwater Conveyance Channel."

[Refer to the previous sections (Part III, Open Channel Flow) for techniques that could be utilized in the improvement of natural stream channels.]

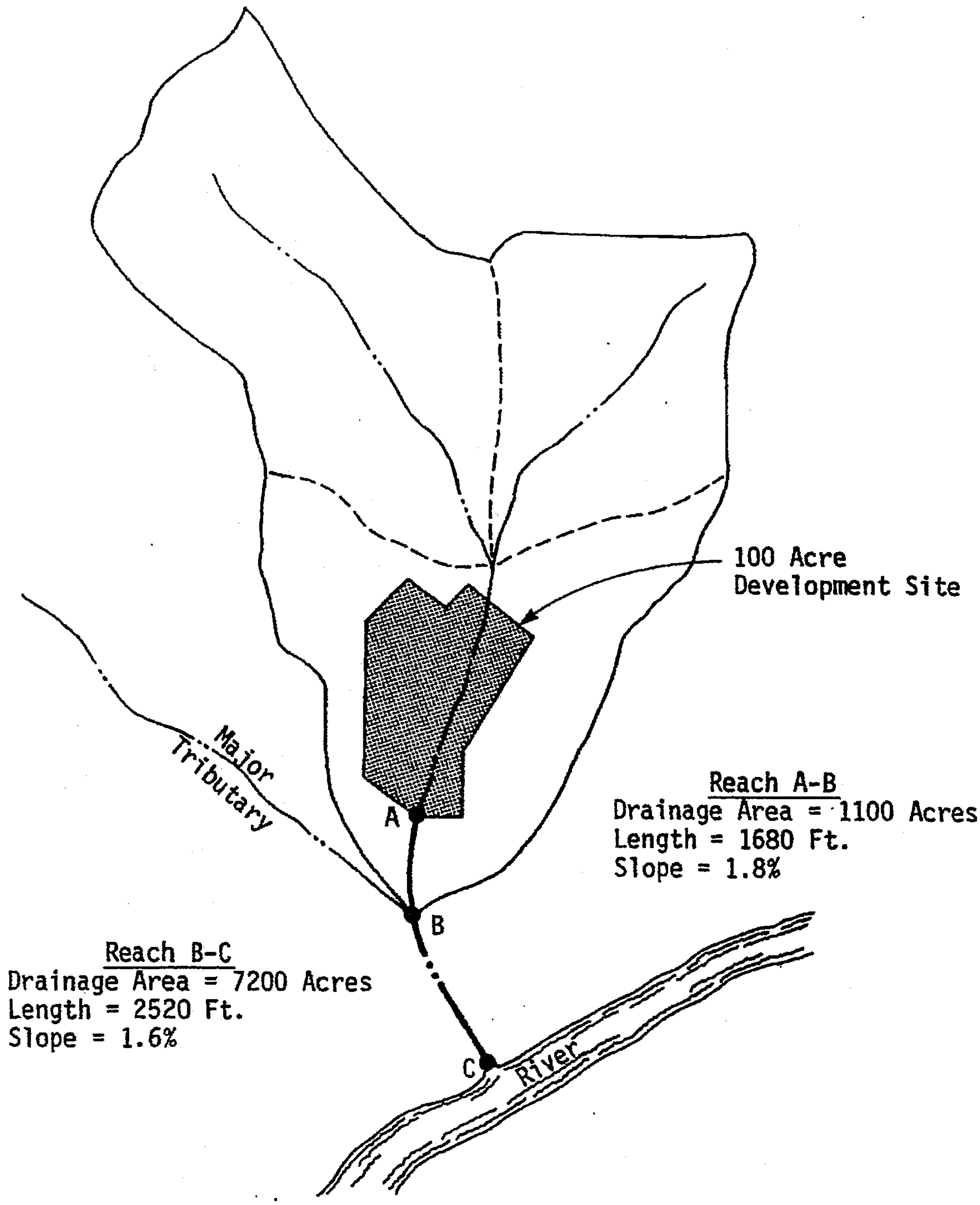
Channel modification should be undertaken only when necessary. Poorly planned and designed modifications can have an adverse impact on:

1. Aesthetics
2. Water quality
3. Aquatic life
4. Terrestrial life
5. Recreation
6. Groundwater

When a channel modification must be performed, care should be taken to attempt to duplicate the natural stream characteristics. Otherwise, the result may be unsightly, a constant source of maintenance problems, and an ecological disaster.

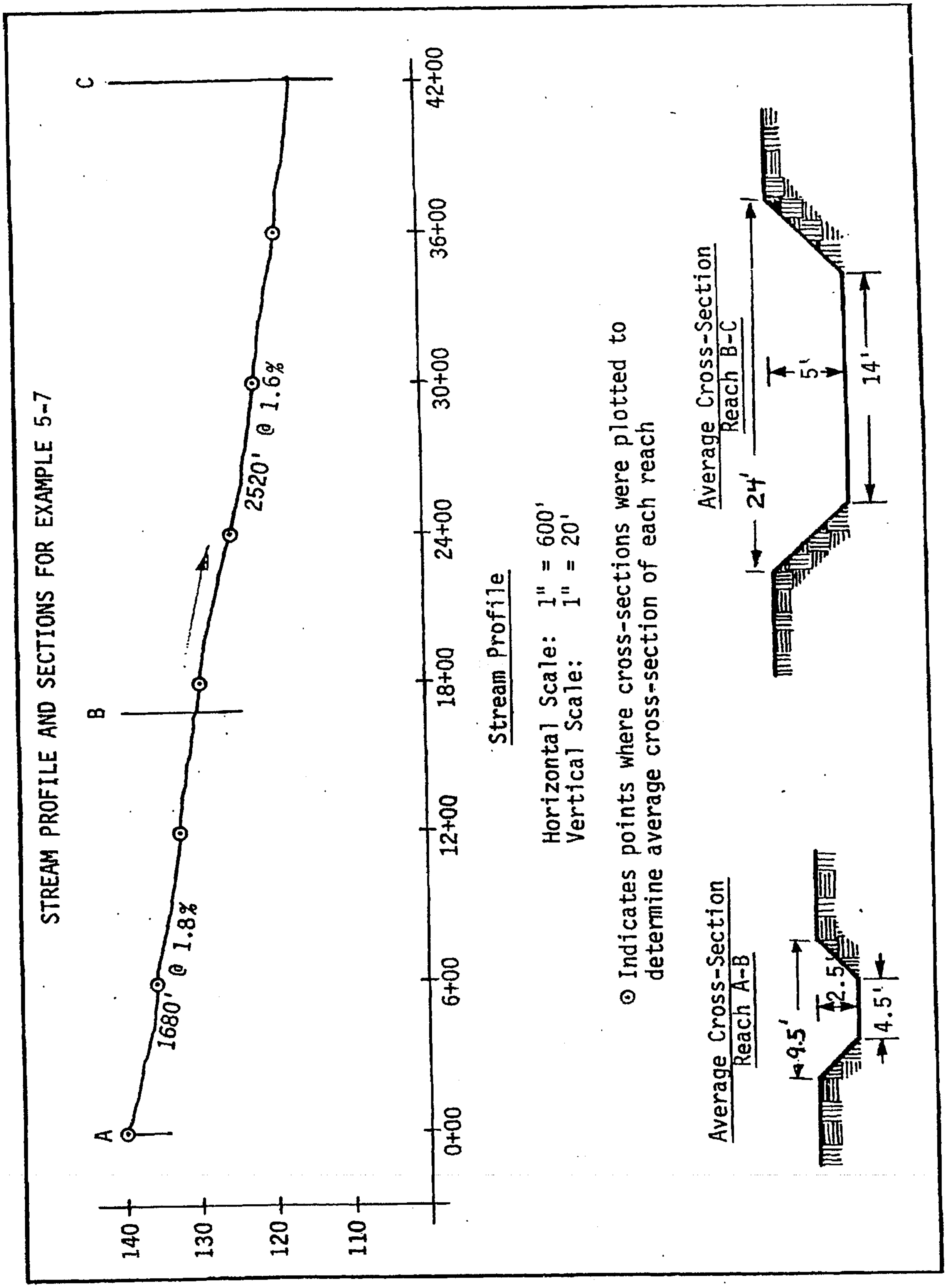
Example 5-12

A 100-acre shopping mall is to be constructed in a watershed as shown on Plate 5-36. The developer wants to analyze the existing stream channels before incorporating on-site runoff measures into the development plan. The following information represents the procedure and conclusion of the channel analysis.



Source: Va DSWC

Plate 5-36



Source: Va DSWC

Plate 5-37

The natural stream channel receiving runoff from the site has been divided into two reaches. Reach A-B extends from the outlet of the development (point A) to the confluence of a major tributary (point B). Reach B-C extends from point B to the confluence with a river (point C). The analysis ends at the river since the drainage area of the river is at least 100 times greater than the drainage area of the development site.

A field survey and watershed analysis provides the following information about each channel reach.

Reach A-B

1. Peak runoff (2-year storm) at point B:

   Pre-development = 95 cfs; Post-development = 170 cfs

2. Channel length = 1680 ft.

3. Channel slope = 1.8%

4. An average channel cross-section is approximated by a trapezoidal section with a 4.5-ft. bottom width, 2.5 ft. depth; and 1:1 side slopes. (See Plate 5-37.)

5. The channel is described as having a fine gravel bed with stiff clay banks; a fairly constant cross-section; few obstructions; very little vegetation in the channel; and slight meandering.

Reach B-C

1. Peak runoff (2-year storm) at point C:

   Pre-development = 500 cfs; Post-development = 585 cfs

2. Channel length = 2520 ft.

3. Channel slope = 1.6%.

4. An average channel cross-section is approximated by a trapezoidal section with a 14-ft. bottom width; 5 ft. depth; and 1:1 side slopes. (See Plate 5-37.)

5. The basic channel roughness characteristics are the same as Reach A-B except there is moderate meandering (e.g., the ratio of meandering length to straight length equals 1.3:1).

The information from the stream channel survey (above) is analyzed and presented in the following steps. Note that the post-development peak discharge rate is used since the purpose of this analysis is to determine whether or not the existing stream channel is adequate to convey the increased runoff from the proposed development. The 2-year storm is used in the analysis because the receiving channel is a natural stream presumedly with an established floodplain. [If the receiving stream channel were a man-made channel, the E&S Regulations (MS-19) would require an analysis using the 2-year storm for erosion resistance and the 10-year storm for capacity.]

Test Reach A-B for Adequacy

Step 1 - Required Q = 170 cfs

Step 2 -
a. $A = 17.5 \text{ ft.}^2$
b. Slope = 1.8%
c. R = 1.53 (Plate 5-38)
d. Permissible Velocity (V) = 5 ft./sec. (Table 5-22)
e. Adjusted Permissible Velocity (V) = 4.3 ft./sec. (Table 5-23 & Plate 5-39).

Step 3 - From the procedure for determining "n" for a natural channel:

a. The channel is cut into fine gravel, $n_1 = 0.024$
b. Moderate surface irregularities, $n_2 = 0.010$
c. Changes in cross-section gradual, $n_3 = 0.0$
d. Obstructions have minor effect, $n_4 = 0.012$
e. Very little vegetation in channel, $n_5 = 0.0$
f. Meandering minor, $n_6 = 0$

$$n = (0.024 + 0.010 + 0.012) = 0.046$$

Step 4 - Calculate (V) and (Q).

$$V = \frac{1.49}{0.046} (1.53)^{2/3} (.018)^{1/2} = 5.77 \, ft./sec.$$

$$Q = VA \doteq (5.77)(17.5) = 101 \, cfs$$

Step 5 - The channel reach is <u>inadequate</u> since the permissible velocity is exceeded (5.77 > 4.3 ft./sec.) and the capacity is insufficient (170 > 101 cfs).

Test Reach B-C for Adequacy

Step 1 - Required Q = 585 cfs

Step 2 -
a. A = 95 $ft.^2$
b. Slope = 1.6%
c. R = 3.38 (Plate 5-38)
d. Permissible Velocity (V) = 5 ft./sec. (Table 5-27)
e. Adjusted Permissible Velocity (V) = 4.6 ft./sec. (Table 5-28 & Plate 5-39)

Step 3 -
n_1 = 0.024
n_2 = 0.010
n_3 = 0.0 } same as Reach B-C
n_4 = 0.012
n_5 = 0.0
n_6 = 0.15

$$n = (0.024 + 0.010 + 0.012)\ (0.15) + (0.024 + 0.010 + 0.012) = 0.053$$

Step 4 - Calculate (V) and (Q)

$$V = \frac{1.49}{.053}\ (3.38)^{2/3}\ (.016)^{1/2} = 8.04\ ft./sec.$$

$$Q = 763.8$$

Step 5 - The capacity of the channel is adequate (763.8 > 585 cfs). However, the velocity should be re-tested using a depth which represents the flow from the 2-year storm.

Try 3.5 ft. depth

New R = 2.56 $ft.^2$

New A = 61.25 ft.

$$V = \frac{1.49}{.053}\ (2.56)^{2/3}\ (.016)^{1/2} = 6.67\ ft./sec. \quad \text{(still too high)}$$

Q = 6.67 ft./sec. x 61.25 $ft.^2$

Q = 408 cfs (too low)

Therefore, the channel is <u>not</u> adequate from a velocity standpoint (6.67 > 5 ft./sec.). Note that choosing the correct (or actual) depth is a trial and error process. The 2-year flow depth would yield a discharge (Q) equal to the 2-year discharge. For this example, additional trials are not necessary since the actual velocity would be within the range of velocities in trials above, and, subsequently, would exceed the allowable velocity.

Conclusion

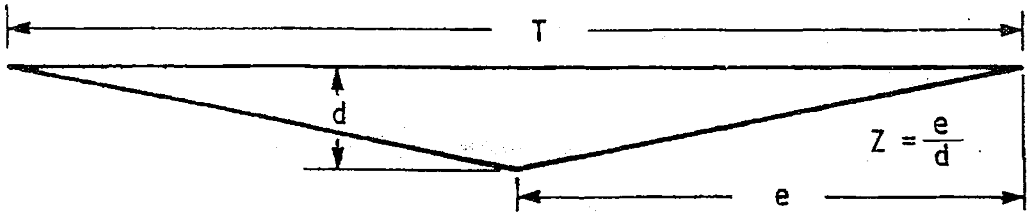
Reach A-B is inadequate for both capacity and velocity; Reach B-C is inadequate for velocity only. Therefore, the developer may choose the option of improving the entire stream channel (4200 ft.) to an "adequate" condition to contain the 10-year storm peak discharge, and with erosion resistance compatible with the 2-year storm.[1] Or, the developer may choose to detain runoff on the site so that the 2-year post-development discharge rate does not exceed the 2-year pre-development discharge rate.[2]

1 The developer must have permission from the property owners before any off-site channel modifications can be made. Channel modifications may require other permits as well.

2 A typical design solution might include an on-site, multi-purpose basin that provides sediment control and runoff quantity control during the land-disturbing phase and provides runoff quantity control as well as water quality benefits after adequate stabilization has been achieved.

CHANNEL GEOMETRY

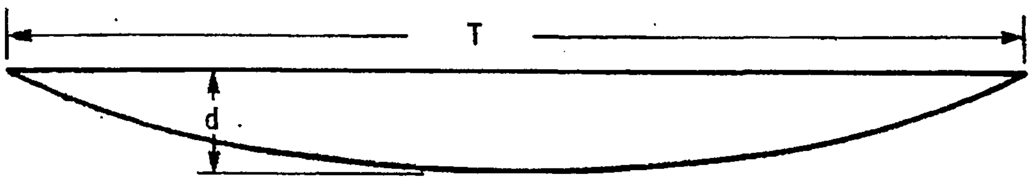
V - Shape



Cross-Sectional Area (A) = Zd^2
Top Width (T) = $2dZ$

Hydraulic Radius (R) = $\dfrac{Zd}{2\sqrt{Z^2 + 1}}$

Parabolic Shape

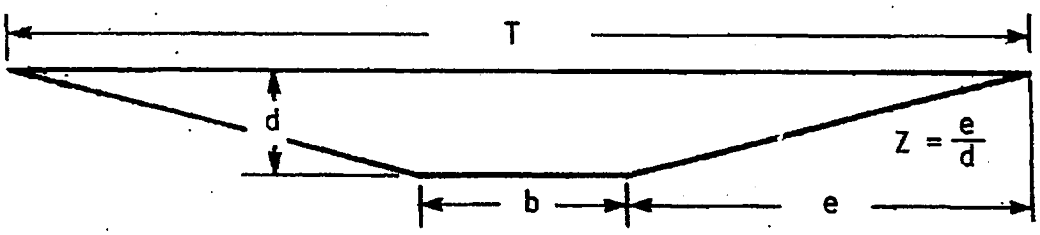


Cross-Sectional Area (A) = $\frac{2}{3}Td$

Top Width (T) = $\dfrac{1.5\,A}{d}$

Hydraulic Radius = $\dfrac{T^2 d}{1.5T^2 + 4d^2}$

Trapezoidal Shape



Cross-Sectional Area (A) = $bd + Zd^2$
Top Width (T) = $b + 2dZ$

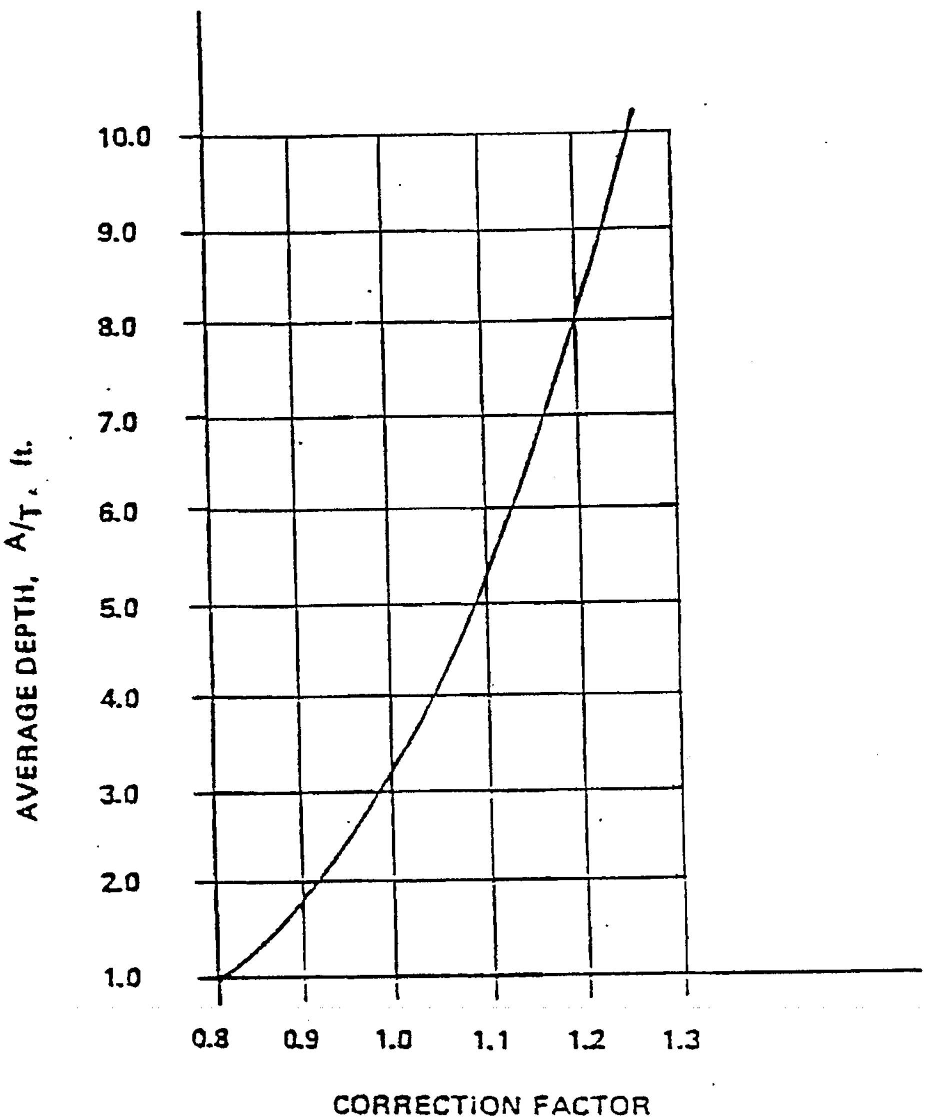
Hydraulic Radius = $\dfrac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}}$

Source: USDA-SCS

When other conditions are the same, a deep channel will convey water at a higher mean velocity (without erosion) than a shallow one. Thus, a correction for flow depth should also be applied to the permissible velocity. Plate 5-39 shows the suggested correction factors to be applied.

CORRECTION FACTORS FOR PERMISSIBLE VELOCITY BASED ON AVERAGE DEPTH OF FLOW

$$\frac{\textit{Cross-Sectional Area of Channel}}{\textit{Top Width of Channel}} = \frac{A}{T}$$



Source: Va DSWC

Plate 5-39

MANNING'S ROUGHNESS COEFFICIENT MODIFYING TABLES FOR NATURAL CHANNELS

Table 5-16
ROUGHNESS COEFFICIENT MODIFIER (n_1)

Character of Channel	Basic n
Channels in earth	0.02
Channels cut into rock	0.025
Channels in fine gravel	0.024
Channels in coarse gravel	0.028

Source: "Estimating Hydraulic Roughness Coefficients," Cowan.

TABLE 5-17
ROUGHNESS COEFFICIENT MODIFIER (n_2)

Degree of Irregularity	Surface Comparable To	Modifying Value
Smooth	The best attainable for the materials involved	0.000
Minor	Good dredged channels, slightly eroded or scoured side slopes of canals or drainage channels	0.005
Moderate	Fair to poor dredged channels, moderately sloughed or eroded side slopes of canals or drainage channels	0.010
Severe	Badly sloughed banks of natural streams; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged and irregular surfaces of channels excavated in rock	0.020

Source: "Estimating Hydraulic Roughness Coefficients," Cowan.

TABLE 5-18
ROUGHNESS COEFFICIENT MODIFIER (n_3)

Character of Variations of Size and Shape of Channel Cross Sections	Modifying Value
Change in size or shape occurring gradually	0.000
Large and small sections alternating occasionally or shape changes causing occasional shifting of main flow from side to side	0.005
Large and small sections alternating frequently or shape changes causing frequent shifting of main flow from side to side	0.010 to 0.015

Source: "Estimating Hydraulic Roughness Coefficients," Cowan.

TABLE 5-19
ROUGHNESS COEFFICIENT MODIFIER (n_4)

Relative effect of obstructions	Modifying value
Negligible	0.000
Minor	0.010 to 0.015
Appreciable	0.020 to 0.030
Severe	0.040 to 0.060

Source: "Estimating Hydraulic Roughness Coefficients," Cowan.

TABLE 5-20

ROUGHNESS COEFFICIENT MODIFIER (n_5)

Vegetation and Flow Conditions Comparable To:	Degree of Effect on "n"	Range in Modifying Value
Dense growths of flexible turf grasses or weeds, of which bermudagrass and bluegrass are examples, where the average depth of flow is two or more times the height of the vegetation.	Low	0.005 to 0.010
Supple seedling tree switches such as willow, cottonwood or salt cedar where the average depth of flow is three or more times the height of the vegetation.		
Turf grasses where the average depth of flow is one to two times the height of the vegetation.	Medium	0.010 to 0.020
Stemmy grasses, weeds or tree seedlings with moderate cover where the average depth of flow is two to three times the height of the vegetation.		
Bushy growths, moderately dense, similar to willows one to two years old, dormant season, along side slopes with no significant vegetation along bottom, where the hydraulic radius is greater than two.		

Source: "Estimating Hydraulic Roughness Coefficients," Cowan.

TABLE 5-20 (continued)
ROUGHNESS COEFFICIENT MODIFIER (n_5)

Vegetation and Flow Conditions Comparable To:	Degree of Effect on "n"	Range in Modifying Value
Turf grasses where the average depth of flow is about equal to the height of vegetation.	High	0.025 to 0.050
Willow or cottonwood trees 8- to 10-years old intergrown with some weeds and brush, dormant season, where the hydraulic radius is 2 to 4 ft.		
Bushy willows about one year old interwoven with some weeds is full foliage along side slopes, no significant vegetation along channel bottom where hydraulic radius is 2 to 4 ft.		
Turf grasses where the average depth of flow is less than one-half the height of the vegetation.	Very High	0.050 to 0.100
Bushy willows about one year old intergrown with weeds along side slopes, dense growth of cattails along channel bottom, all vegetation is full foliage, any value of hydraulic radius up to 10 or 12 ft.		
Trees intergrown with weeds and brush, all vegetation in full foliage, any value of hydraulic radius up to 10 to 12 ft.		

Source: "Estimating Hydraulic Roughness Coefficients," Cowan.

TABLE 5-21
ROUGHNESS COEFFICIENT MODIFIER (n_6)

(Sinuosity) Ratio of meander length to straight length	Degree of meander	Modifying Value
1.0 to 1.2	Minor	0.000
1.2 to 1.5	Appreciable	* $0.15n_s$
1.5 and greater	Severe	* $0.30n_s$

* $n_s = (n_1 + n_2 + n_3 + n_4 + n_5)$

Source: "Estimating Hydraulic Roughness Coefficients," Cowan.

TABLE 5-22

PERMISSIBLE VELOCITIES FOR UNLINED EARTHEN CHANNELS

Soil Types	Permissible Velocity (ft./sec.)
Fine Sand (noncolloidal)	2.5
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (noncolloidal)	5.5
Alluvial Silts (noncolloidal)	3.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Pans	6.0

Source: American Society of Civil Engineers

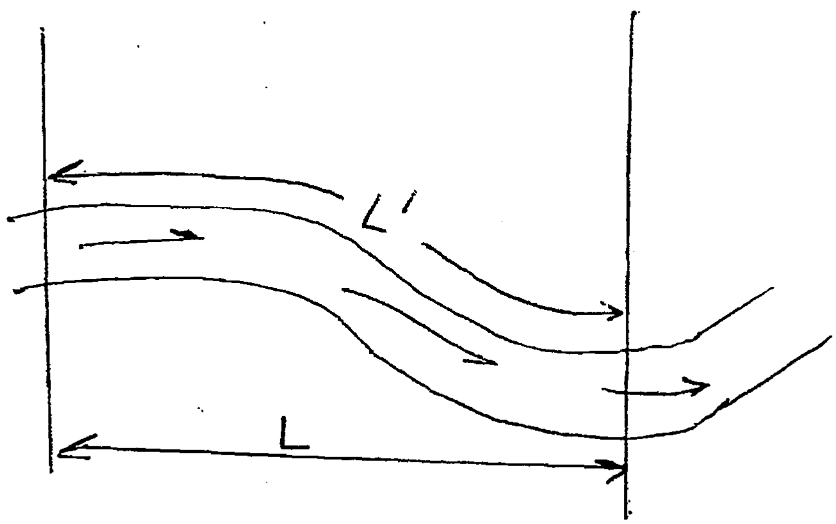
Maximum permissible velocities from Table 5-22 are for straight channels. For curved (sinuous) channels, the reductions shown in Table 5-23 should be applied to the maximum permissible velocities:

TABLE 5-23

REDUCTION IN PERMISSIBLE VELOCITY BASED ON SINUOSITY

Sinuosity*	Percent Reduction in Permissible Velocity
Slight (1.0 to 1.2)	5%
Moderate (1.2 to 1.5)	13%
Very Sinuous (1.5 and greater)	22%

* Sinuosity - degree of curvature of channel.



Sinuosity = L'/L

Source: Chow

CHAPTER 6

Preparing an Erosion and Sediment Control Plan

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CHAPTER 6

PREPARING AN EROSION AND SEDIMENT CONTROL PLAN

This chapter is intended as a complete guide for preparing an erosion and sediment control plan for a construction project. It is divided into three parts:

PART I - GENERAL GUIDELINES: Part I contains the basic information with which all site planners and plan reviewers should be familiar. It describes criteria for plan content and format, ideas for improving planning effectiveness, and sources of technical assistance.

PART II - STEP-BY-STEP PROCEDURE: Part II outlines and describes a step-by-step procedure for developing an erosion and sediment control plan. The procedure covers the steps from data collection through plan preparation. The procedure is written in general terms to be applicable to all types of projects.

PART III - SAMPLE PLAN: A sample plan is developed according to the step-by-step procedure outlined in Part II. This sample plan was developed for a proposed state construction project.

Site planners, as well as local plan approving authorities, are urged to become familiar with the contents of this chapter so that plans will become more standardized, and thus more effective, statewide.

PART I

GENERAL GUIDELINES

What is an Erosion and Sediment Control Plan?

Simply stated, an erosion and sediment control plan is a document which describes the potential for erosion and sedimentation on a construction project. The plan also explains and illustrates the measures which are to be taken to control those problems. The plan has a written portion known as the narrative and a illustrative portion known as a plan.

The erosion and sediment control plan should be an independent entity from the working or construction drawings of the project. While it is a good idea to include erosion and sediment control standards and specifications in contract documents, the erosion and sediment control plan itself should contain notes to ensure that the controls are installed, inspected and maintained properly.

A Narrative Is Important

A narrative is a written statement which explains the erosion and sediment control decisions made for a particular project and the justification for those decisions. The narrative is especially important to the plan approving authority because it contains concise information concerning existing site conditions, construction schedules, and other pertinent items which are not apparent in a typical site plan. Since a plan reviewer cannot always visit the site or discuss the project at length with the site planner, it is essential that the necessary information be provided for the plan review.

The narrative is also important to the construction superintendent and inspector who are responsible for seeing that the plan is implemented properly. It provides them with a single report which describes where and when the various erosion and sediment control practices should be installed.

What Is an "Adequate" Plan ?

An erosion and sediment control plan must contain sufficient information to satisfy the plan approving authority that the problems of erosion and sedimentation have been adequately addressed for a proposed project. The length and complexity of the plan should be commensurate with the size of the project, the severity of site conditions, and the potential for off-site damage.

Obviously, a plan for constructing a house on a single subdivision lot does not need to be as complex as a plan for a shopping center development. Also, plans for projects undertaken on flat terrain will generally be less complicated than plans for projects constructed on steep slopes where erosion potential is greater. The greatest level of planning and detail should be evident on plans for projects which are directly adjacent to flowing streams, dense population centers, or high value properties where damage may be particularly costly or detrimental to the environment.

The primary guidelines for determining the adequacy of a plan are the Virginia Erosion and Sediment Control Regulations (VESCR). Each of the "Minimum Standards" in Section 40 of the Regulations should be satisfied in the E&S plan, unless a specific variance is granted by the plan approving authority. Variance procedures are contained in Section 50 of the Regulations. Maintenance and inspection requirements are contained in Section 60 of the Regulations. (The "Minimum Standards" are listed at the beginning of Chapter 3, or see Chapter 8 for the law and regulations in their entirety.)

As a guide to E&S plan content, the site planners and plan reviewers should use the checklist contained in Part II of this chapter. If the proposed project is subject to local program jurisdiction, the plan preparer should contact the locality since some localities have adopted more stringent requirements. The step-by-step procedure outlined in Part II is recommended for the development of all plans.

Practice Standards and Specifications

Chapter 3 of the Virginia Erosion and Sediment Control Handbook (handbook) contains minimum state standards and specifications for conservation practices. Wherever any of these practices are to be employed on a site, the specific title and number of the practice should be clearly marked on the plan. By referencing the handbook properly, the site planner can reduce the need for lengthy descriptions of the practices in the plan. The plan should contain sketches and notes related to the installation and maintenance of the practices.

Modifications to state standard practices or new innovative conservation practices may also be employed, but such practices must be thoroughly described in detail to the satisfaction of the plan approving authority. Variances from state standards should also be submitted at the time of plan submission.

Standard Practice Coding System

Site planners are urged to use the standard numbering and coding system for conservation practices contained in this handbook. Chapter 2 contains a large fold-out chart which lists each practice with its designated number, symbol and code. This chart can be placed on the wall for fast and easy reference. Use of this coding system will result in increased uniformity of plans and thus increase their readability to plan reviewers, job superintendents, and inspectors statewide.

Comprehensive Site Planning

Erosion and sediment control planning should be an integral part of the site planning process, not an afterthought. The potential for soil erosion should be a significant consideration when deciding upon the layout of buildings, parking lots, roads and other facilities. Costly erosion and sediment control measures can be minimized if the site design can be adapted to existing site conditions and good conservation principles are used.

Who is Responsible for Preparing a Plan ?

The owner or lessee of the land being developed has the responsibility for plan preparation and submission. The owner or lessee may designate someone (e.g., an engineer, architect, contractor, etc.) to prepare the plan, but the owner or lessee retains the ultimate responsibility.

Technical Assistance

There are a number of possible sources of erosion and sediment control planning assistance within the state.

1. Soil and Water Conservation Districts: There are 45 soil and water conservation districts throughout the state serving 94 counties and 13 cities. These districts have elected representatives (directors) from each locality. One of the primary functions of these districts is to provide assistance to landowners for soil conservation planning and implementation. The USDA-Soil Conservation Service provides conservation districts with technical assistance. Requests for assistance in preparing an erosion and sediment control plan for a construction site can be made through the local district.

2. USDA-Soil Conservation Service: The Soil Conservation Service (SCS) provides technical assistance or conservation planning through local soil and water conservation districts to landowners throughout the country. In addition, the SCS, with the Agronomy Department of Virginia Polytechnic Institute and State University (VPI & SU) is involved in soil surveys throughout the state.

   Requests can be made through a SCS field office or a VPI & SU soil survey field office for soil survey on a specific site. Request will be acted upon according to local priorities.

3. Virginia Cooperative Extension Service: The Extension Service can provide valuable information on site planning and establishment of lawns and plant materials. The extension service has a number of useful publications and in addition will have soil samples analyzed upon request to determine fertilization and liming needs for establishing vegetation on a particular site.

4. Virginia Division of Soil and Water Conservation: Division staff members are available to answer any questions concerning the Virginia Erosion and Sediment Control Law (VESCL), the VESCR, and minimum standards and specifications for erosion and sediment control practices. Write or call the Division office in Richmond, or call your local regional office.

Richmond Central Office - 804-786-2064
203 Governor Street, Suite 206
Richmond, Virginia 23219

Regional Offices:

Abingdon	540/676-5529	Chase City	804-372-2191
Dublin	540/674-2937	Richmond	804/527-4481
Staunton	540/332-9991	Suffolk	757/925-2467
Tappahannock	804-443-6752	Warrenton	540-347-6420

5. Local government offices: Many localities have a separate department that is responsible for administering the local erosion and sediment control program. Local staff can be a valuable resource for technical assistance and information concerning local requirements.

PART II

STEP-BY-STEP PROCEDURE

STEP 1 - <u>DATA COLLECTION</u>

A. Topography
B. Drainage
C. Soils
D. Ground Cover
E. Adjacent Areas
F. Requirements

STEP 2 - <u>DATA ANALYSIS</u>

A. Topography - Slope gradients, lengths
B. Drainage - Existing drainage patterns
C. Soil - erodibility, permeability
D. Ground Cover - Trees, grassy areas, unique vegetation
E. Adjacent Areas - Streams, roads, buildings, etc.

STEP 3 - <u>SITE PLAN DEVELOPMENT</u>

A. Develop Site Plan
   1. Fit development to terrain
   2. Locate construction in least critical areas
   3. Utilize cluster development whenever possible
   4. Minimize paved areas
   5. Utilize natural drainage systems
B. Calculate Runoff

STEP 4 - <u>PLAN FOR EROSION AND SEDIMENT CONTROL</u>

A. Determine limits of clearing and grading
B. Divide the site into drainage areas
C. Select erosion and sediment control practices for each drainage area
   1. Vegetative
   2. Structural
   3. Management measures

STEP 5 - <u>PREPARE THE PLAN</u>

A. Narrative
B. Site Plan

STEP 1 - DATA COLLECTION

Inventory the existing site conditions to gather information which will help you develop the most effective erosion and sediment control plan. The information obtained should be plotted on a map and verbally explained in the narrative portion of the plan.

A. TOPOGRAPHY - A small scale topographic map of the site should be prepared to show the existing contour elevations at intervals of from 1 to 5 feet depending upon the slope of the terrain. Existing topographic maps (e.g., USGS or local government topos) can be a good starting point, however, the information should be verified by a field investigation.

B. DRAINAGE PATTERNS - All existing drainage swales and patterns on the site should be located and clearly marked on the topographic map. Live or intermittent streams should be shown on the map.

C. SOILS - Major soil type(s) on the site should be determined and shown on the topographic map. Soils information can be obtained from a soil survey if one has been published for your county. If a soil survey is not available, a request can be made to a district SCS office or the VPI & SU Agronomy Department for a soil survey of your site. Commercial soils evaluations are also available. Soils information should be plotted directly onto the map or an overlay of the same scale for ease of interpretation.

D. GROUND COVER - The existing vegetation such as tree clusters, grassy areas, and unique vegetation should be shown on the map. In addition, existing denuded or exposed soil areas should be indicated.

E. ADJACENT AREAS - Areas adjacent to the site should be delineated on the topographic map. Such features as streams, roads, houses or other buildings, wooded areas, etc. should be shown. Streams which will receive runoff from the site should be surveyed to determine their carrying capacity.

F. REQUIREMENTS - Sources of information include the handbook, the VESCL and VESCR, as well as any information on the local E&S program requirements (e.g, ordinance, handbook, guidelines, etc.).

STEP 2 - DATA ANALYSIS

When all of the data in Step 1 are considered together, a picture of the site potentials and limitations should begin to emerge. The site planner should be able to determine those areas which have potentially critical erosion hazards. The following are some important points to consider in site analysis:

A. <u>Topography</u> - The primary topographic considerations are slope steepness and slope length. Because of the effect of accumulated runoff, erosion potential is greater on long, steep slopes. When the percent of slope has been determined, areas of similar steepness should be outlined. Slope gradients can be grouped into three general ranges of soil erodibility:

0-7%	--	Low erosion hazard
7-15%	--	Moderate erosion hazard
> 15%	--	High erosion hazard

Within these slope gradient ranges, the erosion hazard becomes greater as the slope length increases. Therefore, in determining potential critical areas, the site planner should be aware of excessively long slopes. As a general rule, the erosion hazard will become critical if the slope exceeds the following criteria:

0-7%	--	300 feet
7-15%	--	150 feet
> 15%	--	75 feet

B. <u>Natural Drainage</u> - The existing drainage patterns, which consist of overland flow, swales and depressions, and natural watercourses, should be identified in order to plan around critical areas where water will concentrate. Where possible, natural drainageways should be used to convey runoff over and off the site to avoid the expense and problems of constructing an artificial drainage system. Man-made ditches and waterways can become part of the erosion problem if they are not properly designed and constructed. Care should also be taken to be sure that the increased runoff from the site will not erode or flood the existing natural drainage system. Possible sites for stormwater detention should be located at this time.

C. <u>Soils</u> - Such soils properties as natural drainage, depth to bedrock, depth to seasonal watertable, permeability, shrink-swell potential, texture, and erodibility should exert a strong influence on land development decisions. Appendix 6A contains basic guidelines for using soils information for site planning. A list of Virginia soils and their hydrologic soil groups is included in Appendix 6A.

D. <u>Ground cover</u> - Ground cover is the most important factor in terms of preventing erosion. Any existing vegetation which can be saved will help prevent erosion. Trees and other vegetation protect the soil as well as beautify the site after construction. If the existing vegetation cannot be saved, the planner should consider staging construction and using temporary seeding, or temporary mulching.

Staging of construction involves stabilizing one part of the site before disturbing another. In this way, the entire site is not disturbed at once and the time without ground cover is minimized. Temporary seeding and mulching involve seeding or mulching areas which would otherwise lie exposed for long periods of time. The time of exposure is limited, thus the erosion hazard is reduced.

E. Adjacent Areas - An analysis of adjacent properties should focus on areas downslope from the construction project. Of major concern should be watercourses which will receive direct runoff from the site. The potential for sediment pollution of these watercourses should be considered as well as the potential for downstream channel erosion due to increased volume, velocity and peak flow rate of stormwater runoff from the site. (See Minimum Standard 19.) The potential for sediment deposition on adjacent properties due to sheet and rill erosion should also be analyzed so that appropriate sediment trapping measures can be planned and installed prior to any land-disturbing activity.

F. Requirements - Find out what the requirements are for the development. State agencies that undertake land-disturbing activities are regulated directly by DSWC. Private land-disturbing activities or activities undertaken by localities are regulated by the local E&S program. Contact the appropriate authority for information regarding permits, fees and plan submission, as well as any other requirements.

STEP 3 - SITE PLAN DEVELOPMENT

A. Develop the site plan. After analyzing the data and determining the site limitations, the planner can develop a site plan. When designing the site plan, keep in mind that increases in runoff may require structural runoff control measures or channel improvements. Both items are expensive, and even more so when the site plan has to be re-designed to accommodate the runoff control measures. Therefore, try to minimize the increase in runoff or include runoff control measures in the initial design.

The following are some points to consider when developing the site plan:

1. Fit development to terrain. The development of an area should be tailored to the existing site conditions. This will avoid unnecessary land disturbance, thereby minimizing the erosion hazards and costs. Cutting and filling should be avoided if possible. Slopes should be at a maximum of 2:1 to provide for final stabilization.

2. Confine construction activities to the least critical areas. Any land disturbance in the critically erodible areas will necessitate the installation of more costly control measures.

3. Cluster buildings together. This minimizes the amount of disturbed area, concentrates utility lines and connections in one area, and provides more open natural space. The cluster concept not only lessens the erodible area, but it reduces runoff and generally reduces development costs.

4. Minimize impervious areas. Keep paved areas such as parking lots and roads to a minimum. This goes hand in hand with cluster development in

eliminating the need for duplicating parking areas, access roads, etc. The more land that is kept in vegetative cover, the more water will infiltrate, thus reducing runoff and erosion.

5. Utilize the natural drainage system. If the natural drainage system of a site can be preserved instead of being replaced with storm sewers or concrete channels, the potential for downstream damages due to increased runoff can be minimized.

B. Calculate runoff. Runoff calculations must be done to determine the effect of the development on the existing hydrologic system. Refer to Chapters 4 and 5 for more information on the VESCR and calculation procedures. Also, contact the locality to determine if the locality has adopted more stringent runoff requirements. After the calculations have been done, make the necessary changes to achieve compliance with the runoff requirements.

STEP 4 - PLAN FOR EROSION AND SEDIMENT CONTROL

When the layout of the site has been determined, a plan to control erosion and sedimentation from the disturbed areas must be formulated.

The site planner should be guided by the Minimum Standards in Section 40 of the VESCR. These minimum standards establish a level of control for all projects. The site planner should determine which of the "Minimum Standards" are applicable to the site and select conservation practices which can be used to comply with these regulations. If the site planner feels that any of the "Minimum Standards" are not justified on a given project, the site planner should apply for a variance in accordance with the procedures in the VESCR, Section 50. (See Chapter 8.)

The following procedure is recommended for erosion and sediment control planning:

A. Determine the limits of clearing and grading. Decide which areas must be disturbed in order to accommodate the proposed construction. Pay special attention to critical areas which must be disturbed.

B. Divide the site into drainage areas. Determine how runoff will travel over the developed site. Consider how erosion and sedimentation can be controlled in each small drainage area before looking at the entire site. Remember, it is easier to control erosion than to contend with sediment after it has been carried downstream.

C. Select erosion and sediment control practices. Erosion and sediment control practices can be divided into three broad categories: vegetative controls, structural controls, and management measures. Each of these categories have temporary and permanent control measures to be considered. Vegetative and structural practices should be selected and designed in accordance with Chapter 3. Management measures are construction management techniques which, if properly utilized, can minimize the need for physical controls and possibly reduce costs.

1. Vegetative Controls - Keep in mind that the first line of defense is to prevent erosion. This is accomplished by protecting the soil surface from raindrop impact and overland flow of runoff. The best way to protect the soil surface is to preserve the existing ground cover. Where land disturbance is necessary, temporary seeding or mulching should be used on areas which will be exposed for long periods of time. (See section 40 of "Minimum Standards".)

   Erosion and sediment control plans must contain provisions for permanent stabilization of denuded areas. Selection of permanent vegetation should include the following considerations:

   a. applicability to site conditions
   b. establishment requirements
   c. maintenance requirements
   d. aesthetics.

2. Structural Controls - Structural control practices are generally more costly than vegetative controls. However, they are usually necessary since not all disturbed areas can be protected with vegetation. Structural controls are often used as a second or third line of defense to capture sediment before it leaves the site.

   It is very important that structural practices be selected, designed and constructed according to the standards and specifications in Chapter 3 of this handbook. Improper use or inadequate installation can result in failure of the control and subsequent release of any trapped sediment.

3. Management Measures - Good construction management is as important as structural and vegetative practices for erosion and sediment control, and there is generally little or no cost involved. Following are some management considerations which can be employed:

   a. Include erosion and sediment control as an agenda item for the pre-construction meeting.

   b. Sequence construction so that no area remains exposed for unnecessarily long periods of time.
      - Work in a logical sequence, especially for drainage items.
      - Anticipate the site conditions that will exist as the construction progresses toward the final product.
      - Have the materials on-hand to complete the work without delay.
      - Apply temporary stabilization immediately after grading.

c. On large projects, stage the construction if possible, so that one area can be stabilized before another is disturbed.

d. Consider the time of year:
   - Be prepared for sudden thunderstorms.
   - Install E&S controls immediately.
   - Use straw mulch, especially during poor germination periods.

e. Physically mark off limits of land disturbance on the site with tape, signs or other methods, so that workers can see areas to be protected.

f. Develop and carry out a regular maintenance schedule for erosion and sediment control practices.

g. Designate one individual (preferably the job superintendent) responsible for implementing the erosion and sediment control plan. Make sure that all workers understand the major provisions of the erosion and sediment control plan. Establish reporting procedures for problems identified by workers.

D. Plan for stormwater management. Where increased runoff will cause the carrying capacity of a receiving channel to be exceeded, the site planner must select appropriate stormwater management measures. "Minimum Standard 19" describes the conditions which must be satisfied. (See Chapter 4 for more details.)

STEP 5 - PREPARE THE PLAN

All of the necessary planning work has been done in steps 1-4. The final step consists of consolidating the pertinent information and developing it into a specific erosion and sediment control plan for the project.

The plan consists of two parts: a narrative and site plan. The narrative verbally explains the problems and their solutions with all necessary documentation. The site plan is a map(s) or drawing(s) that depicts information contained in the narrative. Table 6-1 lists some recommended notes that could be placed on the site plan.

The checklist (on the next two pages) should be submitted with the plan. This checklist can be used by a site planner, as well as the plan reviewer, as a quick reference to determine if all the major items are included in the erosion and sediment control plan.

CHECKLIST

FOR EROSION AND SEDIMENT CONTROL PLANS

_____ Minimum Standards - All applicable Minimum Standards must be addressed.

NARRATIVE

_____ Project description - Briefly describes the nature and purpose of the land-disturbing activity, and the area (acres) to be disturbed.

_____ Existing site conditions - A description of the existing topography, vegetation and drainage.

_____ Adjacent areas - A description of neighboring areas such as streams, lakes, residential areas, roads, etc., which might be affected by the land disturbance.

_____ Off-site areas - Describe any off-site land-disturbing activities that will occur (including borrow sites, waste or surplus areas, etc.). Will any other areas be disturbed?

_____ Soils - A brief description of the soils on the site giving such information as soil name, mapping unit, erodibility, permeability, depth, texture and soil structure.

_____ Critical areas - A description of areas on the site which have potentially serious erosion problems (e.g., steep slopes, channels, wet weather/ underground springs, etc.).

_____ Erosion and sediment control measures - A description of the methods which will be used to control erosion and sedimentation on the site. (Controls should meet the specifications in Chapter 3.)

_____ Permanent stabilization - A brief description, including specifications, of how the site will be stabilized after construction is completed.

_____ Stormwater runoff considerations - Will the development site cause an increase in peak runoff rates? Will the increase in runoff cause flooding or channel degradation downstream? Describe the strategy to control stormwater runoff.

_____ Calculations - Detailed calculations for the design of temporary sediment basins, permanent stormwater detention basins, diversions, channels, etc. Include calculations for pre- and post-development runoff.

Checklist (continued)

SITE PLAN

______ Vicinity map - A small map locating the site in relation to the surrounding area. Include any landmarks which might assist in locating the site.

______ Indicate north - The direction of north in relation to the site.

______ Limits of clearing and grading - Areas which are to be cleared and graded.

______ Existing contours - The existing contours of the site.

______ Final contours - Changes to the existing contours, including final drainage patterns.

______ Existing vegetation - The existing tree lines, grassed areas, or unique vegetation.

______ Soils - The boundaries of different soil types.

______ Existing drainage patterns - The dividing lines and the direction of flow for the different drainage areas. Include the size (acreage) of each drainage area.

______ Critical erosion areas - Areas with potentially serious erosion problems. (See Chapter 6 for criteria.)

______ Site Development - Show all improvements such as buildings, parking lots, access roads, utility construction, etc.

______ Location of practices - The locations of erosion and sediment controls and stormwater management practices used on the site. Use the standard symbols and abbreviations in Chapter 3 of this handbook.

______ Off-site areas - Identify any off-site land-disturbing activities (e.g., borrow sites, waste areas, etc.). Show location of erosion controls. (Is there sufficient information to assure adequate protection and stabilization?)

______ Detail drawings - Any structural practices used that are not referenced to the E&S handbook or local handbooks should be explained and illustrated with detail drawings.

______ Maintenance - A schedule of regular inspections and repair of erosion and sediment control structures should be set forth.

TABLE 6-1

GENERAL EROSION AND SEDIMENT CONTROL NOTES

ES-1: Unless otherwise indicated, all vegetative and structural erosion and sediment control practices will be constructed and maintained according to minimum standards and specifications of the Virginia Erosion and Sediment Control Handbook and Virginia Regulations 4VAC50-30 Erosion and Sediment Control Regulations.

ES-2: The plan approving authority must be notified one week prior to the pre-construction conference, one week prior to the commencement of land disturbing activity, and one week prior to the final inspection.

ES-3: All erosion and sediment control measures are to be placed prior to or as the first step in clearing.

ES-4: A copy of the approved erosion and sediment control plan shall be maintained on the site at all times.

ES-5: Prior to commencing land disturbing activities in areas other than indicated on these plans (including, but not limited to, off-site borrow or waste areas), the contractor shall submit a supplementary erosion control plan to the owner for review and approval by the plan approving authority.

ES-6: The contractor is responsible for installation of any additional erosion control measures necessary to prevent erosion and sedimentation as determined by the plan approving authority.

ES-7: All disturbed areas are to drain to approved sediment control measures at all times during land disturbing activities and during site development until final stabilization is achieved.

ES-8: During dewatering operations, water will be pumped into an approved filtering device.

ES-9: The contractor shall inspect all erosion control measures periodically and after each runoff-producing rainfall event. Any necessary repairs or cleanup to maintain the effectiveness of the erosion control devices shall be made immediately.

PART III

SAMPLE PLAN DEVELOPMENT

In this section, all of the previous information is put into use to develop an erosion and sediment control plan for a hypothetical housing project* located in the Williamsburg area. The erosion and sediment control plan for this project was developed according to the step-by-step procedure outlined in Part II. It has been updated to meet the current requirements and minimum standards.

For educational purposes, each step is discussed separately with corresponding maps to illustrate what was done. The actual plan consists of only the four maps, the detail drawings, and the narrative. Actually, maps 1-3 could have been consolidated into one map incorporating existing site conditions, analysis, and the site plan. The site planner should choose the best method of presenting the information. However, local plan approving authorities may require additional drawings or information concerning projects in their jurisdiction.

* Note: The sample plan contained in this section is for educational purposes only. Accordingly, only a sample of the necessary information is included here. If this were an actual plan, additional information would be required.

STEP 1 - DATA COLLECTION
(See Map #1, Plate 6-1.)

Topographic Information
Topographic information was obtained by an aerial survey and is shown on the map at a scale of 1":40' with 5-foot contours.

Drainage Patterns
From on-site inspections and by studying the topographic map, the site was divided into three watersheds, each drained by a distinct swale as shown on map #2.

Soils
Soils information was obtained from the Soil Survey of James City County and the City of Williamsburg. Soil boundaries are shown on the map and each soil type is identified by a symbol.

Ground Cover
An on-site inspection was made to determine the existing vegetation. The site is located in an urban developed area and is heavily wooded. There are areas of hardwood tree growth on the north, east, and west sides of the site. Tree lines are shown on the topo map along with the type of cover on the rest of the site.

Adjacent Property
Center Street borders the property on the west. On the north, there is a two story commercial building with parking space. On the south, there is a storage building with parking space. To the east, the site borders on an unnamed intermittent stream that runs to Harper's Creek. The developer owns the property on both sides of the stream.

STEP 2 - DATA ANALYSIS

(See Map #2, Plate 6-2.)

Topography
The site has a relatively flat topography on the western side with gently sloping natural drainage swales to the east. The area between the limits of clearing and the intermittent stream has been designated a critical area and land disturbance in this area should be avoided if possible. A buffer strip of existing vegetation should be preserved.

Drainage Patterns
The site consist of three major drainage areas identified as I, II, and III on map #2. The approximate acreage of each of these areas is also indicated on the map. Each of these areas is drained by a well defined swale. The swales run from west to east and should continue to be used for site drainage if possible. Extreme care should be exercised to control erosion which will occur from any disturbance in or around these swales. For this reason, these swales have been designated as critical areas on map #2.

Soils
(See map #1.)

The predominant soils on the site are Craven fine sandy loam, Uchee loamy sand, and Emporia loamy sand.

The Craven fine sandy loam soils are deep and moderately drained. Typically, the surface layer of this soil is dark grayish brown fine sandy loam about 4 inches thick. The subsurface layer is pale olive fine sandy loam approximately 5 inches thick. The subsoil extends to a depth of 42 inches. The permeability rate of the soil is 0.12 - 0.15 inches per hour, and erodibility factor (K) is 0.32. The hydrological group is C, and the high water table is between 2 - 3 feet.

The Uchee loamy sand consists of well drained Uchee soils. This soil is found on the side slopes of the narrow ridge tops. Typically, the surface layer of this soil is dark grayish brown fine sandy loam about 4 inches thick. The subsurface layer is pale olive fine sandy loam approximately 5 inches thick. The subsoil extends to a depth of 42 inches. The permeability rate for this soil is 0.10 - 0.15 inches per hour, and the erodibility factor (K) is 0.24. The hydrological group is A, and the high water table is between 3.5 - 5.0 feet.

The Emporia soil consists of areas of deep well drained soils. This soil is on side slopes along the drainage areas. Typically, the surface layer of this soil is dark grayish brown fine sandy loam about 3 inches thick. The subsurface soil layer is pale brown loam approximately 3 inches thick, and the subsoil extends to a depth of 45 inches. The permeability rate for this soil is 2.0 -6.0 inches per hour, and the erodibility factor (K) is 0.28. The hydrological group is C, and the high water table is between 3.0 - 4.5 feet.

Ground Cover
The site is now covered by medium dense tree growth. It is particularly important that trees and undergrowth on the east side of the property be preserved as a buffer area between the site and the stream. For this reason, this area has been identified as a critical area. Land disturbance in this area must be kept to a minimum.

Adjacent Areas
The site drains to an intermittent stream, then to Harper's Creek. There is a high potential during construction for degradation of non-tidal wetlands areas in Harper's Creek from sedimentation. It is important to provide appropriate measures to limit erosion and contain sediment on site during construction. In addition, runoff calculations should be made to determine if there will be an increase in runoff amounts after development, and whether this will result in downstream erosion or flooding. (See Minimum Standard 19, VESCR, Chapters 4 and 8.)

With regard to other adjacent properties, the developer owns the property on the north and south boundaries of the site, and should suffer no ill effects due to erosion or sedimentation. A natural buffer will be preserved along the edge of the proposed site. The west boundary of the site is Center Street which will be used as access for construction equipment and should be protected from sediment and mud being tracked onto the road surface.

STEP 3 - SITE PLAN DEVELOPMENT
(See Map #3, plate 6-3.)

The maps developed for data collection (Map #1) and analysis (Map #2) were used to help determine the most suitable areas for development and the most critical areas from an erosion control standpoint. Erosion potential was one of many factors which were considered in locating the buildings and parking areas.

The final site plan shown on map #3 was developed through a balanced evaluation of such factors as convenience, drainage, maintenance, costs, aesthetics, erosion potential during construction, and stormwater runoff after construction.

The following are some considerations which played a role in site planning:

Roads
The only access will be from Center Street since there is existing development on the north and south boundaries of the site and the stream is on the east boundary of the site.

Buildings
The buildings are located on the portion of the site which will require the least amount of cut and fill, and will not encroach into the critical buffer area to the east. This location also allows the natural drainage patterns to be used after development.

Parking Areas
Parking areas were clustered to provide easy access to both the buildings and Center Street.

Drainage
The larger drainage swales on the north and south were preserved. A storm sewer system has been designed to convey the runoff from impervious surfaces.

STEP 4 - PLAN FOR EROSION AND SEDIMENT CONTROL

(See map #4. Plate 6-4.)

As a first step, the limits of grading were outlined on the site plan (Map #4) so that the areas requiring erosion and sediment control practices could be determined. Since construction will take place in three separate drainage areas, the erosion and sediment control planning was considered by drainage area as follows:

Drainage Area I
Land disturbance in this area will consist of grading for three buildings, streets, sidewalks, and lawn. The primary objective in this area is to keep sediment from being transported into the drainage swale and off-site. This will be accomplished by a combination of structural, vegetative, and management practices.

Drainage Area II
Clearing and grading in this area will be limited to disturbance for streets and parking areas. The objective here is to keep the sediment from entering the drainage swale and being transported off-site. This will also be accomplished by structural, vegetative, and management practices.

Drainage Area III
The major portion of the construction for the buildings will take place in this area. Grading will be done for several buildings, sidewalks and lawns. In addition to grading, a storm sewer system will be installed to manage the stormwater runoff after development. Erosion and sediment control techniques will consist of vegetative, structural, and management practices to minimize and trap sediment on site.

Structural Measures - Area I

1. Sediment Basin
   Drainage area I is completely drained by a single swale and portions of drainage areas II, and III will be drained by a storm sewer into this swale. A sediment basin constructed across the swale below all construction will be the most effective method of removing sediment from the runoff before it leaves the site. The basin will be designed to accommodate the removal of accumulated sediment and to function as a permanent runoff control measure after the site has been stabilized.

2. Check Dam
   Rock check dams built across the drainage swale up-slope from the sediment basin will greatly reduce the velocity of runoff from both the construction site and the adjacent property. This measure will reduce ditchline erosion and help increase the effectiveness by allowing more sediment to settle before the runoff reaches the basin.

3. Diversion Dike
   An earthen diversion dike in conjunction with a temporary slope drain will be the most effective method of diverting runoff into the sediment basin.

4. Inlet Protection
   Storm sewer inlets will need to be protected to prevent sediment-laden runoff from clogging the sewer pipe during construction. Inlet protection should be used on each inlet until upland areas are stabilized.

5. Silt Fence
   Silt fence should be installed downslope of disturbed areas with minimal slopes to filter sheet flow runoff before it enters the drainage swale.

6. Pipe Outlets
   Rip rap outlet protection should be placed at the discharge end of all storm sewer pipes and from the sediment basins to prevent erosion and scouring at the end of the pipes and to slow the velocity of the stormwater discharge to prevent downstream erosion.

7. Tree Protection
   Tree protection fencing should be installed around all areas where existing trees and vegetation are to be preserved to prevent damage and soil compaction from construction equipment and vehicles.

8. Construction Road Stabilization
   All roads should be stabilized with crushed stone or aggregate base material to prevent mud from being tracked onto Center Street.

Structural Measures - Area II

1. Sediment Basin
Drainage Area II is completely drained by a single swale. As in Drainage Area I, a sediment basin incorporating a check dam, sediment trap, and diversion dikes, will be the most effective method of removing sediment from runoff before it leaves the site. The basin will be designed to accommodate the removal of accumulated sediment and to function as a permanent runoff control measure after the site has been stabilized.

2. Construction Entrance
A construction entrance with a wash rack will be needed to clean the tires of vehicles and equipment during wet conditions. There is a high potential for tracking mud and sediment onto Center Street.

3. Construction Road Stabilization
All roads and parking areas should be stabilized with crushed stone or aggregate base material to prevent mud from being tracked onto Center Street.

4. Storm Sewer Inlets
All storm sewer inlets should be protected to prevent sediment from clogging the storm sewer system pipe.

5. Silt Fence
Silt fence should be installed downslope of disturbed areas to filter sediment-laden runoff before it enters the drainage swale.

6. Tree Protection
Tree protection should be installed around areas where trees and other existing vegetation is to be preserved to prevent damage and soil compaction from construction equipment and vehicles.

Structural Measures - Area III

1. Sediment Trap
Drainage Area III is drained by a small less defined swale than Areas I and II. This is also the smallest drainage area of the site. A sediment trap incorporating a diversion dike would be the most effective method of filtering sediment-laden runoff before it leaves the site and enters the drainage swale.

2. Storm Drain Inlets
As in Areas I and II, it is important to provide storm sewer inlet protection around each of the inlets to prevent the system from being clogged with sediment.

Vegetative Measures - Areas I, II and III

1. Topsoil Stockpiling
Topsoil should be stripped from graded areas and stockpiled for use in final grading and permanent stabilization. The stockpiles will have to be kept off-site to stay clear of all construction activity. The stockpile must be stabilized with temporary vegetation to prevent soil loss and sediment transport from the stockpile itself until needed. Prior to land-disturbing activities, the contractor shall submit a supplementary E&S plan to the owner covering the off-site stockpile area which would have to be approved by the plan approving authority.

2. Temporary Seeding
Certain areas of the site will be rough graded as a first stage of construction. Finish grading will occur near project completion. These areas shall be seeded temporarily with fast germinating temporary grasses to reduce erosion potential. Diversion dikes and the sediment basin embankment shall also receive temporary seeding.

3. Permanent Seeding
Immediately following finish grading, permanent vegetation shall be applied in accordance with an overall landscape plan for the site.

4. Stabilization of Earthen Structures
All earthen structures such as sediment basins, sediment traps, and diversion dikes should be seeded and mulched immediately after being constructed with fast germinating temporary vegetation to help prevent structural damage or failure. This will also help to ensure that the structure itself will not become part of an erosion problem.

Management Strategies - Areas I, II, and III

1. Construction traffic should be limited to access roads and areas to be graded. All traffic should be prohibited from crossing drainage swales and streams except where absolutely necessary.

2. The sediment basin, diversion dikes, and sediment traps will be installed as a first step in grading.

3. All major grading should be completed within 30 days of the beginning of the project. Temporary seeding shall be applied immediately after grading is completed on the respective areas.

4. Responsibility for plan implementation should be given to the construction superintendent, and he/she should make all construction workers aware of the provisions of the plan.

5. All erosion and sediment control measures shall be checked continuously and especially after each significant storm to locate damages and conduct maintenance operations.

6. After achieving adequate stabilization, temporary E&S controls will be removed and the sediment basins will be cleaned out and converted to permanent stormwater management basins.

STEP 5 - PREPARE THE PLAN

In steps 1-4, all of the information necessary for preparing an erosion and sediment control plan was developed. In this final step, the actual plan is to be prepared in a logical format containing all the pertinent information. The checklist at the end of Part II was used as a basis for developing the following erosion and sediment control plan.

NARRATIVE

PROJECT DESCRIPTION

The purpose of this project is the construction of a new housing complex. The site is located south of Williamsburg, Virginia, on Center Street. The site will consist of construction of eight buildings, parking areas, and lawn. A total of 9.5 acres will be disturbed during construction.

EXISTING SITE CONDITIONS

The proposed site is relatively flat and drains towards the eastern boundary. Most of the site is covered with dense tree growth. The site is divided into three distinct drainage areas as identified on map #2. Each of these areas is traversed by a distinct swale which drains to the east towards Harper's Creek. The slopes along the swales average between 7 - 10% with some small areas that are 50%.

ADJACENT PROPERTY

Center Street borders the property on the west. On the north, there is a two story commercial building with parking space. On the south, there is a storage building with parking space. To the east, the site borders on an unnamed intermittent stream that runs to Harper's Creek. The developer owns the property on both sides of the stream.

Across from Center Street, there is an existing residential neighborhood of single-family dwellings.

Off-site Areas

Topsoil must be stripped from graded areas and stockpiled for use in final grading and permanent stabilization. The stockpiles will have to be kept off site to stay clear of all construction activity. The stockpile will be stabilized with temporary vegetation to prevent soil loss and sediment transport from the stockpile itself until needed. Prior to land-disturbing activities, the contractor shall submit a supplementary E&S plan to the owner covering the off-site stockpile area which would have to be approved by the plan approving authority before any off-site activity commences.

Soils

(See map #1.)

The predominant soils on the site are Craven fine sandy loam, Uchee loamy sand, and Emporia loamy sand.

The Craven fine sandy loam soils are deep and moderately drained. Typically, the surface layer of this soil is dark grayish brown fine sandy loam about 4 inches thick. The subsurface layer is pale olive fine sandy loam approximately 5 inches thick. The subsoil extends to a depth of 42 inches. The permeability rate of the soil is 0.12 - 0.15 inches per hour, and erodibility factor (K) is 0.32. The hydrological group is C, and the high water table is between 2 - 3 feet.

The Uchee loamy sand consists of well drained Uchee soils. This soil is found on the side slopes of the narrow ridge tops. Typically, the surface layer of this soil is dark grayish brown fine sandy loam about 4 inches thick. The subsurface layer is pale olive fine sandy loam approximately 5 inches thick. The subsoil extends to a depth of 42 inches. The permeability rate for this soil is 0.10 - 0.15 inches per hour, and the erodibility factor (K) is 0.24. The hydrological group is A, and the high water table is between 3.5 - 5.0 feet.

The Emporia soil consists of areas of deep well drained soils. This soil is on side slopes along the drainage areas. Typically, the surface layer of this soil is dark grayish brown fine sandy loam about 3 inches thick. The subsurface soil layer is pale brown loam approximately 3 inches thick, and the subsoil extends to a depth of 45 inches. The permeability rate for this soil is 2.0 - 6.0 inches per hour, and the erodibility factor (K) is 0.28. The hydrological group is C, and the high water table is between 3.0 - 4.5 feet.

CRITICAL EROSION AREAS

Critical areas have been identified on map #2. The area between the site and the stream has been designated as critical due to drainage into Harper's Creek which lies east of the site. This creek has areas of non-tidal wetland vegetation which would experience serious degradation if sediment were to leave the site. Therefore, care will be taken to minimize land disturbance in this area, and sediment must be trapped on the site.

EROSION AND SEDIMENT CONTROL MEASURES

Unless otherwise indicated, all vegetative and structural erosion and sediment control practices shall be constructed and maintained according to minimum standards and specifications of the handbook. The minimum standards of the VESCR shall be adhered to unless otherwise waived or approved by a variance.

STRUCTURAL PRACTICES

1. Temporary Diversion Dike - 3.09 and Sediment Trap - 3.13
   A system of temporary diversion dikes, to direct flow into sediment traps, will be installed below major graded areas

as indicated on map #4. Specific details of the sediment traps are shown on the detail sheet.

2. <u>Temporary Sediment Basins - 3.14</u>
Two permanent sediment basins are to be constructed across the swales in drainage areas I and II as indicated on map #4. Specific dimensions of the embankments and spillways are shown on the detail sheet. Calculations for sediment basins are attached.

3. <u>Outlet Protection - 3.18</u>
Riprap is to be placed at the outlet of all pipes as indicated on map #4 per detail sheet.

4. <u>Silt Fence Barrier - 3.05</u>
Silt fence sediment barriers will be installed downslope of areas with minimal grades to filter sediment-laden runoff from sheet flow as indicated on map #4.

5. <u>Tree Protection - 3.38</u>
A fence barrier is to be placed around the trees and vegetated areas which will not be disturbed to protect the trees and other vegetation from construction equipment and soil compaction.

6. <u>Temporary Construction Entrance - 3.02</u>
A temporary construction entrance with a wash rack shall be installed where the access area intersects with South Henry street. During muddy conditions, drivers of construction vehicles will be required to wash their wheels before entering the highway.

7. <u>Storm Drain Inlet Protection - 3.07</u>
All storm sewer inlets shall be protected during construction. Sediment-laden water shall be filtered before entering the storm sewer inlets.

8. <u>Temporary Diversion Dikes - 3.09 and Sediment Traps - 3.13</u>
A system of diversion dikes to direct flow into sediment traps will be installed below major graded areas as indicated on map #4. Specific details of the sediment traps are shown on the detail sheet.

9. <u>Check Dam - 3.20</u>
Several rock check dams will be installed upslope of the sediment basins to reduce the velocity of concentrated flows which will help to increase the effectiveness of the sediment basins.

10. <u>Temporary Slope Drain - 3.15</u>
Temporary slope drains will be installed to protect the fill slopes from rill and gully erosion. The locations of this practice are indicated on map #4.

VEGETATIVE PRACTICES

1. Topsoiling (Stockpile) - 3.30
   Topsoil will be stripped from areas to be graded and stockpiled for later use. Stockpile locations shall be located off-site and are to be stabilized with temporary vegetation. Prior to land-disturbing activities, the contractor shall submit a supplementary E&S plan to the owner covering the off-site stockpile area which would have to be approved by the plan approving authority before any off-site activity commences.

2. Temporary Seeding - 3.31
   All denuded areas which will be left dormant for extended periods of time shall be seeded with fast germinating temporary vegetation immediately following grading. Selection of the seed mixture will depend on the time of year it is applied.

3. Erosion Control Blankets - 3.36 or Mulch - 3.35
   Erosion control blankets will be installed over fill slopes which have been brought to final grade and have been seeded to protect the slopes from rill and gully erosion and to allow seed to germinate properly. Mulch (straw or fiber) will be used on relatively flat areas and will be applied as a second step in the seeding operation.

MANAGEMENT STRATEGIES

1. Construction will be sequenced so that grading operations can begin and end as quickly as possible.

2. Sediment trapping measures will be installed as a first step in grading and will be seeded and mulched immediately following installation.

3. Temporary seeding or other stabilization will follow immediately after grading.

4. Areas which are not to be disturbed will be clearly marked by flags, signs, etc.

5. The job superintendent shall be responsible for the installation and maintenance of all erosion and sediment control practices.

6. After achieving adequate stabilization, the temporary E&S controls will be cleaned up and removed, and the sediment basins will be cleaned out and converted to permanent stormwater management basins.

PERMANENT STABILIZATION

All areas disturbed by construction shall be stabilized with permanent seeding immediately following finish grading. Seeding shall be done with Kentucky 31 Tall Fescue according to Std. & Spec. 3.32, PERMANENT SEEDING, of the handbook. Erosion control blankets will be installed over fill slopes which have been brought to final grade and have been seeded to protect the slopes from rill and gully erosion and to allow seed to germinate properly. Mulch (straw or fiber) will be used on relatively flat areas. In all seeding operations, seed, fertilizer and lime will be applied prior to mulching.

STORMWATER MANAGEMENT

Calculation of runoff before and after development indicates that there will be a net increase in peak runoff as a result of project development. Consequently, stormwater management basins have been designed to detain and release the runoff at the 2-year pre-developed rate. (See attached runoff calculations using TR-55.)

MAINTENANCE

In general, all erosion and sediment control measures will be checked daily and after each significant rainfall. The following items will be checked in particular:

1. The sediment basin will be cleaned out when the level of sediment buildup reaches the cleanout point indicated on the riser pipe.

2. The sediment traps will be checked regularly for sediment cleanout.

3. The gravel outlets will be checked regularly for sediment buildup which will prevent drainage. If the gravel is clogged by sediment, it shall be removed and cleaned or replaced.

4. The silt fence barrier will be checked regularly for undermining or deterioration of the fabric. Sediment shall be removed when the level of sediment deposition reaches half way to the top of the barrier.

5. The seeded areas will be checked regularly to ensure that a good stand is maintained. Areas should be fertilized and re-seeded as needed.

Worksheet 2: Runoff curve number and runoff

Project SAMPLE E&S PLAN By ____ Date ____

Location ____ Checked ____ Date ____

Circle one: Present Developed ____

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐acres ☐mi^2 ☐%	Product of CN x area
CRAVEN EMPORIA C 85%	WOODED - GOOD	70			8.27	578.9
LKHEE A 15%	WOODED - GOOD	30			1.46	43.80
				Totals =	9.73	622.7

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{622.7}{9.73} = 63.99$; Use CN = $\boxed{64}$

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	2	25	
Rainfall, P (24-hour)	in	3.36	6.5	
Runoff, Q .... (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in	0.65	2.62	

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project SAMPLE E&S PLAN By ____ Date ____

Location ____ Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Unit	Segment ID AB	Segment 2	Total
1. Surface description (table 3-1)		DENSE WOODS		
2. Manning's roughness coeff., n (table 3-1)		0.80		
3. Flow length, L (total L $\leq$ 300 ft)	ft	185		
4. Two-yr 24-hr rainfall, P_2	in	3.36		
5. Land slope, s	ft/ft	.16		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.43	+	= 0.43

Shallow concentrated flow	Unit	Segment ID BC	Segment 2	Total
7. Surface description (paved or unpaved)		UNPAVED		
8. Flow length, L	ft	215		
9. Watercourse slope, s	ft/ft	.14		
10. Average velocity, V (figure 3-1)	ft/s	6.0		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.01	+	= .01

Channel flow	Unit	Segment ID CE	Segment 2	Total
12. Cross sectional flow area, a	ft^2	1.5		
13. Wetted perimeter, p_w	ft	3.6		
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	0.42		
15. Channel slope, s	ft/ft	.0324		
16. Manning's roughness coeff., n		.033		
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	4.55		
18. Flow length, L	ft	340		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.02	+	= .02
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			0.46

Worksheet 4: Graphical Peak Discharge method

Project SAMPLE E&S PLAN By ____ Date ________

Location ______________________ Checked _____ Date ________

Circle one: Present Developed ______________________

1. Data:

   Drainage area .... A_m = .015 mi^2 (acres/640)
   Runoff curve number .... CN = 64 (From worksheet 2)
   Time of concentration .. T_c = .46 hr (From worksheet 3)
   Rainfall distribution type = II (I, IA, II, III)
   Pond and swamp areas spread throughout watershed ...... = — percent of A_m (____ acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	2		
3. Rainfall, P (24-hour)	in	3.36		
4. Initial abstraction, I_a .... (Use CN with table 4-1.)	in	1.125		
5. Compute I_a/P		0.334		
6. Unit peak discharge, q_u .... (Use T_c and I_a/P with exhibit 4-____)	csm/in	440		
7. Runoff, Q .... (From worksheet 2).	in	0.65		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)		—		
9. Peak discharge, q_p .... (Where $q_p = q_u A_m Q F_p$)	cfs	4.3		

Worksheet 2: Runoff curve number and runoff

Project SAMPLE E&S PLAN By ____ Date ____

Location ____ Checked ____ Date ____

Circle one: Present Developed ____

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐acres ☐mi² ☐%	Product of CN x area
C	OPEN SPACE	74			2.83	209.42
C	WOODS	70			3.30	231.0
	IMPERVIOUS	98			4.7	460.60
				Totals =	10.83	901.02

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{901.02}{10.83} = 83.19$; Use CN = $\boxed{83}$

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	2	25	100
Rainfall, P (24-hour)	in	3.36	6.5	8.2
Runoff, Q .... (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in	1.74	4.55	6.17

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project SAMPLE E&S PLAN By ____ Date ____

Location ____ Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Segment ID	AB			
1. Surface description (table 3-1)		DENSE GRASSES			
2. Manning's roughness coeff., n (table 3-1) ..		0.24			
3. Flow length, L (total L $\leq$ 300 ft)	ft	100			
4. Two-yr 24-hr rainfall, P_2	in	3.36			
5. Land slope, s	ft/ft	.01			
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	.30	+		= .30
Shallow concentrated flow	Segment ID	BC			
7. Surface description (paved or unpaved)		PAVED			
8. Flow length, L	ft	200			
9. Watercourse slope, s	ft/ft	.02			
10. Average velocity, V (figure 3-1)	ft/s	2.95			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.02	+		= .02
Channel flow	Segment ID	CD		DE	
12. Cross sectional flow area, a	ft^2			1.5	
13. Wetted perimeter, p_w	ft			3.6	
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			0.42	
15. Channel slope, s	ft/ft			.0324	
16. Manning's roughness coeff., n		.013		.033	
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	AVG. 5.1		4.55	
18. Flow length, L	ft	640		200	
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.03	+	0.01	= 0.04
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr				0.36

Worksheet 4: Graphical Peak Discharge method

oject SAMPLE E&S PLAN By ____ Date ______

cation ________________ Checked ____ Date ______

rcle one: Present Developed ________________

Data:

Drainage area .... A_m = .0169 mi^2 (acres/640)

Runoff curve number .... CN = 83 (From worksheet 2)

Time of concentration .. T_c = .36 hr (From worksheet 3)

Rainfall distribution type = II (I, IA, II, III)

Pond and swamp areas spread throughout watershed ...... = — percent of A_m (____ acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
Frequency	yr	2	25	100
Rainfall, P (24-hour)	in	3.36	6.5	8.2
Initial abstraction, I_a .... (Use CN with table 4-1.)	in	.410	.410	.410
Compute I_a/P		0.122	0.063	0.05
Unit peak discharge, q_u .... (Use T_c and I_a/P with exhibit 4-___)	csm/in	600	625	625
Runoff, Q .... (From worksheet 2).	in	1.74	4.55	6.17
Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)		—	—	—
Peak discharge, q_p .... (Where $q_p = q_u A_m Q F_p$)	cfs	17.6	48.1	65.2

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET

(with or without an emergency spillway)

Project SAMPLE E&S PLAN

Basin # 1 Location AREA I

Total area draining to basin: 10.83 acres.

Basin Volume Design

Wet Storage:

1. Minimum required volume = 67 cu. yds. x Total Drainage Area (acres).

   67 cu. yds. x 10.83 acres = 725.6 cu. yds.

2. Available basin volume = 730* cu. yds. at elevation 39.8. (From storage - elevation curve) * BELOW DEWATERING ORIFACE

3. Excavate 0 cu. yds. to obtain required volume*.

   * Elevation corresponding to required volume = invert of the dewatering orifice.

4. Available volume before cleanout required.

   33 cu. yds. x 10.83 acres = 357.4 cu. yds.

5. Elevation corresponding to cleanout level = 37.9.

   (From Storage - Elevation Curve)

6. Distance from invert of the dewatering orifice to cleanout level = 1.9 ft. (Min. = 1.0 ft.)

Dry Storage:

7. Minimum required volume = 67 cu. yds. x Total Drainage Area (acres).

   67 cu. yds. x 10.83 acres = 725.6 cu. yds.

8. Total available basin volume at crest of riser* = 1343 cu. yds. at elevation 42. (From Storage - Elevation Curve).

* Minimum = 134 cu. yds./acre of total drainage area.

9. Diameter of dewatering orifice = 6 in.

10. Diameter of flexible tubing = 8 in. (diameter of dewatering orifice plus 2 inches).

Preliminary Design Elevations

11. Crest of Riser = 42

Top of Dam = 45

Design High Water = 43

Upstream Toe of Dam = 34

Basin Shape

12. $\frac{\text{Length of Flow}}{\text{Effective Width}}$ $\frac{L}{We}$ = $\frac{200}{70}$

If > 2, baffles are not required 2.85 > 2

If < 2, baffles are required ______

Runoff

13. Q_2 = 17.6 cfs (From Chapter 5) - TR-55

14. Q_{25} = 48.1 cfs (From Chapter 5) - TR-55

Principal Spillway Design

15. With emergency spillway, required spillway capacity $Q_p = Q_2 =$ ______ cfs. (riser and barrel)

Without emergency spillway, required spillway capacity $Q_p = Q_{25} =$ 48.1 cfs. (riser and barrel)

16. With emergency spillway: – NOT USED

Assumed available head (h) = ____________ ft. (Using Q_2)

h = Crest of Emergency Spillway Elevation - Crest of Riser Elevation

Without emergency spillway:

Assumed available head (h) = 1 ft. (Using Q_{25})

h = Design High Water Elevation - Crest of Riser Elevation

17. Riser diameter (D_r) = 60 in. Actual head (h) = 1 ft.

(From Plate 3.14-8.)

Note: Avoid orifice flow conditions.

18. Barrel length (l) = 50 ft.

Head (H) on barrel through embankment = 9 ft.

(From Plate 3.14-7).

19. Barrel diameter = 30 in.

(From Plate 3.14-B [concrete pipe] or Plate 3.14-A [corrugated pipe]).

20. Trash rack and anti-vortex device

Diameter = 90 inches.

Height = 29 inches.

(From Table 3.14-D).

Emergency Spillway Design – NOT USED

21. Required spillway capacity $Q_e = Q_{25} - Q_p$ = ____________ cfs.

22. Bottom width (b) = ________ ft.; the slope of the exit channel (s) = ________ ft./foot; and the minimum length of the exit channel (x) = ________ ft.
(From Table 3.14-C).

Anti-Seep Collar Design

23. Depth of water at principal spillway crest (Y) = 8 ft.

    Slope of upstream face of embankment (Z) = 2 :1.

    Slope of principal spillway barrel (S_b) = 1 %

    Length of barrel in saturated zone (L_s) = 50 ft.

24. Number of collars required = 2 dimensions = 5

    (from Plate 3.14-12).

Final Design Elevations

25. Top of Dam = 45

    Design High Water = 43

    Emergency Spillway Crest = —

    Principal Spillway Crest = 42

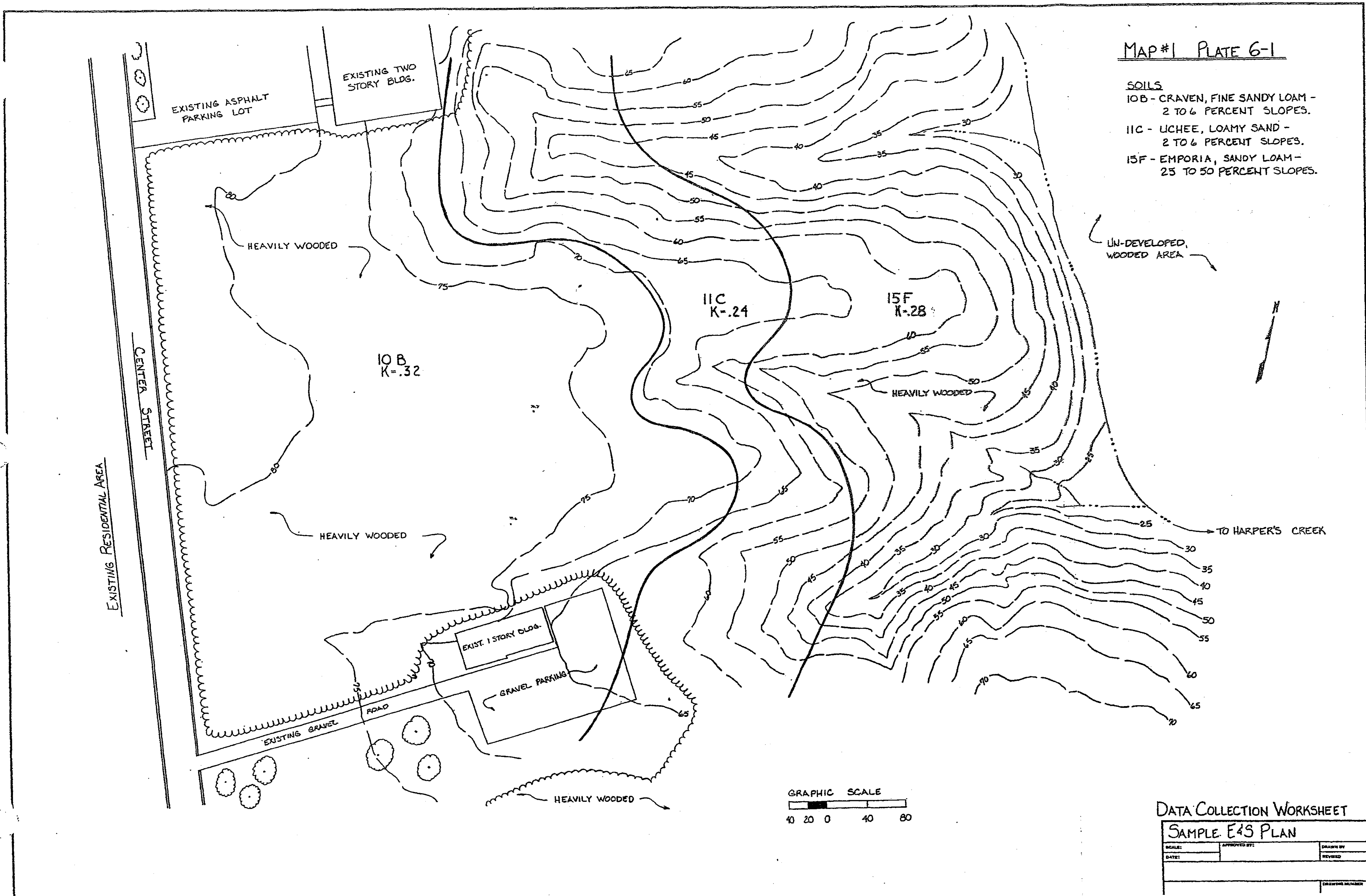
    Dewatering Orifice Invert = 39.8

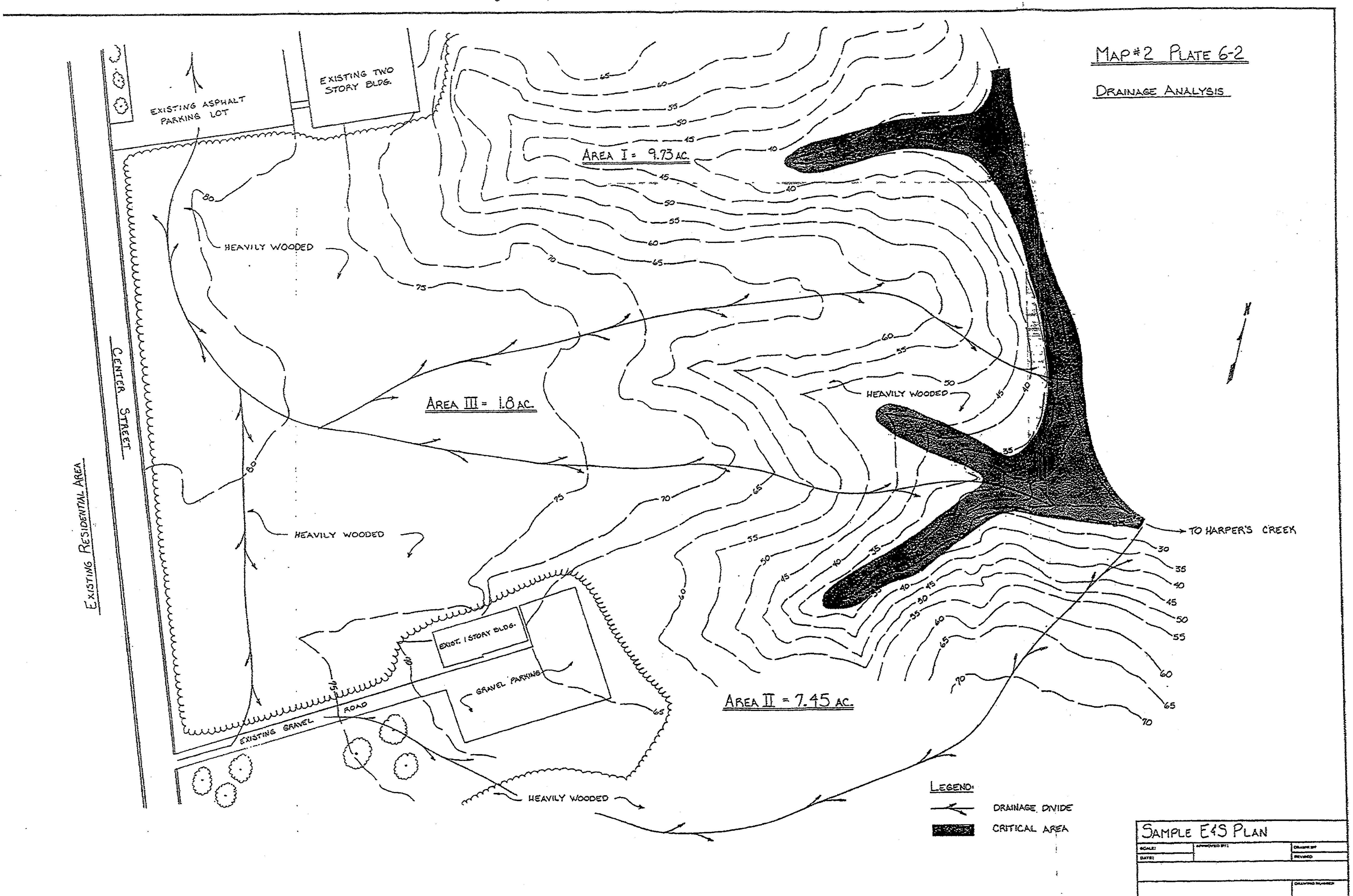
    Cleanout Elevation = 37.9

    Elevation of Upstream Toe of Dam or Excavated Bottom of "Wet Storage Area" (if excavation was performed) = 34

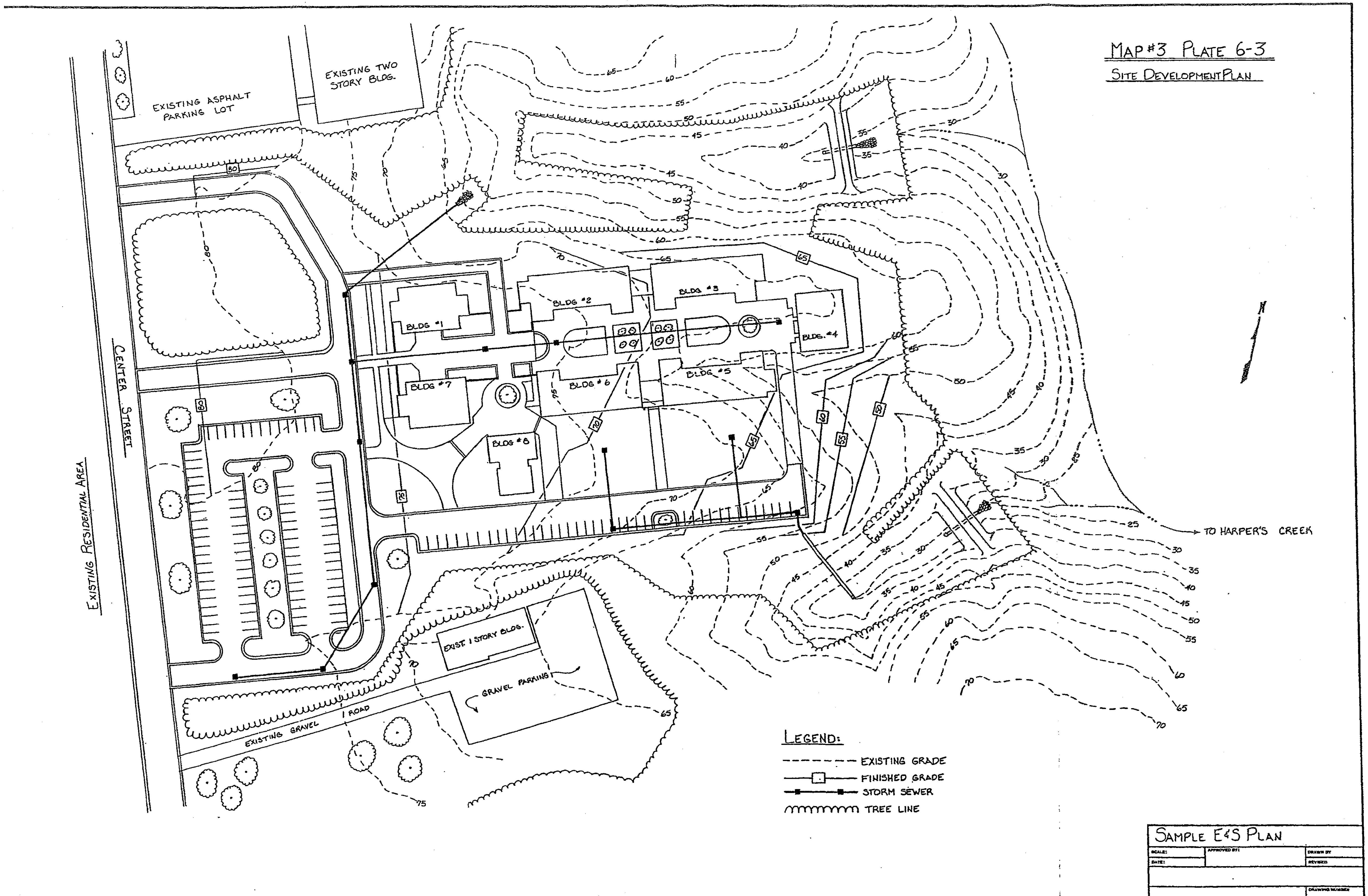
NOTES: 1. The Basin for this example was designed as a temporary sediment basin only. Stormwater Management is required due to the increase in runoff, and the inability to modify the natural channel. This basin would therefore be designed by a Certified Professional Engineer in compliance with the state Stormwater Regulations, and would be modified to act as a temporary sediment basin.

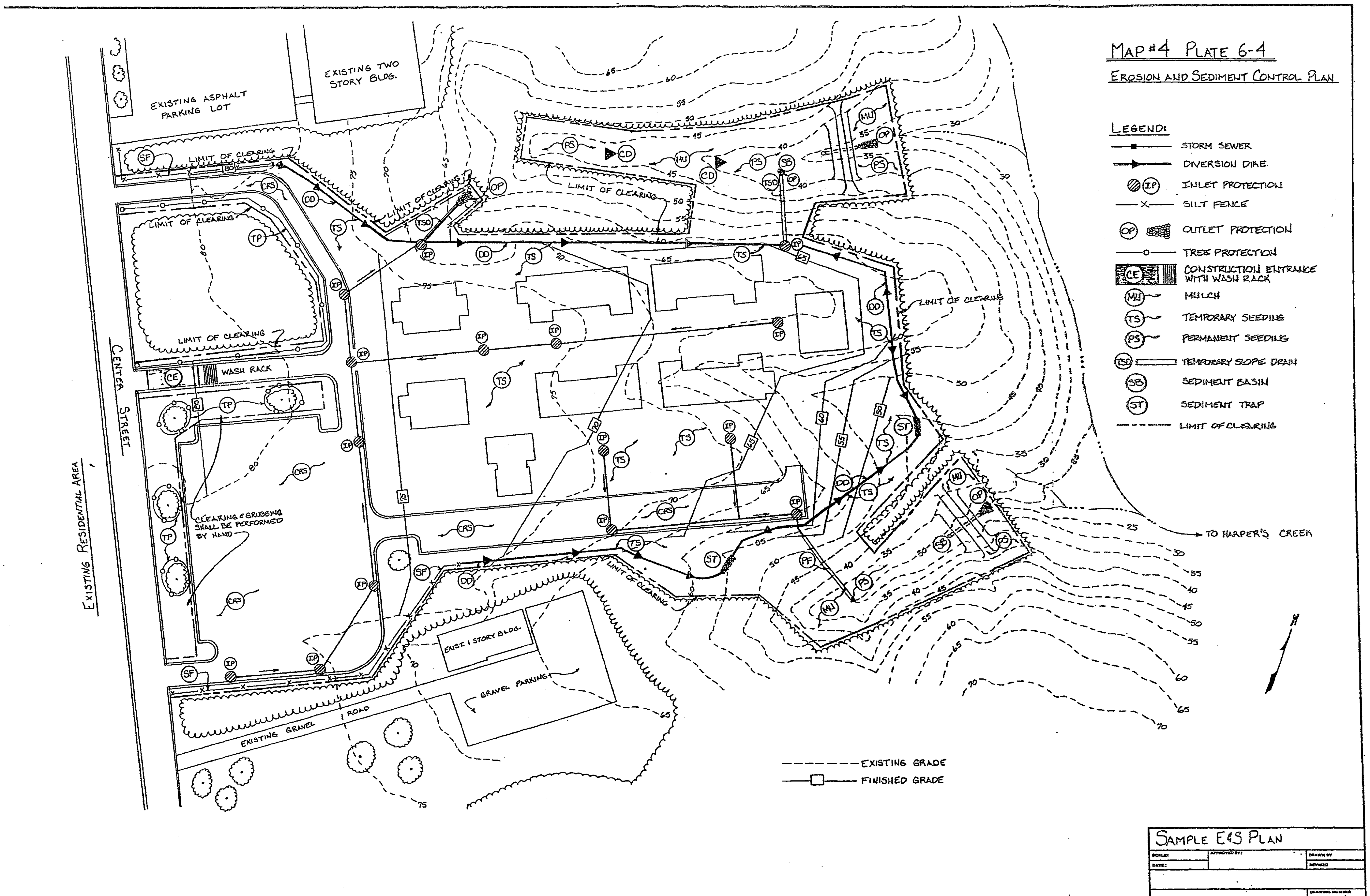
2. The Basin in Area II is not calculated in this example.


MAP #1 PLATE 6-1
SOILS
10B - CRAVEN, FINE SANDY LOAM - 2 TO 6 PERCENT SLOPES.
11C - UCHEE, LOAMY SAND - 2 TO 6 PERCENT SLOPES.
15F - EMPORIA, SANDY LOAM - 25 TO 50 PERCENT SLOPES.
EXISTING TWO STORY BLDG.
EXISTING ASPHALT PARKING LOT
HEAVILY WOODED
UN-DEVELOPED, WOODED AREA
11C K=.24
15F K=.28
10 B K=.32
CENTER STREET
EXISTING RESIDENTIAL AREA
TO HARPER'S CREEK
EXIST. 1 STORY BLDG.
GRAVEL PARKING
EXISTING GRAVEL ROAD
GRAPHIC SCALE
40 20 0 40 80
DATA COLLECTION WORKSHEET
SAMPLE E&S PLAN



Map #2 Plate 6-2
Drainage Analysis
Existing Two Story Bldg.
Existing Asphalt Parking Lot
Area I = 9.73 ac.
Heavily Wooded
Area III = 1.8 ac.
Center Street
Existing Residential Area
Heavily Wooded
Heavily Wooded
To Harper's Creek
Exist. 1 Story Bldg.
Gravel Parking
Existing Gravel Road
Area II = 7.45 ac.
Heavily Wooded
Legend:
Drainage Divide
Critical Area
Sample E&S Plan


MAP #3 PLATE 6-3
SITE DEVELOPMENT PLAN
EXISTING TWO STORY BLDG.
EXISTING ASPHALT PARKING LOT
CENTER STREET
EXISTING RESIDENTIAL AREA
BLDG #1
BLDG #2
BLDG #3
BLDG. #4
BLDG #5
BLDG #6
BLDG #7
BLDG #8
EXIST. 1 STORY BLDG.
GRAVEL PARKING
EXISTING GRAVEL ROAD
TO HARPER'S CREEK
LEGEND:
EXISTING GRADE
FINISHED GRADE
STORM SEWER
TREE LINE
SAMPLE E&S PLAN
SCALE:
DATE:
APPROVED BY:
DRAWN BY
REVISED
DRAWING NUMBER


MAP #4 PLATE 6-4
EROSION AND SEDIMENT CONTROL PLAN
LEGEND:
STORM SEWER
DIVERSION DIKE
INLET PROTECTION
SILT FENCE
OUTLET PROTECTION
TREE PROTECTION
CONSTRUCTION ENTRANCE WITH WASH RACK
MULCH
TEMPORARY SEEDING
PERMANENT SEEDING
TEMPORARY SLOPE DRAIN
SEDIMENT BASIN
SEDIMENT TRAP
LIMIT OF CLEARING
EXISTING GRADE
FINISHED GRADE
EXISTING ASPHALT PARKING LOT
EXISTING TWO STORY BLDG.
LIMIT OF CLEARING
WASH RACK
CENTER STREET
EXISTING RESIDENTIAL AREA
CLEARING & GRUBBING SHALL BE PERFORMED BY HAND
EXIST. 1 STORY BLDG.
GRAVEL PARKING
EXISTING GRAVEL ROAD
TO HARPER'S CREEK
N
SAMPLE E&S PLAN

Map #5 Plate 6-5

Erosion and Sediment Control Plan

Details & Notes

GENERAL EROSION AND SEDIMENT CONTROL NOTES

ES-1: Unless otherwise indicated, all vegetative and structural erosion and sediment control practices will be constructed and maintained according to minimum standards and specifications of the Virginia Erosion and Sediment Control Handbook and Virginia Regulations VR 625-02-00 Erosion and Sediment Control Regulations.

ES-2: The plan approving authority must be notified one week prior to the pre-construction conference, one week prior to the commencement of land disturbing activity, and one week prior to the final inspection.

ES-3: All erosion and sediment control measures are to be placed prior to or as the first step in clearing.

ES-4: A copy of the approved erosion and sediment control plan shall be maintained on the site at all times.

ES-5: Prior to commencing land disturbing activities in areas other than indicated on these plans (including, but not limited to, off-site borrow or waste areas), the contractor shall submit a supplementary erosion control plan to the owner for review and approval by the plan approving authority.

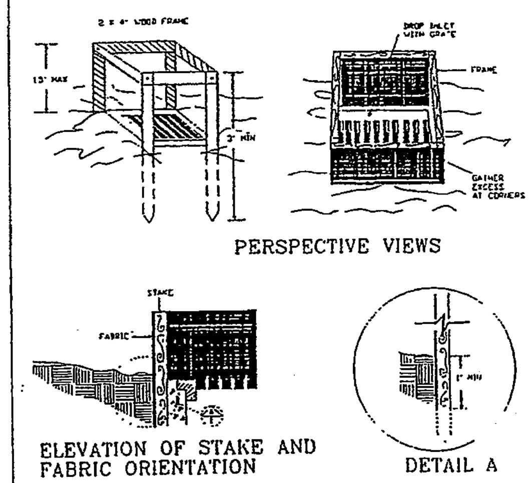
ES-6: The contractor is responsible for installation of any additional erosion control measures necessary to prevent erosion sedimentation as determined by the plan approving authority.

ES-7: Site grading is to drain to the sediment basins at all times during land disturbing activities and during site development until final stabilization is achieved.

ES-8: During dewatering operations, water will be pumped into sediment basins or silt traps.

ES-9: The contractor shall inspect all erosion control measures periodically and after each runoff-producing rainfall event. Any necessary repairs or cleanup to maintain the effectiveness of the erosion control devices shall be made immediately.

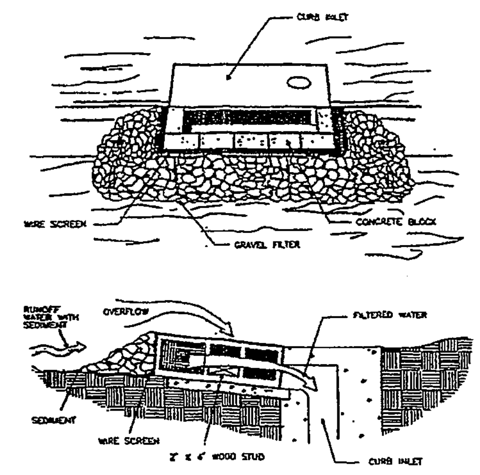
SILT FENCE DROP INLET PROTECTION



SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE THE INLET DRAINS A RELATIVELY FLAT AREA (SLOPE NO GREATER THAN 5%) WHERE THE INLET SHEET OR OVERLAND FLOWS (NOT EXCEEDING 1 C.F.S.) ARE TYPICAL. THE METHOD SHALL NOT APPLY TO INLETS RECEIVING CONCENTRATED FLOWS, SUCH AS IN STREET OR HIGHWAY MEDIANS

BLOCK & GRAVEL CURB INLET SEDIMENT FILTER

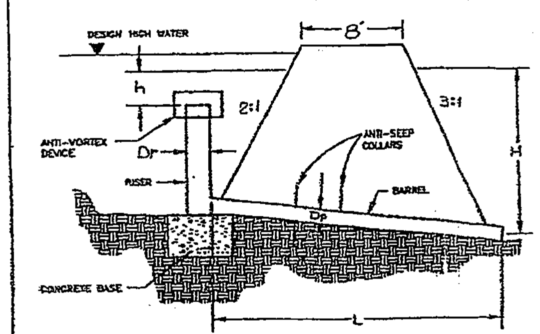


SPECIAL APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE AT CURB INLETS WHERE AN OVERFLOW CAPABILITY IS NECESSARY TO PREVENT EXCESSIVE PONDING IN FRONT OF THE STRUCTURE.

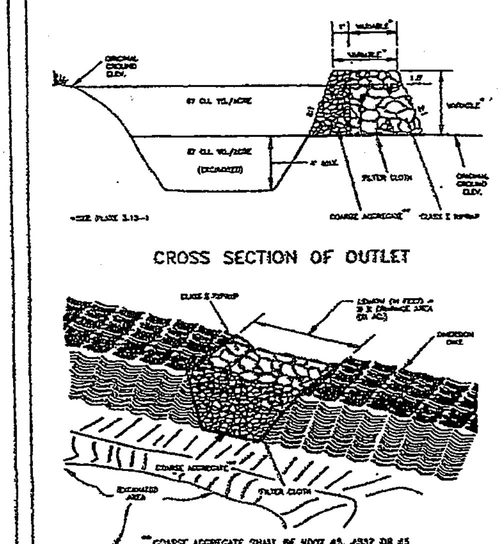
* GRAVEL SHALL BE VDOT #3, #357 OR #5 COARSE AGGREGATE

PRINCIPAL SPILLWAY DESIGN

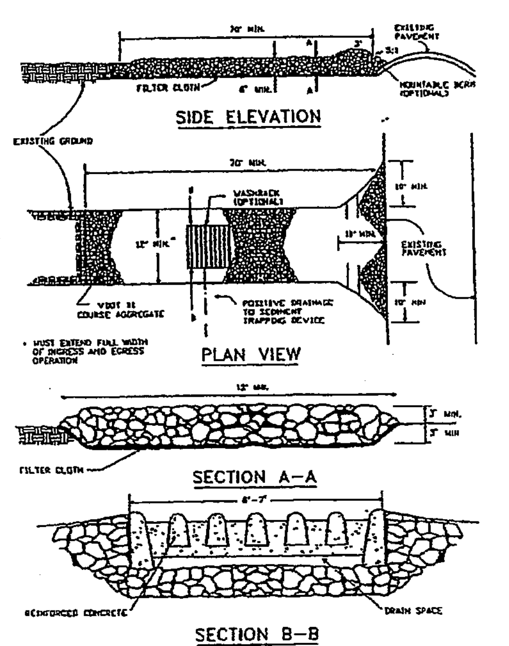


H = HEAD ON PIPE THROUGH EMBANKMENT = 9'
h = HEAD OVER RISER CREST = 1'
L = LENGTH OF PIPE THROUGH EMBANKMENT = 50'
D_p = DIAMETER OF PIPE THROUGH EMBANKMENT = 30"
D_r = DIAMETER OF RISER = 60"

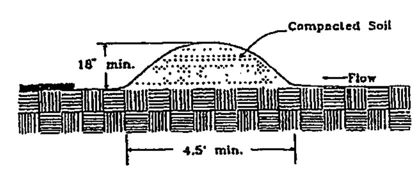
TEMPORARY SEDIMENT TRAP



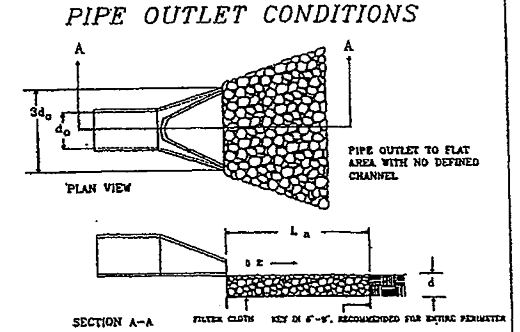
STONE CONSTRUCTION ENTRANCE



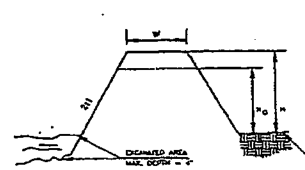
TEMPORARY DIVERSION DIKE



PIPE OUTLET CONDITIONS

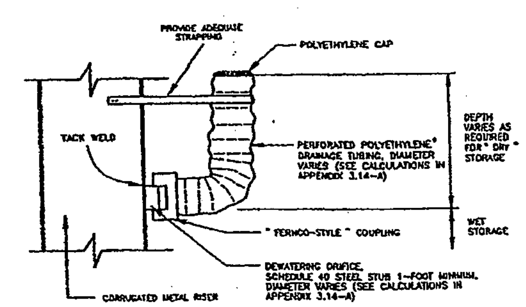


MINIMUM TOP WIDTH (W) REQUIRED FOR SEDIMENT TRAP EMBANKMENTS ACCORDING TO HEIGHT OF EMBANKMENT (FEET)



H	Ho	W
1.5	0.5	2.0
2.0	1.0	2.0
2.5	1.5	2.5
3.0	2.0	2.5
3.5	2.5	3.0
4.0	3.0	3.0
4.5	3.5	4.0
5.0	4.0	4.5

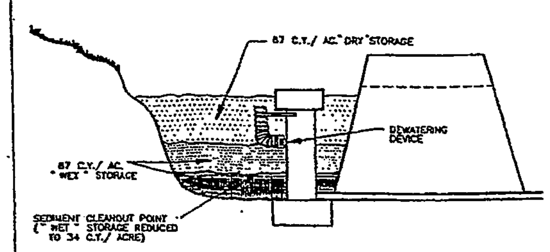
RECOMMENDED DEWATERING SYSTEM FOR SEDIMENT BASIN



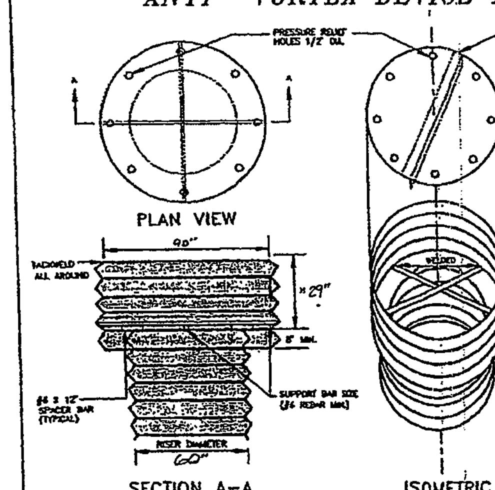
NOTE: WITH CONCRETE RISER, USE PVC SCHEDULE 40 STUB FOR DEWATERING ORIFICE

*DRAINAGE TUBING SHALL COMPLY WITH ASTM F667 AND AASHTO M294

MINIMUM STORAGE VOLUME AND SEDIMENT STORAGE



ANTI- VORTEX DEVICE DESIGN



TOP STIFFENER (IF REQUIRED) IS __ X __ ANGLE WELDED TO TOP AND ORIENTED PERPENDICULAR TO CORRUGATIONS.

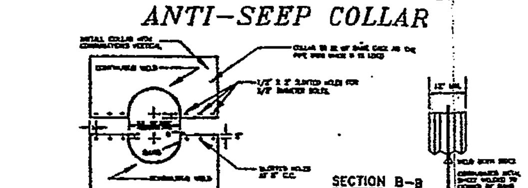
TOP IS __ GAGE CORRUGATED METAL OR 1/8" STEEL PLATE. PRESSURE RELIEF HOLES MAY BE OMITTED, IF ENDS OF CORRUGATIONS ARE LEFT FULLY OPEN WHEN THE TOP IS ATTACHED.

CYLINDER IS __ GAGE CORRUGATED METAL PIPE OR FABRICATED FROM 1/8" STEEL PLATE.

NOTES:

1. THE CYLINDER MUST BE FIRMLY FASTENED TO THE TOP OF THE RISER.
2. SUPPORT BARS ARE WELDED TO THE TOP OF THE RISER OR ATTACHED BY STRAPS BOLTED TO TOP OF RISER.

DETAILS OF CORRUGATED METAL ANTI-SEEP COLLAR



ELEVATION OF UNASSEMBLED COLLAR

NOTES FOR COLLARS:

1. ALL MATERIALS TO BE IN ACCORDANCE WITH CONSTRUCTION AND CONSTRUCTION MATERIAL SPECIFICATIONS.
2. WHEN SPECIFIED ON THE PLANS, COATING OF COLLARS SHALL BE IN ACCORDANCE WITH CONSTRUCTION AND CONSTRUCTION MATERIAL SPECIFICATIONS.
3. UNASSEMBLED COLLARS SHALL BE MARKED BY PAINTING OR TAGGING TO IDENTIFY MATCHING PAIRS.
4. THE LAP BETWEEN THE TWO HALF SECTIONS AND BETWEEN THE PIPE AND CONNECTING BAND SHALL BE CAULKED WITH ASPHALT MASTIC AT TIME OF INSTALLATION.
5. EACH COLLAR SHALL BE FURNISHED WITH TWO 1/2" DIAMETER RODS WITH STANDARD TANK LUGS FOR CONNECTING COLLARS TO PIPE.

Sample E&S Plan		
SCALE:	APPROVED BY:	DRAWN BY
DATE:		REVISED
Details & Notes		DRAWING NUMBER

APPENDIX 6A

SOILS INFORMATION

In many instances, a major soil-related problem is discovered after a site has been selected and construction is either well under way or in some cases completed. These problems often necessitate delays in construction and ultimately increase the total cost of the project. By consulting a soil survey during early in the planning process, designs can be prepared to address soil characteristics or alternate sites can be selected. Knowing the types of soil, the topography, and surface drainage patterns will prove very beneficial in planning and designing almost any type of land development project and is essential for erosion control planning.

Reference to soil maps and accompanying supportive data contained in soil surveys enables planners to determine the soil conditions in proposed construction areas. Soil surveys have proven to be of great savings in time and money, and their use has resulted in improved designs, more effective planning, and more accurate preliminary estimates of construction costs. In many cases, the survey will provide adequate information, but in other situations, it may only provide warnings or indications of soil-related problems likely to be encountered. In such cases, a more in-depth, on-site investigation may be needed.

Soil surveys are helpful in providing interpretations of the effect of soil properties on various land uses. This information can aid in determining soil suitability as a source of topsoil, fill for highway subgrade, or sand and gravel. The interpretations also show the degree of limitation of soils used for such purposes as: building foundations, highways, streets, roads, parking lots, pipelines, underground utility lines, and septic tank absorption fields.

Soil surveys describe soil properties that become important in erosion and sediment control planning for construction sites. These properties include the following:

Erodibility - The major soil consideration from an erosion and sediment control standpoint is its erodibility. An erodibility factor (K) indicates the susceptibility of different soils to the forces of erosion. A soil survey report includes the K factor for each soil found in the survey area. These K factors are used in the Universal Soil Loss Equation to determine soil loss from an area over a period of time due to splash, sheet, and rill erosion. K factors in Virginia range from about .10 (lowest erodibility) to about .50 (highest erodibility). K factors can be grouped into three general ranges:

0.23 and lower	-	low erodibility
0.23 to 0.36	-	moderate erodibility
0.36 and up	-	high erodibility

Cohesiveness of soil particles varies with different layers of the same soil, causing varying degrees of erodibility at different depths. Therefore, depth of excavation must be considered in determining soil erodibility on a construction site.

Table 6-1 lists the majority of currently known soil types in Virginia along with their corresponding erodibility factors at various depths.

Slope - Slope ranges are recorded in soil surveys. Cut and fill slopes can be identified by studying soil maps. The erosion potential increases as the slope becomes longer and steeper.

Soil Permeability - Permeability is one of the major factors influencing erosion. Soil permeability is a charactistic of the soil that enables it to transmit water or air. Deep, permeable soils are less erodible simply because more of the rainfall soaks in, reducing surface runoff. Permeability also varies with different layers and must be considered when excavating.

Hydrologic Soil Group - The hydrologic soil group is a direct reflection of the infiltration rate of the soil. The hydrologic soil groups, based on the infiltration and transmission rates of the soil, are:

A. (Low runoff potential) Soils having high infiltration rates even when thoroughly wetted.

B. Soils having moderate infiltration rates when thoroughly wetted.

C. Soils having slow infiltration rates when thoroughly wetted.

D. (High runoff potential) Soils having very slow infiltration rates when thoroughly wetted.

Texture - Soil texture refers specifically to the proportions of clay, silt, and sand below 2 millimeters in diameter contained in a mass of soil. Plate 6-5 shows the percentages of clay, silt, and sand in the basic soil textural classes.

Soil texture is a primary factor affecting soil erodibility and is reflected in the erodibility factor (K). Erodibility tends to increase with greater silt and very fine sand content. Soils with high clay content are generally more resistant to detachment, but once detached, the clay particles are easily transported.

Shrink-Swell Potential - Certain soils have clays that shrink when dry and swell when wet. In this situation, special foundations are required to allow for this variation. By consulting the soil survey, soils with these problems can be identified and the necessary precautions can be taken.

Flood Hazard - Although soil survey information does not take the place of hydrologic studies, it does provide estimates of where floods are most likely to occur. The hazards of flooding and ponding are rated in soil surveys, and flood-prone areas are shown on soil maps.

<u>Soil Reaction (pH)</u> - Soil survey information includes the pH of the individual layers of each soil. This factor becomes very helpful when planning the establishment of vegetation on a construction site.

<u>Wetness</u> - Data indicating natural soil drainage, depth to seasonal water table, and suitability for winter grading for various kinds of soils are available in soil surveys. With this information such things as seasonal limitations on the use of heavy earth-moving machinery and the hazard estimation of flooding or damage to underground structures due to soil wetness can be determined.

<u>Depth to Bedrock</u> - Soil surveys indicate the type of bedrock and the areas where bedrock will be encountered at a depth of less than 5 to 6 feet. This factor becomes very helpful in determining time and cost of excavation.

APPENDIX 6B

SOIL SURVEY INFORMATION

Soil surveys in Virginia are conducted as a joint effort by the USDA-Soil Conservation Service, VPI & SU Agronomy Department, and the Virginia Division of Soil and Water Conservation. Additional soils information may be obtained by contacting the local representative of any of these agencies in your area.

The following report details the status of soil surveys in Virginia.

VIRGINIA COOPERATIVE SOIL SURVEY
PROGRESS REPORT through March 31, 1992

Published Modern Soil Surveys (year of publication shown):

Total 55

1985 Albemarle
1979 Augusta
1989 Bedford
1977 Campbell and City of Lynchburg
1967 Carroll
1974 Charlotte
1959 Chesapeake (Norfolk County)
1979 Chesterfield
1982 Clarke
1952 Culpeper
1989 Essex
1963 Fairfax
1956 Fauquier
1958 Fluvanna
1987 Frederick
1985 Giles
1980 Gloucester
1980 Goochland
1986 Greene
1989 Greensville
1980 Hanover
1975 Henrico
1986 Isle of Wight
1985 James City
1974 King George
1963 Lancaster
1960 Loudoun
1976 Louisa
1981 Lunenburg
1975 Madison
1962 Mathews
1956 Mecklenburg
1985 Middlesex
1985 Montgomery
1990 New Kent
1990 Northampton
1963 Northumberland
1960 Nottoway
1961 Orange
1988 Powhatan
1958 Prince Edward
1985 Prince George
1990 Prince William
1985 Pulaski
1961 Rappahannock
1982 Richmond
1982 Rockingham
1991 Shenandoah
1985 Spotsylvania
1974 Stafford
1981 Suffolk
1985 Virginia Beach
1984 Warren
1981 Westmoreland
1985 York

Modern Soil Surveys Completed but not Published (year field work completed):

1988 Accomack
1990 Amelia
1990 Appomattox
1988 Botetourt
1988 Charles City
1988 Dinwiddie
1990 King and Queen
1989 King William
1989 Nelson
1989 Roanoke
1989 Rockbridge
1988 Pittsylvania
1991 Smyth
1988 Wythe

Progressive Surveys Underway:

County	Size Acres	Acres Mapped	Approximate % Completed as of 3/31/92	Other Comments
Alleghany	290,300	125,629	43%	
Amherst	306,300	166,880	54%	
Bath	344,100	127,486	37%	
Brunswick	364,400	98,069	30%	
Buckingham	373,600	56,064	15%	
Caroline	345,300	143,824	42%	
Cumberland	192,400	39,824	21%	
Floyd	244,000	103,926	43%	
Franklin	455,300	153,585	34%	
Grayson	252,900	32,700	13%	
Halifax	530,800	243,755	46%	
Henry	252,700	218,517	86%	
Lee	260,600	-	%	Preliminary
Page	202,400	202,400	100%	
Patrick	311,100	177,704	57%	
Southampton	390,800	256,375	66%	
Surry	198,500	151,392	76%	
Sussex	315,600	92,298	29%	
Tazewell	325,100	153,328	47%	
Tidewater	243,400	54,720	22%	6 Cities
Washington	349,000	335,627	96%	
Jefferson Nat'l Forest:				
South -	385,095	202,647	53%	
North -	306,684	301,479	98%	
Total state:	**26,090,600**	**20,171,650**	**77%**	**5,918,950**

Note: Mapping in progressive survey areas was 235,910 acres from January 1, 1992 through March 31, 1992.

Requests: Total 2

Requests with Priorities: Total 2

Russell
Scott

Remaining Counties without Soil Surveys: Total 6

Bland
Buchanan
Craig
Dickenson
Highland
Wise

Prepared by:

Department of Conservation and Recreation
Division of Soil and Water Conservation
203 Governor Street, Suite 206
Richmond, Virginia 23219-2094
Telephone (804)786-2064

APPENDIX 6C

LISTING OF SOIL TYPES IN VIRGINIA

The majority of soils currently found in Virginia along with their corresponding Hydrologic Soil Group designation are listed on the following pages.

The following key explains some of the abbreviations found the on attached soils list. For abbreviations not listed here, consult your local soil survey.

CL	-	clay loam	LS	-	loamy sand
FS	-	fine sand	SICL	-	silt clay loam
FSL	-	fine sandy loam	SIL	-	silt loam
L	-	loam	SL	-	sandy loam
LFS	-	loamy fine sand	VFSL	-	very fine sandy loam

WTDEPL and WTDEPH refer to range of depths to the surface of the groundwater.

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
ABELL	FSL	B	0.28	2.00	3.50
ABELL	L	B	0.32	2.00	3.50
ABELL	SIL	B	0.32	2.00	3.50
ABELL	SL	B	0.28	2.00	3.50
ABELL VARIANT	L	B	0.32	2.00	3.50
ACKWATER	SICL	D	0.37	1.50	3.00
ACKWATER	SIL	D	0.43	1.50	3.00
ACREDALE	SIL	D	0.37	0.00	1.00
ADEN	SIL	C	0.43	0.00	1.00
AIRMONT	FLV-L	C	0.10	1.50	3.00
ALAGA	FS	A	0.10	6.00	6.00
ALAGA	LS	A	0.10	4.00	6.00
ALAGA	LS	A	0.10	6.00	6.00
ALAGA	S	A	0.10	6.00	6.00
ALBANO	SIL	D	0.37	0.00	1.50
ALBEMARLE	FSL	B	0.20	6.00	6.00
ALBEMARLE	L	B	0.32	6.00	6.00
ALBEMARLE	STV-FSL	B	0.20	6.00	6.00
ALDERFLATS	SIL	D	0.43	0.00	1.00
ALDIE	SIL	D	0.37	1.50	2.50
ALDINO	SIL	C	0.43	1.50	2.50
ALLEGHENY	CB-FSL	B	0.20	6.00	6.00
ALLEGHENY	CB-L	B	0.20	6.00	6.00
ALLEGHENY	FSL	B	0.28	6.00	6.00
ALLEGHENY	L	B	0.32	6.00	6.00
ALLEGHENY	SIL	B	0.32	6.00	6.00
ALONZVILLE	CB-L	B	0.20	6.00	6.00
ALONZVILLE	CB-L	B	0.32	6.00	6.00
ALONZVILLE	FSL	B	0.20	6.00	6.00
ALONZVILLE	L	B	0.32	6.00	6.00
ALTAVISTA	FSL	C	0.24	1.50	2.50
ALTAVISTA	FSL	C	0.37	1.00	2.50
ALTAVISTA	L	C	0.24	1.50	2.50
ALTAVISTA	LS	C	0.17	1.50	2.50
ALTAVISTA	SIL	C	0.32	1.50	2.50
ALTAVISTA	SIL	C	0.37	1.00	2.50
ALTAVISTA	SL	C	0.24	1.50	2.50
ALTAVISTA VARIANT	L	C	0.24	1.50	2.50
ALTICREST	FSL	B	0.24	6.00	6.00
ALTICREST	RB-FSL	B	0.24	6.00	6.00
ALTICREST	SL	B	0.24	6.00	6.00
ANGIE	L	D	0.32	3.00	5.00
ANGIE VARIANT	L	D	0.32	3.00	5.00
APPLING	CL	B	0.24	6.00	6.00
APPLING	CL	B	0.28	6.00	6.00
APPLING	FSL	B	0.24	6.00	6.00
APPLING	GR-COSL	B	0.15	6.00	6.00
APPLING	GR-FSL	B	0.24	6.00	6.00
APPLING	GR-SL	B	0.15	6.00	6.00
APPLING	L	B	0.32	6.00	6.00
APPLING	SCL	B	0.28	6.00	6.00
APPLING	SL	B	0.24	6.00	6.00
APPLING	SL	B	0.28	6.00	6.00
APPLING	VFSL	B	0.24	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
APPLING FINE SANDY L	FSL	B	0.24	6.00	6.00
APPLING GRITTY	GR-SL	B	0.15	6.00	6.00
APPOMATTOX	FSL	B	0.20	4.00	4.00
APPOMATTOX	SL	B	0.20	4.00	4.00
AQUENTS	L	D	0.32	0.00	1.00
AQUULTS	FSL	D	0.28	0.00	1.00
ARAPAHOE	MK-L	B/D	0.15	0.00	1.00
ARCOLA	GR-SIL	C	0.24	6.00	6.00
ARCOLA	SIL	C	0.37	6.00	6.00
ARGENT	SIL	D	0.32	0.00	1.00
ASHBURN*	SIL	C	0.43	1.50	3.00
ASHE	L	B	0.24	6.00	6.00
ASHE	SL	B	0.24	6.00	6.00
ASHE	STV-L	B	0.15	6.00	6.00
ASHE	STV-SL	B	0.15	6.00	6.00
ASHLAR	FSL	B	0.24	6.00	6.00
ASHLAR	GR-SL	B	0.24	6.00	6.00
ASHLAR	LCOS	B	0.20	6.00	6.00
ASHLAR	SL	B	0.24	6.00	6.00
ASHLAR FINE SANDY LO	FSL	B	0.24	6.00	6.00
ASSATEAGUE	FS	A	0.10	6.00	6.00
ASSATEAGUE	S	A	0.10	6.00	6.00
ATKINS	FSL	D	0.28	0.00	1.00
ATKINS	L	D	0.28	0.00	1.00
ATKINS	SIL	D	0.32	0.00	1.00
ATLEE	L	C	0.37	1.50	2.50
ATLEE	SIL	C	0.37	1.50	2.50
ATLEE	VFSL	C	0.37	1.50	2.50
AUGUSTA	FSL	C	0.20	1.00	2.00
AUGUSTA	L	C	0.24	1.00	2.00
AUGUSTA	SIL	C	0.24	1.00	2.00
AUGUSTA	SIL	C	0.43	0.00	1.00
AUGUSTA	SL	C	0.20	1.00	2.00
AUGUSTA VARIANT	SIL	C	0.24	1.00	2.00
AURA	GR-SL	B	0.37	6.00	6.00
AUSTINVILLE	CL	B	4.20	6.00	6.00
AUSTINVILLE	SICL	B	4.20	6.00	6.00
AXIS	VFSL	D	0.24		
AYCOCK	SIL	B	0.37	4.00	6.00
BACKBAY	MPT	D			
BADIN	SIL	B	0.32	6.00	6.00
BAILE	L	D	0.43	0.00	0.50
BAILE	SIL	D	0.43	0.00	0.50
BAILE	ST-SIL	D	0.43	0.00	0.50
BAILEGAP	CB-FSL	B	0.17	6.00	6.00
BAILEGAP	FSL	B	0.24	6.00	6.00
BAILEGAP	FSL	B	0.28	3.00	3.00
BAILEGAP	SL	B	0.24	6.00	6.00
BAILEGAP	STV-FSL	B	0.28	6.00	6.00
BAILEGAP	STV-FSL	B	0.32	6.00	6.00
BAILEGAP	STV-L	B	0.28	6.00	6.00
BAILEGAP	STX-L	B	0.15	6.00	6.00
BAMA	L	B	0.24	6.00	6.00
BAMA	SL	B	0.24	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
BAYBORO	L	D	0.17	0.00	1.00
BAYBORO	MK-L	D	0.10	0.00	1.00
BEACHES	S	D	0.05	0.00	6.00
BECKHAM	CL	B	0.20	6.00	6.00
BELHAVEN	MUCK	D		0.00	1.00
BELTSVILLE	L	C	0.32	1.00	2.50
BELTSVILLE	L	C	0.43	1.50	2.50
BELTSVILLE	SIL	C	0.43	1.50	2.50
BELTSVILLE	SL	C	0.15	1.00	2.50
BELVOIR	L	C	0.37	1.00	2.00
BELVOIR	SL	C	0.37	1.00	2.00
BERKS	CN-L	C	0.17	6.00	6.00
BERKS	CN-SIL	C	0.17	6.00	6.00
BERKS	CNV-SIL	C	0.17	6.00	6.00
BERKS	SIL	C	0.24	6.00	6.00
BERKS	STV-L	C	0.17	6.00	6.00
BERKS	STV-SIL	C	0.17	6.00	6.00
BERKS VARIANT	CN-SIL	D	0.32	0.00	0.50
BERMUDIAN	SIL	B	0.37	3.00	6.00
BERTIE	FSL	B	0.20	1.50	2.50
BERTIE	VFSL	B	0.17	1.50	2.50
BERTIE VARIANT	FSL	B	0.20	1.50	2.50
BETHERA	SIL	D	0.28		
BIBB	FSL	D	0.20	0.50	1.50
BIBB	L	D	0.28	0.50	1.50
BIBB	LS	D	0.15	0.50	1.50
BIBB	SL	D	0.20	0.50	1.50
BILTMORE	FSL	A	0.15	3.50	6.00
BILTMORE	LS	A	0.10	3.50	6.00
BIRDSBORO	L	B	0.37	2.00	6.00
BIRDSBORO	SIL	B	0.37	2.00	6.00
BIRDSBORO*	L	C	0.37	6.00	6.00
BLADEN	L	D	0.37	0.00	1.00
BLADEN	SIL	D	0.37	0.00	1.00
BLAIRTON	SIL	C	0.43	0.50	3.00
BLAND	SICL	C	0.43	6.00	6.00
BLEAKHILL	FSL	C	0.28	1.50	3.00
BLUEMONT*	CB-SIL	B	0.24	6.00	6.00
BOHICKET	MK-SICL	D	0.28		
BOHICKET	MUCK	D	0.28		
BOHICKET	SICL	D	0.28		
BOJAC	FSL	B	0.24	4.00	6.00
BOJAC	FSL	C	0.28	3.00	4.50
BOJAC	GR-LS	B	0.15	4.00	6.00
BOJAC	GR-LS	B	0.24	4.00	6.00
BOJAC	LFS	B	0.17	4.00	6.00
BOJAC	LS	B	0.17	4.00	6.00
BOJAC	SL	B	0.24	4.00	6.00
BOLLING	FSL	C	0.28	1.50	2.50
BOLLING	L	C	0.28	1.50	2.50
BOLLING	SIL	C	0.28	1.50	2.50
BOLLING VARIANT	GR-SL	C	0.20	2.00	3.00
BOLTON	FSL	B	0.28	6.00	6.00
BOLTON	L	B	0.37	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
BOLTON	STV-FSL	B	0.28	6.00	6.00
BOLTON VARIANT	STV-FSL	B	0.28	6.00	6.00
BONNEAU	LS	A	0.15	3.50	5.00
BOOKWOOD	SIL	B	0.32	6.00	6.00
BOTETOURT	L	C	0.32	1.50	2.50
BOTETOURT	SIL	C	0.32	1.50	2.50
BOURNE	FSL	C	0.28	1.50	2.50
BOURNE	L	C	0.37	1.50	2.50
BOURNE	SL	C	0.28	1.50	2.50
BOURNE VARIANT	FSL	C	0.28	1.50	2.50
BOWMANSVILLE	SIL	B/D	0.32	0.00	1.50
BRADDOCK	CB-CL	B	0.24	6.00	6.00
BRADDOCK	CB-FSL	B	0.10	6.00	6.00
BRADDOCK	CB-FSL	B	0.24	6.00	6.00
BRADDOCK	CB-L	B	0.24	6.00	6.00
BRADDOCK	CL	B	0.32	6.00	6.00
BRADDOCK	FSL	B	0.32	6.00	6.00
BRADDOCK	GR-L	B	0.24	6.00	6.00
BRADDOCK	L	B	0.32	6.00	6.00
BRADDOCK	SL	B	0.32	6.00	6.00
BRADDOCK	ST-L	B	0.28	6.00	6.00
BRADDOCK	STV-FSL	B	0.24	6.00	6.00
BRADDOCK	STV-L	B	0.24	6.00	6.00
BRADLEY	FSL	C	0.32	6.00	6.00
BRANDYWINE	GRF-L	C	0.24	6.00	6.00
BRANDYWINE	L	A	0.24	6.00	6.00
BRANDYWINE	L	C	0.24	6.00	6.00
BRANDYWINE	SIL	C	0.24	6.00	6.00
BRANDYWINE	SL	A	0.24	6.00	6.00
BRANDYWINE	ST-L	C	0.24	6.00	6.00
BRANDYWINE GRITTY	GR-L	C	0.20	6.00	6.00
BRECKNOCK	L	B	0.32	6.00	6.00
BRECKNOCK	SIL	B	0.32	6.00	6.00
BREMO	L	C	0.28	6.00	6.00
BREMO	SIL	C	0.28	6.00	6.00
BRENTSVILLE	L	C	0.32	6.00	6.00
BRENTSVILLE	SL	C	0.28	6.00	6.00
BROADWAY	SIL	B	0.28	6.00	6.00
BROCKROAD	L	C	0.32	6.00	6.00
BROCKROAD	SIL	C	0.32	6.00	6.00
BRUSHY	CN-L	B	0.17	6.00	6.00
BRUSHY	CR-L	B	0.17	6.00	6.00
BRUSHY	GR-L	B	0.20	6.00	6.00
BRUSHY	GRV-SIL	B	0.17	6.00	6.00
BRUSHY	GRV-SIL	C	0.20	6.00	6.00
BRUSHY	GRX-L	B	0.17	6.00	6.00
BRUSHY	GRX-L	B	0.20	6.00	6.00
BRUSHY	GRX-SIL	B	0.20	6.00	6.00
BUCHANAN	CB-FSL	C	0.24	0.50	3.00
BUCHANAN	FSL	C	0.32	0.50	3.00
BUCHANAN	L	C	0.32	0.50	3.00
BUCHANAN	SIL	C	0.32	0.50	3.00
BUCHANAN	STV-FSL	C	0.20	0.50	3.00
BUCHANAN	STV-SL	C	0.20	0.50	3.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
BUCHANAN	STX-FSL	C	0.24	0.50	3.00
BUCKHALL	L	B	0.32	6.00	6.00
BUCKHALL	SL	B	0.28	6.00	6.00
BUCKS	L	B	0.32	6.00	6.00
BUCKS	SICL	B	0.32	6.00	6.00
BUCKS	SIL	B	0.32	6.00	6.00
BUCKS	SIL	B	0.37	6.00	6.00
BUCKS	SIL	C	0.37	6.00	6.00
BUCKTON	L	B	0.37	6.00	6.00
BUCKTON	SICL	B	0.37	6.00	6.00
BUCKTON	SIL	B	0.37	6.00	6.00
BUFFSTAT	GR-L	B	0.24	6.00	6.00
BUFFSTAT	SIL	C	0.37	6.00	6.00
BUGLEY	CN-SIL	C/D	0.20	6.00	6.00
BUNCOMBE	LFS	A	0.10	6.00	6.00
BUNCOMBE	LS	A	0.10	6.00	6.00
BURKETOWN	FSL	C	0.28	2.00	3.50
BURROWSVILLE	LS	C	0.32	1.50	3.00
BURROWSVILLE	SL	C	0.32	1.50	3.00
CALVERTON	L	C	0.43	1.00	2.00
CALVERTON	SIL	C	0.43	1.00	2.00
CALVIN	CB-L	C	0.20	6.00	6.00
CALVIN	CN-SIL	C	0.20	6.00	6.00
CALVIN	SIL	C	0.24	6.00	6.00
CALVIN	STV-L	C	0.15	6.00	6.00
CALVIN	STV-SIL	C	0.15	6.00	6.00
CAMOCCA	FS	A/D	0.10	0.00	1.00
CANEYVILLE	SIL	C	0.43	6.00	6.00
CARBO	SICL	C	0.37	6.00	6.00
CARBO	SIL	C	0.37	6.00	6.00
CARDIFF	SY-L	B	0.28	6.00	6.00
CAROLINE	CL	C	0.43	3.50	5.00
CAROLINE	CL	C	0.43	6.00	6.00
CAROLINE	FSL	C	0.43	3.50	5.00
CAROLINE	FSL	C	0.43	6.00	6.00
CAROLINE	L	C	0.43	6.00	6.00
CAROLINE	SIL	C	0.43	3.50	5.00
CAROLINE	SL	C	0.43	6.00	6.00
CAROLINE	VFSL	C	0.43	3.50	5.00
CARRVALE	SIL	D	0.32	1.00	2.00
CARTECAY	FSL	C	0.24	0.50	1.50
CARTECAY	SL	C	0.24	0.50	1.50
CATASKA	CN-SIL	D	0.20	6.00	6.00
CATASKA	STV-L	D	0.15	6.00	6.00
CATASKA	STV-SIL	D	0.15	6.00	6.00
CATASKA	SY-SIL	D	0.20	6.00	6.00
CATHARPIN	SIL	C	0.32	6.00	6.00
CATLETT	GR-SIL	C/D	0.20	6.00	6.00
CATLETT	SIL	C/D	0.32	6.00	6.00
CATOCTIN	CB-SIL	C	0.17	6.00	6.00
CATOCTIN	SIL	C	0.32	6.00	6.00
CATOCTIN	ST-SIL	C	0.17	6.00	6.00
CATOCTIN	STV-L	C	0.32	6.00	6.00
CATOCTIN	STV-SIL	C	0.32	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
CATOCTIN	STX-SIL	C	0.20	6.00	6.00
CATPOINT	FS	A	0.10	4.00	6.00
CATPOINT	LS	A	0.10	4.00	6.00
CAVERNS	SL	B	0.20	6.00	6.00
CECIL	CB-FSL	B	0.28	6.00	6.00
CECIL	CL	B	0.24	6.00	6.00
CECIL	CL	B	0.28	6.00	6.00
CECIL	FSL	B	0.20	6.00	6.00
CECIL	FSL	B	0.28	6.00	6.00
CECIL	GR-FSL	B	0.15	6.00	6.00
CECIL	GR-SL	B	0.15	6.00	6.00
CECIL	GRF-SL	B	0.28	6.00	6.00
CECIL	L	B	0.28	6.00	6.00
CECIL	SCL	B	0.28	6.00	6.00
CECIL	SL	B	0.28	6.00	6.00
CECIL	VFSL	B	0.28	6.00	6.00
CHAGRIN	FSL	B	0.32	4.00	6.00
CHAGRIN	L	B	0.32	4.00	6.00
CHAGRIN	SIL	B	0.32	4.00	6.00
CHAGRIN VARIANT	LS	A	0.10	6.00	6.00
CHAPANOKE	SIL	C	0.43	0.50	1.50
CHASTAIN	L	D	0.32	0.00	1.00
CHASTAIN	SICL	D	0.32	0.00	1.00
CHASTAIN	SIL	D	0.32	0.00	1.00
CHATUGE	L	D	0.32	1.00	2.00
CHATUGE	SL	D	0.32	1.00	2.00
CHAVIES	FSL	B	0.24	6.00	6.00
CHAVIES	SL	B	0.24	6.00	6.00
CHAVIES VARIANT	SL	B	0.24	3.50	3.50
CHENNEBY	L	C	0.37	1.00	2.50
CHENNEBY	SIL	C	0.37	1.00	2.50
CHESTER	CB-L	B	0.32	6.00	6.00
CHESTER	CN-L	B	0.28	6.00	6.00
CHESTER	L	B	0.32	6.00	6.00
CHESTER	SIL	B	0.32	6.00	6.00
CHESTER	SL	B	0.32	6.00	6.00
CHESTER	STV-L	B	0.24	5.00	5.00
CHESTER	STV-L	B	0.32	5.00	5.00
CHESTER LOAM	L	B	0.32	6.00	6.00
CHEWACLA	FSL	C	0.24	0.50	1.50
CHEWACLA	L	C	0.28	0.50	1.50
CHEWACLA	L	C	0.49	1.00	2.00
CHEWACLA	SIL	C	0.28	0.50	1.50
CHEWACLA	SIL	C	0.49	1.00	2.00
CHICKAHOMINY	L	D	0.37		
CHICKAHOMINY	L	D	0.37	0.00	0.50
CHICKAHOMINY	SIL	D	0.37	0.00	0.50
CHILHOWIE	C	C	0.37	6.00	6.00
CHILHOWIE	CN-SICL	C	0.20	6.00	6.00
CHILHOWIE	CN-SICL	C	0.37	6.00	6.00
CHILHOWIE	SIC	C	0.37	6.00	6.00
CHILHOWIE	SICL	C	0.37	6.00	6.00
CHINCOTEAGUE	SIL	D	0.32		
CHIPLEY	S	C	0.10	2.00	3.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
CHISWELL	CN-SIL	D	0.24	6.00	6.00
CHISWELL	CNV-SIL	D	0.20	6.00	6.00
CHISWELL	SIL	D	0.37	6.00	6.00
CHRISTIAN	FSL	C	0.37	6.00	6.00
CHRISTIAN	GR-SIL	C	0.20	6.00	6.00
CHRISTIAN	GRV-SIL	C	0.20	6.00	6.00
CHRISTIAN	SICL	C	0.37	6.00	6.00
CHRISTIAN	SIL	C	0.37	6.00	6.00
CID	L	C	0.37	1.50	2.50
CLAPHAM*	SIL	C	0.43	2.00	3.00
CLEARBROOK	CN-SIL	D	0.32	0.00	0.50
CLIFTON	ST-L	C	0.17	6.00	6.00
CLUBCAF	SIL	D	0.28	0.00	1.50
CLYMER	CN-L	B	0.20	6.00	6.00
CLYMER	FSL	B	0.24	6.00	6.00
CLYMER	L	B	0.24	6.00	6.00
CLYMER	RB-FSL	B	0.10	6.00	6.00
CLYMER	RB-SL	B	0.10	6.00	6.00
CLYMER	RB-SL	B	0.17	6.00	6.00
CLYMER	SL	B	0.24	6.00	6.00
CLYMER	STV-FSL	B	0.17	6.00	6.00
CLYMER	STV-SL	B	0.17	6.00	6.00
CLYMER VARIANT	RB-SL	B	0.10	6.00	6.00
CLYMER VARIANT	STV-SL	B	0.17	6.00	6.00
COASTAL BEACH		D	0.05	0.00	6.00
CODORUS	FSL	C	0.49	1.00	2.00
CODORUS	L	C	0.49	1.00	2.00
CODORUS	SIL	C	0.49	1.00	2.00
CODORUS VARIANT	L	C	0.49	1.00	2.00
COLFAX	FSL	C	0.17	0.50	1.50
COLFAX	FSL	C	0.28	0.50	1.50
COLFAX	L	C	0.32	0.50	1.50
COLFAX	SL	C	0.17	0.50	1.50
COLFAX VARIANT	FSL	C	0.17	0.50	1.50
COLLEEN	GR-L	C	0.24	6.00	6.00
COLLEEN	L	C	0.20	6.00	6.00
COLVARD	FSL	B	0.15	4.00	6.00
COMBS	FSL	B	0.24	6.00	6.00
COMBS	FSL	B	0.28	6.00	6.00
COMBS	L	B	0.28	6.00	6.00
COMBS	SL	B	0.24	6.00	6.00
COMUS	FSL	B	0.43	6.00	6.00
COMUS	L	B	0.43	6.00	6.00
COMUS	SIL	B	0.43	6.00	6.00
CONETOE	LFS	A	0.15	6.00	6.00
CONETOE	LS	A	0.15	6.00	6.00
CONGAREE	FSL	B	0.24	2.50	4.00
CONGAREE	FSL	B	0.43	6.00	6.00
CONGAREE	L	B	0.37	2.50	4.00
CONGAREE	SIL	B	0.37	2.50	4.00
CONGAREE	SIL	B	0.43	6.00	6.00
COOSAW	LS	B	0.10	2.00	3.00
COROLLA	FS	D	0.10	1.50	3.00
CORYDON	SICL	D	0.32	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
COTACO	CB-FSL	C	0.24	1.50	2.50
COTACO	FSL	C	0.37	1.50	2.50
COTACO	L	C	0.37	1.50	2.50
COTACO	SIL	C	0.37	1.50	2.50
COTACO VARIANT	CB-L	C	0.24	2.00	3.00
COTACO VARIANT	SIL	C	0.43	2.00	3.00
COURSEY	L	C	0.32	2.00	3.00
COWEE	CH-L	B	0.20	6.00	6.00
COXVILLE	FSL	D	0.24	0.00	1.50
COXVILLE	L	D	0.24	0.00	1.50
CRAIGSVILLE	CB-FSL	B	0.28	6.00	6.00
CRAIGSVILLE	CB-SL	B	0.20	6.00	6.00
CRAIGSVILLE	CB-SL	B	0.28	6.00	6.00
CRAIGSVILLE	CBV-L	B	0.10	6.00	6.00
CRAIGSVILLE	GR-FSL	B	0.17	6.00	6.00
CRAIGSVILLE	L	B	0.28	6.00	6.00
CRAIGSVILLE	SL	B	0.17	6.00	6.00
CRAVEN	CL	C	0.37	2.00	3.00
CRAVEN	FSL	C	0.32	2.00	3.00
CRAVEN	L	C	0.32	2.00	3.00
CRAVEN	SCL	C	0.37	2.00	3.00
CRAVEN	SIL	C	0.32	2.00	3.00
CREEDMOOR	FSL	C	0.28	1.50	2.00
CREEDMOOR	GR-FSL	C	0.28	1.50	2.00
CREEDMOOR	GRV-SL	C	0.28	1.50	2.00
CREEDMOOR	L	C	0.28	1.50	2.00
CREEDMOOR	SL	C	0.28	1.50	2.00
CREEDMOOR VARIANT	FSL	C	0.37	0.50	1.50
CREEDMORE	FSL	C	0.28	1.50	2.00
CROTON	SIL	D	0.37	0.00	1.50
CROTON	SIL	D	0.43	0.00	0.50
CULLEN	CL	C	0.24	6.00	6.00
CULLEN	L	C	0.37	6.00	6.00
CULPEPER	CL	C	0.37	6.00	6.00
CULPEPER	FSL	C	0.37	6.00	6.00
CULPEPER	L	C	0.37	6.00	6.00
DALEVILLE	L	D	0.32	0.00	1.00
DALEVILLE	SIL	D	0.32	0.00	1.00
DANDRIDGE	SH-SICL	D	0.17	6.00	6.00
DAVIDSON	C	B	0.28	6.00	6.00
DAVIDSON	CL	B	0.24	6.00	6.00
DAVIDSON	CL	B	0.28	6.00	6.00
DAVIDSON	CL	B	0.37	6.00	6.00
DAVIDSON	ST-CL	B	0.20	6.00	6.00
DAWHOO VARIANT	FSL		0.17		
DECATUR	CL	B	0.32	6.00	6.00
DEKALB	CB-FSL	C	0.17	6.00	6.00
DEKALB	CB-L	C	0.17	6.00	6.00
DEKALB	CB-SL	C	0.17	6.00	6.00
DEKALB	CN-FSL	C	0.17	6.00	6.00
DEKALB	CN-L	C	0.17	6.00	6.00
DEKALB	CN-SL	C	0.17	6.00	6.00
DEKALB	FSL	C	0.24	6.00	6.00
DEKALB	RB-FSL	C	0.17	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
DEKALB	SL	C	0.24	6.00	6.00
DEKALB	ST-FSL	C	0.17	6.00	6.00
DEKALB	STV-FSL	C	0.17	6.00	6.00
DEKALB	STV-L	C	0.17	6.00	6.00
DEKALB	STV-SL	C	0.17	6.00	6.00
DEKALB	STX-FSL	C	0.17	6.00	6.00
DEKALB	STX-SL	C	0.17	6.00	6.00
DELANCO	FSL	C	0.37	1.00	2.50
DELANCO	L	C	0.37	1.00	2.50
DELANCO	SIL	C	0.37	1.00	2.50
DELOSS	MK-L	B/D	0.15		
DERROC	CB-FSL	B	0.17	6.00	6.00
DERROC	CB-L	B	0.17	6.00	6.00
DERROC	CB-SL	B	0.17	6.00	6.00
DERROC	CBV-L	B	0.17	6.00	6.00
DERROC	CBV-SL	B	0.17	6.00	6.00
DILLARD	L	C	0.32	2.00	3.00
DOGUE	FSL	C	0.28	1.50	3.00
DOGUE	L	C	0.37	1.50	3.00
DOGUE	SIL	C	0.37	1.50	3.00
DOGUE	SL	C	0.28	1.50	3.00
DOGUE VARIANT	L	C	0.37	1.50	3.00
DOROVAN	MPT	D			
DOTHAN	LS	B	0.15	3.00	5.00
DRAGSTON	FSL	C	0.20	1.00	2.50
DRAGSTON	LFS	C	0.17	1.00	2.50
DRAGSTON	SL	C	0.20	1.00	2.50
DRALL	CN-SL	B	0.17	6.00	6.00
DRALL	STV-LS	B	0.17	6.00	6.00
DRALL	STX-SL	B	0.17	6.00	6.00
DRYPOND	CN-L	D	0.17	6.00	6.00
DRYPOND	CN-SL	D	0.17	6.00	6.00
DRYPOND	GR-SL	D	0.17	6.00	6.00
DRYPOND	GRV-SL	D	0.15	6.00	6.00
DRYPOND	RB-SL	D	0.17	6.00	6.00
DRYPOND	SL	D	0.17	6.00	6.00
DUCKSTON	FS	A/D	0.10	0.00	1.00
DUFFIELD	SIL	B	0.32	6.00	6.00
DULLES	SIL	D	0.43	1.00	2.50
DUMFRIES	SL	B	0.28	6.00	6.00
DUMPS				6.00	6.00
DUMPS	VAR			6.00	6.00
DUMPS, MINES	VAR			6.00	6.00
DUNBAR	FSL	D	0.32	1.00	2.50
DUNNING	SICL	D	0.32	0.00	0.50
DUPLIN	CL	C	0.24	2.00	3.00
DUPLIN	FSL	C	0.24	2.00	3.00
DUPLIN	SIL	C	0.24	2.00	3.00
DUPLIN	VFSL	C	0.24	2.00	3.00
DURHAM	FSL	B	0.24	6.00	6.00
DURHAM	FSL	C	0.28	0.50	1.50
DURHAM	LCOS	B	0.17	6.00	6.00
DURHAM	SL	B	0.24	6.00	6.00
DYKE	CL	B	0.37	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
DYKE	L	B	0.37	6.00	6.00
DYKE	SIL	B	0.37	6.00	6.00
EBBING	L	C	0.37	1.50	3.00
EDGEHILL	GRV-FSL	C	0.15	6.00	6.00
EDGEHILL	GRV-SL	C	0.15	6.00	6.00
EDGEHILL VARIANT	GRV-SL	B	0.24	6.00	6.00
EDGEMONT	CN-FSL	B	0.15	6.00	6.00
EDGEMONT	CN-SL	B	0.15	6.00	6.00
EDGEMONT	STV-SL	B	0.15	6.00	6.00
EDGEMONT	STX-SL	B	0.15	6.00	6.00
EDNEDYTOWN	L	B	0.20	6.00	6.00
EDNEYTOWN	L	B	0.15	6.00	6.00
EDNEYTOWN	L	B	0.20	6.00	6.00
EDNEYTOWN	STV-L	B	0.15	6.00	6.00
EDNEYTOWN	STX-L	B	0.10	6.00	6.00
EDNEYTOWN	STX-L	B	0.15	6.00	6.00
EDNEYVILLE	FSL	B	0.24	6.00	6.00
EDNEYVILLE	L	B	0.24	6.00	6.00
EDNEYVILLE	RB-SL	B	0.17	6.00	6.00
EDNEYVILLE	SL	B	0.17	6.00	6.00
EDNEYVILLE	SL	B	0.24	6.00	6.00
EDNEYVILLE	ST-FSL	B	0.17	6.00	6.00
EDNEYVILLE	STV-L	B	0.15	6.00	6.00
EDNEYVILLE	STV-L	B	0.17	6.00	6.00
EDNEYVILLE	STV-SL	B	0.15	6.00	6.00
EDNEYVILLE	STX-FSL	B	0.17	6.00	6.00
EDNEYVILLE	STX-L	B	0.17	6.00	6.00
EDNEYVILLE	STX-SL	B	0.17	6.00	6.00
EDOM	SH-SICL	C	0.28	6.00	6.00
EDOM	SICL	C	0.28	6.00	6.00
EDOM	SIL	C	0.28	6.00	6.00
ELBERT	L	D	0.37	0.00	1.00
ELBERT	SIL	D	0.43	0.00	1.00
ELBERT VARIANT	SIL	D	0.43	0.00	1.00
ELIOAK	CL	C	0.28	6.00	6.00
ELIOAK	FSL	C	0.32	6.00	6.00
ELIOAK	L	C	0.32	6.00	6.00
ELIOAK	SCL	C	0.32	6.00	6.00
ELIOAK	SICL	C	0.28	6.00	6.00
ELIOAK	SIL	C	0.32	6.00	6.00
ELIOAK	STV-SCL	C	0.32	6.00	6.00
ELIOK	CL	C	0.28	6.00	6.00
ELIOK	FSL	C	0.32	6.00	6.00
ELKTON	SIL	C/D	0.43		
ELLIBER	CRV-SIL	A	0.17	6.00	6.00
ELLIBER	CRV-SIL	A	0.24	6.00	6.00
ELLIBER	GR-L	A	0.24	6.00	6.00
ELSINBORO	L	B	0.37	5.00	5.00
ELSINBORO	SL	B	0.37	5.00	5.00
EMPORIA	FSL	C	0.28	3.00	4.50
EMPORIA	GR-FSL	C	0.28	3.00	4.50
EMPORIA	L	C	0.28	3.00	4.50
EMPORIA	LFS	C	0.28	3.00	4.50
EMPORIA	LS	C	0.28	3.00	4.50

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
EMPORIA	LS	C	0.43	6.00	6.00
EMPORIA	SL	C	0.28	3.00	4.50
ENDCAV	SICL	C	0.37	6.00	6.00
ENDCAV	SIL	C	0.37	6.00	6.00
ENON	CL	C	0.24	6.00	6.00
ENON	FSL	C	0.28	6.00	6.00
ENON	L	C	0.32	6.00	6.00
ENON	SL	C	0.28	6.00	6.00
ENOTT	FSL	C	0.20	6.00	6.00
ENOTT	L	C	0.32	6.00	6.00
ENOTT	SL	C	0.20	6.00	6.00
ERNEST	L	C	0.43	1.50	3.00
ERNEST	SIL	C	0.43	1.50	3.00
ERNEST	STV-L	C	0.32	1.50	3.00
EUBANKS	CL	B	0.32	6.00	6.00
EUBANKS	GRF-L	B	0.24	6.00	6.00
EUBANKS	L	B	0.32	6.00	6.00
EUBANKS	SIL	B	0.32	6.00	6.00
EUBANKS	ST-L	B	0.28	6.00	6.00
EUBANKS	ST-SIL	B	0.28	6.00	6.00
EULONIA	L	C	0.15	1.50	3.50
EULONIA	SL	C	0.24	1.50	3.50
EUNOLA	FSL	C	0.20	1.50	2.50
EUNOLA	L	C	0.20	1.50	2.50
EUNOLA	LFS	C	0.15	1.50	2.50
EUNOLA	SL	C	0.20	1.50	2.50
EVANSHAM	SICL	D	0.20	0.00	0.50
EVARD	FSL	B	0.24	6.00	6.00
EVARD	GRV-SL	B	0.24	6.00	6.00
EVARD	L	B	0.28	6.00	6.00
EVARD	SL	B	0.24	6.00	6.00
EVERGREEN	SIL	B	0.37	2.00	3.00
EXUM	SIL	C	0.37	2.00	3.00
FACEVILLE	FSL	B	0.28	6.00	6.00
FACEVILLE	GR-FSL	B	0.17	6.00	6.00
FACEVILLE	L	B	0.17	6.00	6.00
FACEVILLE	LS	B	0.17	6.00	6.00
FACEVILLE	SL	B	0.28	6.00	6.00
FAIRFAX	L	B	0.43	6.00	6.00
FAIRFAX	SIL	B	0.43	6.00	6.00
FALLSINGTON	FSL	B/D	0.24	0.00	1.00
FALLSINGTON	VFSL	B/D	0.24	0.00	1.00
FAUGUIER	SICL	C	0.32	6.00	6.00
FAUQUIER	L	C	0.32	6.00	6.00
FAUQUIER	SIC	C	0.32	6.00	6.00
FAUQUIER	SICL	C	0.32	6.00	6.00
FAUQUIER	SIL	C	0.32	6.00	6.00
FAUQUIER	ST-SIL	C	0.32	6.00	6.00
FAUQUIER	STV-L	C	0.28	6.00	6.00
FAUQUIER	STV-SIL	C	0.28	6.00	6.00
FAYWOOD	SICL	C	0.37	6.00	6.00
FAYWOOD	SIL	C	0.37	6.00	6.00
FEATHERSTONE	MK-SIL	D	0.49		
FISHERMAN	FS	D	0.10	1.50	3.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
FLATWOODS	SIL	C	0.28	1.50	3.00
FLETCHER	L	B	0.43	6.00	6.00
FLUVANNA	CL	C	0.37	6.00	6.00
FLUVANNA	FSL	C	0.37	6.00	6.00
FLUVANNA	L	C	0.37	6.00	6.00
FLUVANNA	SIL	C	0.37	6.00	6.00
FLUVANNA	STV-SIL	C	0.24	6.00	6.00
FLUVAQUENTS	FSL	D	0.37		
FLUVAQUENTS	SIL	C	0.28	0.50	1.50
FLUVAQUENTS	SIL	D	0.32	0.00	1.00
FORESTDALE	FSL	D	0.37	0.50	2.00
FORESTDALE	L	D	0.43	0.50	2.00
FORESTDALE	SICL	D	0.37	0.50	2.00
FORESTDALE	SIL	D	0.37	0.50	2.00
FORESTDALE	SIL	D	0.43	0.50	2.00
FORK	FSL	C	0.37	1.00	2.00
FORK VARIANT	SIL	C	0.43	1.00	2.00
FRANKSTOWN	CN-SIL	B	0.37	6.00	6.00
FREDERICK	GR-L	B	0.28	6.00	6.00
FREDERICK	GR-L	C	0.15	1.00	2.50
FREDERICK	GR-SIL	B	0.28	6.00	6.00
FREDERICK	GR-SL	B	0.28	6.00	6.00
FREDERICK	GRV-L	B	0.28	6.00	6.00
FREDERICK	GRV-SIL	B	0.28	6.00	6.00
FREDERICK	L	B	0.32	6.00	6.00
FREDERICK	SICL	B	0.32	6.00	6.00
FREDERICK	SIL	B	0.32	6.00	6.00
FREDERICK	STV-SIL	B	0.32	6.00	6.00
FRENCH	L	C	0.28	1.00	2.50
FRERDERICK	GR-L	B	0.28	6.00	6.00
FRIPP	S	A	0.10	6.00	6.00
GAILA	SL	B	0.28	6.00	6.00
GAINESBORO	SIL	C	0.32	6.00	6.00
GALESTOWN	LS	A	0.17	6.00	6.00
GEORGEVILLE	CL	B	0.49	6.00	6.00
GEORGEVILLE	FSL	B	0.43	6.00	6.00
GEORGEVILLE	L	B	0.43	6.00	6.00
GEORGEVILLE	SICL	B	0.49	6.00	6.00
GEORGEVILLE	SIL	B	0.49	6.00	6.00
GEORGEVILLE	VFSL	B	0.43	6.00	6.00
GILPIN	CN-L	C	0.24	6.00	6.00
GILPIN	CN-SIL	C	0.24	6.00	6.00
GILPIN	L	C	0.32	6.00	6.00
GILPIN	SIL	C	0.32	6.00	6.00
GILPIN	ST-SIL	C	0.24	6.00	6.00
GILPIN	STV-SIL	C	0.24	6.00	6.00
GLADEHILL	FSL	B	0.20	6.00	6.00
GLENELG	CB-L	B	0.32	6.00	6.00
GLENELG	CN-L	B	0.28	6.00	6.00
GLENELG	L	B	0.32	6.00	6.00
GLENELG	SIL	B	0.32	6.00	6.00
GLENELG	STV-L	C	0.43	1.50	2.50
GLENVILLE	L	C	0.32	0.50	3.00
GLENVILLE	SIL	C	0.32	0.50	3.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
GLENWOOD	CB-L	B	0.20	6.00	6.00
GLENWOOD VARIANT	RB-L	B	0.05	6.00	6.00
GOLDSBORO	FSL	B	0.20	2.00	3.00
GOLDSBORO	SL	B	0.20	2.00	3.00
GOLDSTON	CN-L	C	0.15	6.00	6.00
GOLDSTON	CN-SIL	C	0.15	6.00	6.00
GOLDSTON	CNV-SIL	C	0.05	6.00	6.00
GOLDSTON	SIL	C	0.15	6.00	6.00
GOLDVEIN	GRF-SIL	C	0.28	1.00	2.00
GOLDVEIN GRITTY	GRF-SIL	C	0.28	1.00	2.00
GORESVILLE*	GR-SIL	B	0.24	6.00	6.00
GREENLEE	STV-L	B	0.10	6.00	6.00
GRIMSLEY	CB-L	B	0.20	6.00	6.00
GRIMSLEY	CB-SL	B	0.20	6.00	6.00
GRIMSLEY	ST-L	B	0.20	6.00	6.00
GRIMSLEY	STX-L	B	0.20	6.00	6.00
GRITNEY	FSL	C	0.20	6.00	6.00
GRITNEY	GR-FSL	C	0.15	6.00	6.00
GROSECLOSE	GR-L	C	0.28	6.00	6.00
GROSECLOSE	GR-SIL	C	0.28	6.00	6.00
GROSECLOSE	L	C	0.43	6.00	6.00
GROSECLOSE	SICL	C	0.32	6.00	6.00
GROSECLOSE	SIL	C	0.43	6.00	6.00
GROVER	FSL	B	0.24	6.00	6.00
GROVER	SCL	B	0.28	6.00	6.00
GROVER	SL	B	0.24	6.00	6.00
GUERNSEY	SIL	C	0.43	1.50	3.00
GULLIED LAND	VAR			6.00	6.00
GULLION	L	C	0.32	1.50	3.00
GULLION	SIL	C	0.32	1.50	3.00
GUNSTOCK	CN-L	C	0.37	6.00	6.00
GUNSTOCK	SL	C	0.28	6.00	6.00
GUYAN	SIL	C	0.32	0.50	1.50
GWINNETT VARIANT	CL	B	0.28	6.00	6.00
HAGERSTOWN	SIL	C	0.32	6.00	6.00
HAGERSTWON	SIL	C	0.32	6.00	6.00
HALEWOOD	L	B	0.32	6.00	6.00
HALEWOOD	STV-FSL	C	0.24	6.00	6.00
HARTLETON	CN-L	B	0.20	6.00	6.00
HARTLETON	STV-L	B	0.15	6.00	6.00
HATBORO	L	D	0.49	0.00	0.50
HATBORO	SIL	D	0.49	0.00	0.50
HAWKSBILL	CB-L	B	0.17	6.00	6.00
HAWKSBILL	CBV-L	B	0.17	6.00	6.00
HAWKSBILL	STX-L	B	0.17	6.00	6.00
HAYESVILE	L	B	0.20	6.00	6.00
HAYESVILLE	CB-L	B	0.20	6.00	6.00
HAYESVILLE	CL	B	0.20	6.00	6.00
HAYESVILLE	CL	B	0.24	6.00	6.00
HAYESVILLE	FSL	B	0.20	6.00	6.00
HAYESVILLE	GR-FSL	B	0.20	6.00	6.00
HAYESVILLE	L	B	0.20	6.00	6.00
HAYESVILLE	STV-FSL	C	0.15	6.00	6.00
HAYESVILLE	STV-L	C	0.15	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
HAYESVILLE	STV-L	C	0.24	6.00	6.00
HAYESVILLE	STV-SCL	C	0.32	6.00	6.00
HAYMARKET	SIL	D	0.32	6.00	6.00
HAYTER	CB-L	B	0.20	6.00	6.00
HAYTER	CBV-L	B	0.15	6.00	6.00
HAYTER	L	B	0.28	6.00	6.00
HAYWOOD	L	B	0.24	6.00	6.00
HAZEL	CN-L	C	0.24	6.00	6.00
HAZEL	L	C	0.32	6.00	6.00
HAZEL	SIL	C	0.32	6.00	6.00
HAZEL	ST-L	C	0.24	6.00	6.00
HAZEL	STV-L	C	0.24	6.00	6.00
HAZEL CHANNERY	CN-SIL	C	0.32	6.00	6.00
HAZELTON	STV-L	B	0.15	6.00	6.00
HAZLETON	CN-SL	B	0.17	6.00	6.00
HAZLETON	ST-SL	B	0.15	6.00	6.00
HAZLETON	STV-SL	B	0.15	6.00	6.00
HAZLETON	STX-SL	B	0.15	6.00	6.00
HELENA	CL	C	0.28	1.50	2.50
HELENA	FSL	C	0.20	1.50	2.50
HELENA	FSL	C	0.24	1.50	2.50
HELENA	GR-COSL	C	0.15	1.50	2.50
HELENA	GRF-FSL	C	0.15	1.50	2.50
HELENA	L	C	0.20	1.50	2.50
HELENA	L	C	0.24	1.50	2.50
HELENA	SL	C	0.20	1.50	2.50
HELENA	SL	C	0.24	1.50	2.50
HERNDON	L	B	0.43	6.00	6.00
HERNDON	SICL	B	0.49	6.00	6.00
HERNDON	SIL	B	0.43	6.00	6.00
HERNDON	VFSL	B	0.43	6.00	6.00
HIWASSEE	CB-FSL	B	0.28	6.00	6.00
HIWASSEE	CB-SL	B	0.24	6.00	6.00
HIWASSEE	CL	B	0.28	6.00	6.00
HIWASSEE	FSL	B	0.28	6.00	6.00
HIWASSEE	GR-L	B	0.24	6.00	6.00
HIWASSEE	L	B	0.28	6.00	6.00
HIWASSEE	SIL	B	0.32	6.00	6.00
HIWASSEE VARIANT	L	B	0.32	6.00	6.00
HOADLY	L	C	0.28	0.50	1.50
HOBUCKEN	L	D	0.10		
HOGELAND*	CB-SIL	C	0.24	6.00	6.00
HOLLYWOOD	CL	D	0.32	6.00	6.00
HUNTINGTON	L	B	0.28	6.00	6.00
HUNTINGTON	SIL	B	0.28	6.00	6.00
HYATTSVILLE	FSL	B	0.28	4.00	6.00
HYDE	SIL	B/D	0.17	0.00	1.50
HYDRAQUENTS	SL	B	0.37	4.00	6.00
HYDRAQUENTS	SL	D	0.37		
INGLEDOVE	L	B	0.32	6.00	6.00
IREDELL	CL	C/D	0.32	1.00	2.00
IREDELL	FSL	C/D	0.28	1.00	2.00
IREDELL	L	C/D	0.32	1.00	2.00
IREDELL	SIL	C/D	0.32	1.00	2.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
IREDELL	SIL	D	0.32	1.00	2.00
IREDELL	SL	C/D	0.28	1.00	2.00
IREDELL	ST-L	C/D	0.24	1.00	2.00
IREDELL	ST-SIL	D	0.28	1.00	2.00
IREDELL VARIANT	SIL	C/D	0.32	1.00	2.00
IRONGATE	L	B	0.37	1.50	3.00
IRONGATE	SL	B	0.37	1.50	3.00
IUKA	FSL	C	0.24	1.00	3.00
IUKA	SL	C	0.24	1.00	3.00
IZAGORA	L	C	0.37	2.00	3.00
IZAGORA	SIL	C	0.37	2.00	3.00
JACKLAND	GR-L	D	0.32	1.00	2.00
JACKLAND	GR-SIL	D	0.32	1.00	2.00
JACKLAND	L	D	0.32	1.00	2.00
JACKLAND	SIL	D	0.32	1.00	2.00
JACKLAND	STV-SIL	D	0.32	1.00	2.00
JEDBURG	L	C	0.32	0.50	1.50
JEFFERSON	CB-FSL	B	0.17	6.00	6.00
JEFFERSON	CB-L	B	0.17	6.00	6.00
JEFFERSON	FSL	B	0.24	6.00	6.00
JEFFERSON	GRV-FSL	B	0.28	6.00	6.00
JEFFERSON	L	B	0.24	6.00	6.00
JEFFERSON	SL	B	0.10	6.00	6.00
JEFFERSON	SL	B	0.24	6.00	6.00
JEFFERSON	STV-FSL	B	0.10	6.00	6.00
JEFFERSON	STV-L	B	0.10	6.00	6.00
JEFFERSON	STV-SL	B	0.10	6.00	6.00
JEFFERSON	STX-L	B	0.10	6.00	6.00
JEFFERSON VARIANT	STV-SL	B	0.24	6.00	6.00
JOHNS	SL	C	0.20	1.50	3.00
JOHNS VARIANT	LS	C	0.43	1.00	2.00
JOHNSTON	L	D	0.20		
JOHNSTON	MK-L	D	0.17		
JUNALUSKA	CN-L	B	0.15	6.00	6.00
KALMIA	FSL	B	0.15	4.00	6.00
KALMIA	FSL	B	0.20	6.00	6.00
KALMIA	SL	B	0.20	6.00	6.00
KELLY	SIL	D	0.37	1.50	2.50
KEMPSVILLE	FSL	B	0.28	6.00	6.00
KEMPSVILLE	GR-FSL	B	0.24	6.00	6.00
KEMPSVILLE	GR-SL	B	0.24	6.00	6.00
KEMPSVILLE	L	B	0.32	6.00	6.00
KEMPSVILLE	LS	B	0.28	6.00	6.00
KEMPSVILLE	SL	B	0.28	6.00	6.00
KEMPSVILLE	VFSL	B	0.32	6.00	6.00
KEMPSVILLE FINE SAND	FSL	B	0.28	6.00	6.00
KENANSVILLE	FS	A	0.15	4.00	6.00
KENANSVILLE	FS	A	0.15	6.00	6.00
KENANSVILLE	LFS	A	0.15	4.00	6.00
KENANSVILLE	LFS	A	0.15	6.00	6.00
KENANSVILLE	LS	A	0.15	4.00	6.00
KENANSVILLE	LS	A	0.15	6.00	6.00
KENANSVILLE	S	A	0.15	6.00	6.00
KENANSVILLE VARIANT	LS	C		3.50	4.50

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
KEYPORT	FSL	C	0.37	1.50	4.00
KEYPORT	SIL	C	0.43	1.50	4.00
KINKORA	L	D	0.43	0.00	0.50
KINKORA	SIL	D	0.43	0.00	0.50
KINSTON	FSL	B/D	0.24	0.00	1.00
KINSTON	L	B/D	0.37	0.00	1.00
KINSTON	SIL	B/D	0.37	0.00	1.00
KLEJ	LFS	B	0.17	1.50	2.00
KLINESVILLE	CN-SIL	C/D	0.20	6.00	6.00
KLINESVILLE	SIL	C/D	0.20	6.00	6.00
KOANNAROCK	CN-SIL	C	0.17	6.00	6.00
KONNAROCK	CN-SIL	C	0.17	6.00	6.00
KONNAROCK	CNV-SIL	C	0.17	6.00	6.00
LAIDIG	CB-FSL	C	0.28	2.50	4.00
LAIDIG	CB-SL	C	0.28	2.50	4.00
LAIDIG	CN-FSL	C	0.24	2.50	4.00
LAIDIG	CN-L	C	0.28	2.50	4.00
LAIDIG	CN-SL	C	0.32	2.50	4.00
LAIDIG	FL-FSL	C	0.24	2.50	4.00
LAIDIG	FSL	C	0.24	2.50	4.00
LAIDIG	FSL	C	0.28	2.50	4.00
LAIDIG	GR-FSL	C	0.24	2.50	4.00
LAIDIG	RB-FSL	C	0.24	2.50	4.00
LAIDIG	RB-SL	C	0.24	2.50	4.00
LAIDIG	SL	C	0.24	2.50	4.00
LAIDIG	STV-FSL	C	0.28	2.50	4.00
LAIDIG	STV-L	C	0.28	2.50	4.00
LAIDIG	STV-SL	C	0.28	2.50	4.00
LAIDIG	STX-SL	C	0.24	2.50	4.00
LAKEHURST VARIANT	S	A	0.10	1.50	3.00
LAKELAND	FS	A	0.10	6.00	6.00
LAKIN	LS	A	0.17	6.00	6.00
LANEXA	MK-SIC	D	0.32		
LANSDALE	L	B	0.28	6.00	6.00
LAROQUE	L	B	0.37	6.00	6.00
LAWNES	MK-SL	D	0.20		
LAWNES	MUCK	D			
LEAF	SIL	D	0.32	0.50	1.50
LEAKSVILLE	SIL	D	0.43	0.00	2.00
LECK KILL	SIL	B	0.32	6.00	6.00
LEEDSVILLE*	CB-L	B	0.28	6.00	6.00
LEETONIA	STV-LS	C	0.17	6.00	6.00
LEETONIA	STX-LS	C	0.17	6.00	6.00
LEGORE	L	B	0.24	6.00	6.00
LEGORE	STV-SIL	B	0.24	6.00	6.00
LEHEW	CB-L	C	0.24	6.00	6.00
LEHEW	CB-SL	C	0.17	6.00	6.00
LEHEW	CN-FSL	C	0.17	6.00	6.00
LEHEW	CN-L	C	0.17	6.00	6.00
LEHEW	CNV-L	C	0.24	6.00	6.00
LEHEW	FL-FSL	C	0.17	6.00	6.00
LEHEW	FSL	C	0.24	6.00	6.00
LEHEW	RB-L	C	0.17	6.00	6.00
LEHEW	STV-L	C	0.17	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
LEHEW	STV-SL	C	0.17	6.00	6.00
LEHEW	STX-FSL	C	0.17	6.00	6.00
LEHEW	STX-L	C	0.17	6.00	6.00
LEHEW	STX-L	C	0.24	6.00	6.00
LENOIR	L	D	0.37	1.00	2.50
LENOIR	SIL	D	0.37	1.00	2.50
LENOIR	VFSL	D	0.37	1.00	2.50
LEON	S	B/D	0.10	0.00	1.00
LEON	S	B/D	0.10	0.50	1.50
LEVY	MK-SIC	D	0.37		
LEVY	SIC	D	0.32		
LEVY	SICL	D	0.37		
LEVY	SIL	D	0.37		
LEW	BY-SIL	B	0.17	6.00	6.00
LEW	CB-SIL	B	0.17	6.00	6.00
LEW	CN-L	B	0.15	6.00	6.00
LEW	SIL	B	0.37	6.00	6.00
LEW	STV-L	B	0.17	6.00	6.00
LEW	STV-SIL	B	0.17	6.00	6.00
LEW	STX-L	B	0.10	6.00	6.00
LEW	STX-SIL	B	0.10	6.00	6.00
LEWISBERRY	SL	B	0.20	6.00	6.00
LIBRARY	SIL	D	0.37	0.50	1.50
LIGNUM	L	C	0.43	1.00	2.50
LIGNUM	SIL	C	0.37	1.00	2.50
LIGNUM	SIL	C	0.43	1.00	2.50
LILY	GR-FSL	B	0.28	6.00	6.00
LILY	GR-SL	B	0.28	6.00	6.00
LILY	L	B	0.28	6.00	6.00
LILY	RB-FSL	B	0.24	6.00	6.00
LILY	SL	B	0.28	6.00	6.00
LILY	STV-FSL	B	0.24	6.00	6.00
LILY	STV-L	B	0.24	6.00	6.00
LILY	STV-SL	B	0.24	6.00	6.00
LILY	STX-SL	B	0.17	6.00	6.00
LINDSIDE	SIL	C	0.32	1.50	3.00
LITTLEJOE	GR-L	B	0.20	6.00	6.00
LITTLEJOE	L	B	0.37	6.00	6.00
LITTLEJOE	SIL	B	0.37	6.00	6.00
LITZ	CN-SIL	C	0.32	6.00	6.00
LITZ	SIL	C	0.37	6.00	6.00
LLOYD	CL	C	0.24	6.00	6.00
LLOYD	FSL	C	0.20	6.00	6.00
LLOYD	L	C	0.37	6.00	6.00
LLOYD	SIL	C	0.37	6.00	6.00
LLOYD VARIANT	L	C	0.37	6.00	6.00
LOBDELL	L	B	0.37	2.00	3.50
LOBDELL	SIL	B	0.37	2.00	3.50
LODI	GR-L	B	0.20	6.00	6.00
LODI	GR-SIL	B	0.20	6.00	6.00
LODI	GRV-SIL	B	0.17	6.00	6.00
LODI	L	B	0.37	6.00	6.00
LODI	SICL	B	0.28	6.00	6.00
LODI	SIL	B	0.37	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
LOUISA	FSL	B	0.28	6.00	6.00
LOUISA	L	B	0.28	6.00	6.00
LOUISA	SL	B	0.28	6.00	6.00
LOUISA VARIANT	L	B	0.28	6.00	6.00
LOUISBURG	FSL	B	0.24	6.00	6.00
LOUISBURG	GR-COSL	B	0.24	6.00	6.00
LOUISBURG	SL	B	0.20	6.00	6.00
LOUISBURG	SL	B	0.24	6.00	6.00
LOUISBURG	ST-SL	B	0.10	6.00	6.00
LOUISBURG	STV-SL	B	0.10	6.00	6.00
LOWELL	SIL	C	0.37	6.00	6.00
LUCKETTS	SIL	B	0.32	6.00	6.00
LUCKETTS*	SIL	B	0.32	6.00	6.00
LUCY	LS	A	0.10	6.00	6.00
LUGNUM	SIL	C	0.43	1.00	2.50
LUMBEE	L	B/D	0.24	0.00	1.50
LUMBEE	SIL	B/D	0.24	0.00	1.50
LUMBEE	SL	B/D	0.24	0.00	1.50
LUMBEE VARIANT	SL	D	0.24	0.00	0.50
LUNT	FSL	C	0.32	6.00	6.00
LUNT	L	C	0.32	6.00	6.00
LYNCHBURG	FSL	C	0.20	0.50	1.50
LYNCHBURG	L	C	0.20	0.50	1.50
MACOVE	CB-SIL	B	0.20	6.00	6.00
MACOVE	CNV-SIL	B	0.20	6.00	6.00
MACOVE	GR-SIL	B	0.20	6.00	6.00
MACOVE	RB-SIL	B	0.05	6.00	6.00
MACOVE	RB-SIL	B	0.20	6.00	6.00
MADE LAND				6.00	6.00
MADELAND				6.00	6.00
MADISON	CB-FSL	B	0.24	6.00	6.00
MADISON	CL	B	0.28	6.00	6.00
MADISON	FSL	B	0.24	6.00	6.00
MADISON	L	B	0.24	6.00	6.00
MADISON	SCL	B	0.28	6.00	6.00
MADISON	SL	B	0.24	6.00	6.00
MAGOTHA	FSL	D	0.28	0.00	1.00
MANASSAS	SIL	B	0.37	2.00	3.00
MANOR	L	B	0.37	6.00	6.00
MANOR	SIL	B	0.37	6.00	6.00
MANOR	STV-L	B	0.32	6.00	6.00
MANTACHIE	L	C	0.28	1.00	1.50
MANTEO	CN-L	C/D	0.28	6.00	6.00
MANTEO	CN-SIL	C/D	0.28	6.00	6.00
MANTEO	CNV-L	C/D	0.28	6.00	6.00
MANTEO	CNV-SIL	C/D	0.28	6.00	6.00
MANTEO	SIL	C/D	0.28	6.00	6.00
MARBIE	SIL	C	0.37	2.00	4.00
MARGO	L	B	0.37	1.00	3.00
MARLBORO	FSL	B	0.20	6.00	6.00
MARR	VFSL	B	0.32	6.00	6.00
MARUMSCO	L	C	0.32	1.00	1.50
MASADA	FSL	C	0.32	6.00	6.00
MASADA	GR-FSL	C	0.24	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
MASADA	GR-L	C	0.24	6.00	6.00
MASADA	L	C	0.32	6.00	6.00
MASADA	SCL	C	0.24	6.00	6.00
MASADA	SCL	C	0.32	6.00	6.00
MASSADA	FSL	C	0.32	6.00	6.00
MASSANETTA	L	B	0.37	2.00	3.50
MASSANETTA	SIL	B	0.37	2.00	3.50
MASSANUTTEN	CN-SIL	B	0.24	6.00	6.00
MASSANUTTEN	STV-L	B	0.24	6.00	6.00
MASSANUTTEN	STV-SIL	B	0.24	6.00	6.00
MATAPEAKE	FSL	B	0.24	6.00	6.00
MATAPEAKE	FSL	B	0.28	4.00	6.00
MATAPEAKE	FSL	B	0.37	6.00	6.00
MATAPEAKE	SIL	B	0.49	6.00	6.00
MATNEFLAT	ST-SL	B	0.15	6.00	6.00
MATTAN	MK-CL	D			
MATTAN	MK-L	D	0.32		
MATTAN	MK-SICL	D	0.32		
MATTAN	MUCK	D			
MATTAPEX	FSL	C	0.37	1.50	2.50
MATTAPEX	L	C	0.32	1.00	1.50
MATTAPEX	SIL	C	0.37	1.50	2.50
MATTAPONI	FSL	C	0.28	3.00	6.00
MATTAPONI	GR-SL	C	0.28	3.00	6.00
MATTAPONI	SCL	C	0.28	3.00	6.00
MATTAPONI	SL	C	0.28	3.00	6.00
MATTAPONI	SL	C	0.32	3.00	6.00
MAURERTOWN	SICL	D	0.37	0.00	0.50
MAURERTOWN	SIL	D	0.43	0.00	0.50
MAYODAN	FSL	B	0.24	6.00	6.00
MAYODAN	GR-FSL	B	0.15	6.00	6.00
MAYODAN	GR-SL	B	0.15	6.00	6.00
MAYODAN	GRV-SL	B	0.24	6.00	6.00
MAYODAN	L	B	0.24	6.00	6.00
MAYODAN	SIL	B	0.24	6.00	6.00
MAYODAN	SL	B	0.24	6.00	6.00
MAYODAN	STV-FSL	B	0.17	6.00	6.00
MAYODAN, CLAYEY SUBS	SL	B	0.24	6.00	6.00
MCGARY	SICL	C	0.43	1.00	3.00
MCGARY	SIL	C	0.43	1.00	3.00
MCQUEEN	L	C	0.37	5.00	6.00
MEADOWS	GR-L	D	0.20	6.00	6.00
MEADOWS	GR-SIL	D	0.20	6.00	6.00
MEADOWVILLE	FSL	B	0.37	3.00	5.00
MEADOWVILLE	L	B	0.37	3.00	5.00
MEADOWVILLE	SIL	B	0.37	3.00	5.00
MEADOWVILLE	STV-SIL	B	0.37	3.00	5.00
MECKLENBURG	CL	C	0.28	6.00	6.00
MECKLENBURG	FSL	C	0.24	6.00	6.00
MECKLENBURG	GR-L	C	0.17	6.00	6.00
MECKLENBURG	L	C	0.24	6.00	6.00
MECKLENBURG	L	D	0.32	6.00	6.00
MECKLENBURG	SIL	C	0.24	6.00	6.00
MECKLENBURG VARIANT	L	C	0.24	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
MEGGETT	SL	D	0.24	0.00	1.00
MELFA	MPT	D		0.00	1.00
MELVIN	SIL	D	0.43	0.00	1.00
MILLROCK	LFS	A	0.17	6.00	6.00
MILLROCK	LS	A	0.17	6.00	6.00
MINE DUMP				6.00	6.00
MINES		A	0.17	6.00	6.00
MINNIEVILLE	CL	C	0.28	6.00	6.00
MINNIEVILLE	L	C	0.37	6.00	6.00
MIXED ALLUVIUM	SL	D	0.24	0.00	1.00
MOLENA	LFS	A	0.10	6.00	6.00
MOLENA	LS	A	0.10	6.00	6.00
MONACAN	SIL	C	0.43	0.50	2.00
MONGLE	L	C	0.37	0.50	1.50
MONONGAHELA	CB-FSL	C	0.37	1.50	3.00
MONONGAHELA	CB-L	C	0.37	1.50	3.00
MONONGAHELA	FSL	C	0.43	1.50	3.00
MONONGAHELA	GR-L	C	0.37	1.50	3.00
MONONGAHELA	L	C	0.43	1.50	3.00
MONONGAHELA	SIL	C	0.43	1.50	3.00
MONTALTO	L	C	0.32	5.00	5.00
MONTALTO	SICL	B	0.28	6.00	6.00
MONTALTO	SICL	C	0.32	5.00	5.00
MONTALTO	SIL	B	0.32	6.00	6.00
MONTALTO	SIL	C	0.32	5.00	5.00
MONTALTO	SIL	C	0.32	6.00	6.00
MONTALTO	ST-SIL	B	0.24	6.00	6.00
MONTALTO	STV-L	C	0.28	6.00	6.00
MONTRESSOR*	GR-SIL	B	0.24	4.00	6.00
MONTROSS	SIL	C	0.49	1.00	2.50
MOOMAW	CB-FSL	C	0.24	1.50	3.00
MOOMAW	FSL	C	0.17	1.50	3.00
MOOMAW	L	C	0.28	1.50	3.00
MORRISONVILLE*	SIL	B	0.32	6.00	6.00
MORRISONVILLE*	STV-SIL	B	0.28	6.00	6.00
MORRISONVILLE*	STV-SIL	B	0.32	6.00	6.00
MORVEN*	SIL	B	0.37	5.00	6.00
MOUNT LUCAS	SIL	C	0.32	0.50	3.00
MT WEATHER*	STV-SIL	B	0.17	6.00	6.00
MUCKALEE	L	D	0.20	0.50	1.50
MUNDEN	FSL	B	0.20	1.50	2.50
MUNDEN	LFS	B	0.17	1.50	2.50
MUNDEN	LS	B	0.17	1.50	2.50
MUNDEN	SL	B	0.20	1.50	2.50
MURRILL	CN-FSL	B	0.32	6.00	6.00
MURRILL	CN-SIL	B	0.28	6.00	6.00
MURRILL	L	B	0.32	6.00	6.00
MURRILL	STV-FSL	B	0.24	6.00	6.00
MURRILL	STV-L	B	0.24	6.00	6.00
MURRILL	STV-SL	B	0.24	6.00	6.00
MYATT	FSL	D	0.28	0.00	1.00
MYATT	L	D	0.32	0.00	1.00
MYATT	SIL	D	0.32	0.00	1.00
MYATT	SL	D	0.28	0.00	1.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
MYATT VARIANT	FSL	D		0.00	1.00
MYERSVILLE	CN-SIL	B	0.20	6.00	6.00
MYERSVILLE	L	B	0.37	6.00	6.00
MYERSVILLE	SIL	B	0.37	6.00	6.00
MYERSVILLE	ST-L	B	0.32	6.00	6.00
MYERSVILLE	ST-SIL	B	0.32	6.00	6.00
MYERSVILLE	STV-L	B	0.28	6.00	6.00
MYERSVILLE	STV-L	B	0.32	6.00	6.00
MYERSVILLE	STV-SIL	B	0.28	6.00	6.00
MYERSVILLE	STV-SIL	B	0.32	6.00	6.00
MYERSVILLE	STX-SIL	B	0.32	6.00	6.00
MYSERSVILLE	STV-L	B	0.28	6.00	6.00
NAHUNTA	SIL	C	0.43	1.00	2.50
NANSEMOND	FSL	C	0.20	1.50	2.50
NANSEMOND	LFS	C	0.15	1.50	2.50
NANSEMOND	LS	C	0.15	1.50	2.50
NANSEMOND	SL	C	0.20	1.50	2.50
NASON	GR-L	B	0.24	6.00	6.00
NASON	GR-SIL	B	0.24	6.00	6.00
NASON	L	C	0.43	6.00	6.00
NASON	SICL	C	0.49	6.00	6.00
NASON	SIL	C	0.43	6.00	6.00
NAWNEY	L	D	0.24	0.00	0.50
NAWNEY	SIL	D	0.32		
NAWNEY	SIL	D	0.32	0.00	0.50
NEABSCO	L	C	0.32	1.00	2.50
NESTORIA	GR-SIL	C/D	0.28	6.00	6.00
NEVARC	CL	C	0.32	1.50	3.00
NEVARC	FSL	C	0.32	1.50	3.00
NEVARC	L	C	0.37	1.50	3.00
NEVARC	SIL	C	0.37	1.50	3.00
NEVARC	SL	C	0.32	1.50	3.00
NEVRAC	SL	C	0.32	1.50	3.00
NEWARK	SIL	C	0.43	0.50	1.50
NEWARK VARIANT	SIL	C	0.43	0.50	1.50
NEWBERN	SIL	C	0.28	6.00	6.00
NEWFLAT	SIL	D	0.37	0.50	1.50
NEWHAN	FS	A	0.10	6.00	6.00
NEWMARC	SIL	C	0.32	0.50	1.50
NICHOLSON	SIL	C	0.43	1.50	2.50
NIMMO	FSL	D	0.20	0.00	1.00
NIMMO	L	D	0.20	0.00	1.00
NIMMO	SL	D	0.20	0.00	1.00
NIXA	CRV-SIL	C	0.32	6.00	6.00
NIXA	GR-L	C	0.32	6.00	6.00
NOLICHUCKY	GR-SL	B	0.15	6.00	6.00
NOLICHUCKY	L	B	0.28	6.00	6.00
NOLICHUCKY	STV-SL	B	0.20	6.00	6.00
NOLIN	SIL	B	0.43	3.00	6.00
NOMBERVILLE	L	B	0.28	6.00	6.00
NOMBERVILLE	SIL	B	0.28	6.00	6.00
NORFOLK	FSL	B	0.20	4.00	6.00
OAKHILL	GR-SIL	B	0.20	6.00	6.00
OAKLET	SIL	C	0.37	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
OATLANDS	L	B	0.32	6.00	6.00
OCCOQUAN	L	B	0.37	6.00	6.00
OCCOQUAN	SL	B	0.24	6.00	6.00
OCCOQUAN	STV-L	B	0.20	6.00	6.00
OCHLOCKONEE	SIL	B	0.24	3.00	5.00
OCHLOCKONEE	SL	B	0.20	3.00	5.00
OCHLOCKONEE VARIANT	SL	C		2.00	4.50
OKEETEE	SL	D	0.24	0.50	1.00
OPEQUON	SIC	C	0.37	6.00	6.00
OPEQUON	SICL	C	0.37	6.00	6.00
OPEQUON	SIL	C	0.43	6.00	6.00
ORAGNE	SIL	D	0.28	1.00	3.00
ORANGE	FSL	D	0.15	1.00	3.00
ORANGE	L	D	0.28	1.00	3.00
ORANGE	SIL	D	0.28	1.00	3.00
ORANGE	SIL	D	0.32	1.00	2.00
ORANGE	SL	D	0.15	1.00	3.00
ORANGE	STV-SIL	D	0.24	1.00	3.00
ORANGE VARIANT	SIL	D	0.28	1.00	3.00
ORANGEBURG	FSL	B	0.20	6.00	6.00
ORANGEBURG	LS	B	0.10	6.00	6.00
ORANGEBURG	SL	B	0.20	6.00	6.00
ORENDA	L	B	0.37	6.00	6.00
ORISKANY	BYX-SL	B	0.10	6.00	6.00
ORISKANY	L	B	0.15	6.00	6.00
ORISKANY	RB-L	B	0.05	6.00	6.00
ORISKANY	RB-SL	B	0.05	6.00	6.00
ORISKANY	STV-L	B	0.15	6.00	6.00
ORISKANY	STV-SL	B	0.15	6.00	6.00
OSIER	LFS	A/D	0.15	0.00	1.00
OTHELLO	FSL	C/D	0.37	0.00	1.00
OTHELLO	SIL	C/D	0.37	0.00	1.00
PACOLET	CL	B	0.24	6.00	6.00
PACOLET	FSL	B	0.20	6.00	6.00
PACOLET	GR-FSL	B	0.15	6.00	6.00
PACOLET	GR-SL	B	0.15	6.00	6.00
PACOLET	SCL	B	0.24	6.00	6.00
PACOLET	SL	B	0.15	6.00	6.00
PACOLET	SL	B	0.20	6.00	6.00
PACTOLUS	FS	A	0.10	1.50	3.00
PACTOLUS	LFS	A	0.10	1.50	3.00
PACTOLUS	LS	A	0.10	1.50	3.00
PAGEBROOK	SICL	D	0.37	2.00	4.00
PAGEBROOK	SIL	D	0.37	2.00	4.00
PAMLICO	MUCK	D			
PAMLICO	MUCK	D		0.00	1.00
PAMUNKEY	CL	B	0.28	6.00	6.00
PAMUNKEY	FSL	B	0.28	4.00	6.00
PAMUNKEY	FSL	B	0.28	6.00	6.00
PAMUNKEY	L	B	0.28	4.00	6.00
PAMUNKEY	L	B	0.28	6.00	6.00
PAMUNKEY	LS	B	0.28	6.00	6.00
PAMUNKEY	SL	B	0.28	6.00	6.00
PAMUNKEY VARIANT	GR-SL	A	0.20	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
PANORAMA	SIL	B	0.37	6.00	6.00
PARKER	CB-L	B	0.17	6.00	6.00
PARKER	STV-L	B	0.17	6.00	6.00
PARKER	STV-SL	B	0.17	6.00	6.00
PARKER	STX-L	B	0.17	6.00	6.00
PARTLOW	FSL	D	0.28	0.00	1.00
PARTLOW	L	D	0.32	0.00	1.00
PARTLOW	SL	D	0.28	0.00	1.00
PASQUOTANK	VFSL	B/D	0.43	1.00	2.00
PEAKS	BY-SIL	C	0.15	6.00	6.00
PEAKS	CN-SIL	C	0.17	6.00	6.00
PEAKS	GR-FSL	C	0.17	6.00	6.00
PEAKS	GR-L	C	0.17	6.00	6.00
PEAKS	GR-SL	C	0.17	6.00	6.00
PEAKS	RB-SIL	C	0.15	6.00	6.00
PEAKS	RB-SL	C	0.15	6.00	6.00
PEAKS	STV-FSL	C	0.15	6.00	6.00
PEAKS	STV-L	C	0.15	6.00	6.00
PEAKS	STV-SL	C	0.15	6.00	6.00
PEAKS	STX-SL	C	0.15	6.00	6.00
PEAWICK	CL	D	0.37	1.50	3.00
PEAWICK	L	D	0.37	1.50	3.00
PEAWICK	SIL	D	0.37	1.50	3.00
PENN	CN-SIL	C/D	0.17	6.00	6.00
PENN	GR-L	C/D	0.28	6.00	6.00
PENN	L	C	0.32	6.00	6.00
PENN	SH-SIL	C	0.28	6.00	6.00
PENN	SIL	C	0.32	6.00	6.00
PENN	SIL	C	0.37	6.00	6.00
PENN	SIL	C/D	0.28	6.00	6.00
PENNN	L	C	0.32	6.00	6.00
PHILO	SIL	B	0.37	1.50	3.00
PHILO	SL	B	0.28	1.50	3.00
PHILOMOMT*	STV-SIL	B	0.32	6.00	6.00
PHILOMONT	SL	B	0.32	6.00	6.00
PINEYWOODS	L	D	0.37	0.00	1.00
PINEYWOODS	SIL	D	0.37	0.00	1.00
PINKSTON	CB-SL	B	0.17	6.00	6.00
PINKSTON	FSL	B	0.20	6.00	6.00
PINKSTON	GR-SL	B	0.10	6.00	6.00
PINKSTON	SL	B	0.20	6.00	6.00
PINKSTON	STV-SL	B	0.15	6.00	6.00
PISGAH	SIL	C	0.37	6.00	6.00
PITS				6.00	6.00
PITS		A	0.02	6.00	6.00
PITS		A	0.17	6.00	6.00
PITS	UWB			6.00	6.00
PITS	VAR			6.00	6.00
PITS AND DUMPS				6.00	6.00
PITS QUARRIES	VAR			6.00	6.00
PITS, BEDROCK	UWB			6.00	6.00
PITS, GRAVEL		A	0.02	6.00	6.00
PITS, GRAVEL	GRX-COS	A	0.02	6.00	6.00
PITS, GRAVELLY	GRX-S	A	0.02	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
PITS, QUARRIES	VAR			6.00	6.00
PITS, QUARRIES, LAND				6.00	6.00
PITS, QUARRY				6.00	6.00
PITS, QUARRY	UWB			6.00	6.00
POCATY	MUCK	D			
POCATY	PEAT	D			
POCOMOKE	FSL	B/D	0.20		
POINDEXTER	FSL	B	0.28	6.00	6.00
POINDEXTER	GR-SIL	B	0.32	6.00	6.00
POINDEXTER	L	B	0.37	6.00	6.00
POINDEXTER	SIL	B	0.37	6.00	6.00
POINDEXTER	SL	B	0.28	6.00	6.00
POLAWANA	LS	A/D	0.10		
POLAWANA	MK-SL	A/D	0.10		
POOLER VARIANT	L	D	0.24	0.00	1.00
POPE	FSL	B	0.28	6.00	6.00
POPE	GR-FSL	B	0.28	6.00	6.00
POPLIMENTO	GR-L	C	0.32	6.00	6.00
POPLIMENTO	GR-SIL	C	0.24	6.00	6.00
POPLIMENTO	GRV-L	C	0.24	6.00	6.00
POPLIMENTO	L	C	0.32	6.00	6.00
POPLIMENTO	SIL	C	0.32	6.00	6.00
PORTERS	CB-L	B	0.17	6.00	6.00
PORTERS	L	B	0.28	6.00	6.00
PORTERS	RB-L	B	0.17	6.00	6.00
PORTERS	SL	B	0.24	6.00	6.00
PORTERS	ST-L	B	0.17	6.00	6.00
PORTERS	STV-FSL	B	0.17	6.00	6.00
PORTERS	STV-L	B	0.17	6.00	6.00
PORTSMOUTH	L	B/D	0.24	0.00	1.00
PORTSMOUTH	MK-L	B/D	0.24	0.00	1.00
PORTSMOUTH	SIL	B/D	0.32	0.00	1.00
PORTSMOUTH	SL	B/D	0.24	0.00	1.00
POUNCEY	FSL	D	0.28	0.00	0.00
POUNCEY	SL	D	0.28	0.00	0.00
POYNER	GRV-SIL	B	0.28	6.00	6.00
POYNOR	GRV-SIL	B	0.28	6.00	6.00
POYNOR	GRX-L	B	0.28	6.00	6.00
POYNOR	GRX-SIL	B	0.28	6.00	6.00
PUNGO	MUCK	D		0.00	1.00
PURCELLVILLE	SIL	B	0.32	6.00	6.00
PURDY	L	D	0.43		
PURDY	SICL	D	0.43		
PURDY	SIL	D	0.43		
QUANTICO	L	B	0.32	6.00	6.00
QUANTICO	SL	B	0.32	6.00	6.00
QUARRIES				6.00	6.00
QUARRY				6.00	6.00
RABUM	SIL	B	0.32	6.00	6.00
RABUN	C	B	0.32	6.00	6.00
RABUN	CL	B	0.32	6.00	6.00
RABUN	SIL	B	0.32	6.00	6.00
RABUN	STV-CL	B	0.20	6.00	6.00
RAINS	FSL	B/D	0.20	0.00	1.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
RAINS	L	B/D	0.15	0.00	1.00
RAINS	VFSL	B/D	0.20	0.00	1.00
RAMSEY	ST-FSL	D	0.17	6.00	6.00
RAMSEY	ST-SL	D	0.17	6.00	6.00
RAMSEY	STV-L	D	0.20	6.00	6.00
RAMSEY	STV-SL	D	0.10	6.00	6.00
RAPIDAN	SICL	B	0.37	6.00	6.00
RAPIDAN	SIL	B	0.37	6.00	6.00
RAPPAHANNOCK	M-PT	D			
RAPPAHANNOCK	MUCK	D			
RAPPAHANNOCK	SICL	D	0.32		
RAPPAHANNOCK	SP	D			
RARITAN	SIL	C	0.37	0.50	3.00
RARITAN	SIL	C	0.43	0.50	3.00
RAYNE	CN-L	B	0.20	6.00	6.00
RAYNE	SIL	B	0.28	6.00	6.00
READINGTON	SIL	C	0.43	1.50	3.00
REAVILLE	SIL	C	0.43	0.50	3.00
REMLIK	FS	A	0.10	4.00	6.00
REMLIK	GR-LS	A	0.10	4.00	6.00
REMLIK	LFS	A	0.10	4.00	6.00
REMLIK	LS	A	0.10	4.00	6.00
RIGLEY	STV-SL	B	0.24	6.00	6.00
RION	FSL	B	0.24	6.00	6.00
RIVERVIEW	L	B	0.32	3.00	5.00
RIVERVIEW	LFS	B	0.20	3.00	5.00
RIVERVIEW	SIL	B	0.32	3.00	5.00
RIVERVIEW	SL	B	0.24	3.00	5.00
RIVERWASH	CBX-SL	D		0.00	2.00
ROANOKE	FSL	D	0.28	0.00	1.00
ROANOKE	L	D	0.37	0.00	1.00
ROANOKE	SIL	D	0.37		
ROANOKE	SIL	D	0.37	0.00	1.00
ROCK LAND		D		6.00	6.00
ROCK LAND BASIC		D		6.00	6.00
ROCK OURCROP	UWB	D		6.00	6.00
ROCK OUTCROP		D		6.00	6.00
ROCK OUTCROP	UWB	D		6.00	6.00
ROCK OUTCROP	VAR	D		6.00	6.00
ROHRERSVILLE	SIL	D	0.43	0.50	1.50
ROHRERSVILLE	STV-SIL	D	0.43	0.50	1.50
ROHRESVILLE	SIL	D	0.43	0.50	1.50
ROSS	L	B	0.32	4.00	6.00
ROWLAND	SIL	C	0.43	1.00	3.00
RUBBLE LAND	FRAG	A		6.00	6.00
RUBBLELAND	FRAG	A		6.00	6.00
RUMFORD	FSL	B	0.24	6.00	6.00
RUMFORD	LFS	B	0.17	6.00	6.00
RUMFORD	LS	B	0.17	6.00	6.00
RUSHTOWN	CN-SIL	A	0.24	6.00	6.00
RUSHTOWN	CNV-SIL	A	0.17	6.00	6.00
RUSTON	FSL	B	0.28	6.00	6.00
SAFELL	FSL	B	0.24	6.00	6.00
SASSAFRAS	FSL	B	0.24	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
SASSAFRAS	FSL	B	0.28	6.00	6.00
SASSAFRAS	LFS	B	0.17	6.00	6.00
SASSAFRAS	SL	B	0.24	6.00	6.00
SASSFRAS	FSL	B	0.24	6.00	6.00
SAUNOOK	L	B	0.24	6.00	6.00
SAUNOOK	STV-L	B	0.24	6.00	6.00
SAVANNAH	FSL	C	0.24	1.50	3.00
SAVANNAH	L	C	0.37	1.50	3.00
SAVANNAH	SL	C	0.28	1.50	2.50
SCATTERSVILLE*	GR-L	C	0.37	1.50	3.00
SCHAFFENAKER	STV-LS	A	0.17	6.00	6.00
SEABROOK	LFS	C	0.10	2.00	4.00
SEABROOK	LS	C	0.10	2.00	4.00
SEDGEFIELD	FSL	C	0.28	1.00	1.50
SEKIL	SL	B	0.32	6.00	6.00
SENECA	FSL	B	0.28	2.00	3.50
SENECA	FSL	B	0.37	3.00	5.00
SENECA	L	B	0.37	3.00	5.00
SENECA	SIL	B	0.32	2.00	3.50
SENECA	SL	B	0.28	2.00	3.50
SEQUOIA	L	C	0.37	6.00	6.00
SEQUOIA	SIL	C	0.37	6.00	6.00
SEQUOIA	STV-L	C	0.17	6.00	6.00
SHELOCTA	CB-FSL	B	0.32	6.00	6.00
SHELOCTA	CN-SIL	B	0.28	6.00	6.00
SHELOCTA	FSL	B	0.32	6.00	6.00
SHELOCTA	GR-SIL	B	0.28	6.00	6.00
SHELOCTA	RB-SIL	B	0.32	6.00	6.00
SHELOCTA	SIL	B	0.32	6.00	6.00
SHELOCTA VARIANT	ST-L		0.32	5.00	5.00
SHELOCTA VARIANT	STV-L		0.32	5.00	5.00
SHENVAL	CB-L	B	0.24	6.00	6.00
SHENVAL	L	B	0.32	6.00	6.00
SHERANDO	CB-FSL	B	0.20	6.00	6.00
SHERANDO	CB-SL	B	0.20	6.00	6.00
SHERANDO	CBV-FSL	B	0.10	6.00	6.00
SHERANDO	CBV-SL	B	0.10	6.00	6.00
SHERANDO	GR-SL	B	0.28	6.00	6.00
SHERANDO	RB-SL		0.32	5.00	5.00
SHERANDO	RB-SL	B	0.10	6.00	6.00
SHERANDO	RB-SL	B	0.20	6.00	6.00
SHERANDO	SL	B	0.28	6.00	6.00
SHEVA	FSL	C	0.20	1.50	2.00
SHOTTOWER	CB-L	B	0.24	6.00	6.00
SHOTTOWER	L	B	0.32	6.00	6.00
SINDION	L	B	0.32	1.50	3.00
SINDION	SIL	B	0.32	1.50	3.00
SKETERVILLE	L	C	0.37	1.50	2.50
SKETERVILLE	SIL	C	0.37	1.50	2.50
SLABTOWN	SIL	B	0.43	1.50	3.00
SLAGLE	FSL	C	0.28	1.50	3.00
SLAGLE	L	C	0.37	1.50	3.00
SLAGLE	LS	C	0.24	1.50	3.00
SLAGLE	SIL	C	0.37	1.50	3.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
SLAGLE	SL	C	0.28	1.50	3.00
SLICKENS		B	0.64	0.00	2.00
SNICKERSVILLE*	GR-L	B	0.24	4.00	6.00
SPEEDWELL	FSL	B	0.17	6.00	6.00
SPEEDWELL	L	B	0.32	6.00	6.00
SPEEDWELL	SL	B	0.17	6.00	6.00
SPESSARD	LS	A	0.10	6.00	6.00
SPIVEY	BY-L	B	0.17	6.00	6.00
SPIVEY	GR-L	B	0.17	6.00	6.00
SPIVEY	RB-L	B	0.17	6.00	6.00
SPOTSYLVANIA	FSL	C	0.32	6.00	6.00
SPOTSYLVANIA	SL	C	0.32	6.00	6.00
SPRIGGS	GR-L	C	0.37	6.00	6.00
SPRIGGS	L	C	0.37	6.00	6.00
SPRIGGS	SIL	C	0.37	6.00	6.00
SPRIGGS	STV-L	C	0.20	6.00	6.00
SPRIGGS	STV-L	C	0.37	6.00	6.00
SPRINGWOOD	SIL	B	0.32	6.00	6.00
SPRINGWOOD*	SIL	B	0.32	6.00	6.00
STANTON	SIL	D	0.43	0.00	0.50
STARR	L	C	0.28	6.00	6.00
STARR	SICL	C	0.28	6.00	6.00
STARR	SIL	B	0.37	3.00	5.00
STARR	SIL	C	0.28	6.00	6.00
STATE	FSL	B	0.28	4.00	6.00
STATE	GR-FSL	B	0.28	4.00	6.00
STATE	L	B	0.24	6.00	6.00
STATE	L	B	0.28	4.00	6.00
STATE	L	B	0.37	5.00	5.00
STATE	LFS	B	0.28	4.00	6.00
STATE	LS	B	0.28	4.00	6.00
STATE	SIL	B	0.28	4.00	6.00
STATE	SL	B	0.28	4.00	6.00
STATE	VFSL	B	0.28	4.00	6.00
STEINSBURG	FSL	C	0.28	6.00	6.00
STONEVILLE	SIL	B	0.32	6.00	6.00
STONY ALLUVIAL LAND		D		0.00	2.00
STONY COLLUVIAL LAND		A		6.00	6.00
STONY LOCAL ALLUVIAL	ST-L	D		0.00	2.00
STUART	L	C	0.37	1.50	3.00
STUMPTOWN	FL-L	B	0.20	6.00	6.00
STUMPTOWN	FLV-L	B	0.20	6.00	6.00
SUCHES	FSL	B	0.24	2.50	4.00
SUCHES	L	B	0.24	2.50	4.00
SUDLEY	L	B	0.37	6.00	6.00
SUEQUEHANNA	L	D	0.37	6.00	6.00
SUFFOLK	FSL	B	0.28	6.00	6.00
SUFFOLK	LFS	B	0.24	6.00	6.00
SUFFOLK	LS	B	0.24	6.00	6.00
SUFFOLK	SL	B	0.28	6.00	6.00
SUSDLEY	L	B	0.37	6.00	6.00
SUSQUEHANNA	L	D	0.37	6.00	6.00
SWAMP	L	D	0.28	0.50	1.50
SWEETAPPLE	FSL	B	0.28	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
SWIMLEY	SICL	C	0.37	6.00	6.00
SWIMLEY	SIL	C	0.37	6.00	6.00
SYCOLINE	SIL	D	0.32	1.50	3.00
SYCOLINE	SIL	D	0.43	1.50	3.00
SYLCO	CN-SIL	C	0.24	6.00	6.00
SYLCO	FL-SIL	C	0.24	6.00	6.00
SYLCO	STV-L	C	0.20	6.00	6.00
SYLCO	STV-SIL	C	0.20	6.00	6.00
SYLCO	STX-SIL	C	0.20	6.00	6.00
SYLVATUS	CN-SIL	D	0.26	6.00	6.00
SYLVATUS	CN-SIL	D	0.28	6.00	6.00
SYLVATUS	CNV-SIL	D	0.16	6.00	6.00
SYLVATUS	STV-L	D	0.26	6.00	6.00
SYLVATUS	STX-L	D	0.28	6.00	6.00
SYLVATUS	STX-SIL	D	0.12	6.00	6.00
SYLVATUS	STX-SIL	D	0.28	6.00	6.00
TALLADEGA	CN-L	C	0.28	6.00	6.00
TALLADEGA	CN-SIL	C	0.28	6.00	6.00
TALLADEGA	SIL	C	0.32	6.00	6.00
TALLAPOOSA	L	C	0.32	6.00	6.00
TALLAPOOSA VARIANT	FSL	C	0.28	6.00	6.00
TALLEDEGA	CN-L	C	0.28	6.00	6.00
TARBORO	LS	A	0.10	6.00	6.00
TARBORO	S	A	0.10	6.00	6.00
TATE	L	B	0.24	6.00	6.00
TATE	ST-L	B	0.17	6.00	6.00
TATUM	CL	B	0.32	6.00	6.00
TATUM	GR-L	B	0.20	6.00	6.00
TATUM	GR-SIL	B	0.20	6.00	6.00
TATUM	L	B	0.37	6.00	6.00
TATUM	SICL	B	0.32	6.00	6.00
TATUM	SIL	B	0.20	6.00	6.00
TATUM	SIL	B	0.37	6.00	6.00
TETOTUM	FSL	C	0.28	1.50	2.50
TETOTUM	L	C	0.37	1.50	2.50
TETOTUM	SIL	C	0.37	1.50	2.50
TETOTUM	SL	C	0.28	1.50	2.50
TETOTUM VARIANT	L	C	0.24	1.50	2.50
THUNDER	BY-L	B	0.05	6.00	6.00
THUNDER	CBV-L	B	0.05	6.00	6.00
THUNDER	GR-L	B	0.05	6.00	6.00
THUNDER	RB-L	B	0.05	6.00	6.00
THUNDER	STV-L	B	0.05	6.00	6.00
THURMONT	CB-L	B	0.20	4.00	6.00
THURMONT	FSL	B	0.32	4.00	6.00
THURMONT	GR-L	B	0.24	4.00	6.00
THURMONT	L	B	0.32	4.00	6.00
THURMONT	SL	B	0.32	4.00	6.00
THURMONT	ST-L	B	0.28	4.00	6.00
THURMONT	STV-L	B	0.24		6.00
THURMONT	STV-L	B	0.24	4.00	6.00
TIDAL MARSH	MK-L	D	0.49		
TIMBERVILLE	FSL	B	0.17	6.00	6.00
TIMBERVILLE	GR-SIL	B	0.24	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
TIMBERVILLE	L	B		6.00	6.00
TIMBERVILLE	L	B	0.28	3.00	3.00
TIMBERVILLE	L	B	0.32	6.00	6.00
TIMBERVILLE	SIL	B		6.00	6.00
TIMBERVILLE	SIL	B	0.32	6.00	6.00
TIMBERVILLE VARIANT	L	B	0.28	3.00	3.00
TIMBERVILLE VARIANT	SIL	B		6.00	6.00
TIOGA	FSL	B	0.37	3.00	6.00
TOCCOA	FSL	B	0.10	2.50	5.00
TOCCOA	FSL	B	0.24	2.50	5.00
TOCCOA	L	B	0.24	2.50	5.00
TOCCOA	LFS	B	0.24	2.50	5.00
TOCCOA	LS	B	0.10	2.50	5.00
TOCCOA	SIL	B	0.24	2.50	5.00
TOCCOA	SL	B	0.10	2.50	5.00
TODDSTAV	SIL	D	0.32		
TOMOTLEY	FSL	B/D	0.20	0.00	1.00
TOMOTLEY	L	B/D	0.24	0.00	1.00
TOMOTLEY	SL	B/D	0.20	0.00	1.00
TOMS	SIL	C	0.43	0.50	1.50
TORHUNTA	L	C	0.15	0.50	1.50
TOTIER	SICL	C	0.37	6.00	6.00
TOTIER	SIL	C	0.37	6.00	6.00
TOXAWAY	SIL	B/D	0.17	0.00	1.00
TRAPPIST	SIL	C	0.37	6.00	6.00
TREGO	L	B	0.32	6.00	6.00
TRENHOLM	SL	D	0.32	1.00	3.00
TUCKAHOE	L	B	0.37	6.00	6.00
TUMBLING	BYV-L	B	0.24	6.00	6.00
TUMBLING	CB-L	B	0.22	6.00	6.00
TUMBLING	CB-L	B	0.24	6.00	6.00
TUMBLING	FSL	B	0.24	6.00	6.00
TUMBLING	L	B	0.32	6.00	6.00
TUMBLING	STV-L	B	0.24	6.00	6.00
TURBEVILLE	CB-FSL	C	0.28	6.00	6.00
TURBEVILLE	CL	C	0.28	6.00	6.00
TURBEVILLE	FSL	C	0.32	6.00	6.00
TURBEVILLE	GR-FSL	C	0.24	6.00	6.00
TURBEVILLE	L	C	0.37	6.00	6.00
TURBEVILLE	SCL	C	0.28	6.00	6.00
TURBEVILLE	SIL	C	0.37	6.00	6.00
TUSQUITEE	CB-L	B	0.24	6.00	6.00
TUSQUITEE	L	B	0.28	6.00	6.00
TUSQUITEE	ST-L	B	0.17	6.00	6.00
TUSQUITEE	STV-L	B	0.17	6.00	6.00
TYGART	L	C	0.37	1.50	2.50
TYGART	L	D	0.43	0.50	1.50
TYGART	SIL	D	0.43	0.50	1.50
UCHEE	LFS	A	0.10	3.50	5.00
UCHEE	LS	A	0.10	3.50	5.00
UDIFLUVENTS	FSL	B	0.10	2.50	5.00
UNISON	CB-FSL	B	0.24	6.00	6.00
UNISON	CB-L	B	0.24	6.00	6.00
UNISON	FSL	B	0.32	6.00	6.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
UNISON	GR-L	B	0.24	6.00	6.00
UNISON	L	B	0.32	6.00	6.00
UNISON	SIL	B	0.32	6.00	6.00
UNISON	STV-L	B	0.24	6.00	6.00
UNISON	STV-SIL	B	0.24	6.00	6.00
UNISON VARIANT	L	B	0.32	6.00	6.00
URBAN LAND				2.00	2.00
URBAN LAND	0-30			2.00	2.00
URBAN LAND	VAR			2.00	2.00
URBANLAND	VAR			2.00	2.00
VANCE	CL	C	0.28	6.00	6.00
VANCE	FSL	C	0.24	6.00	6.00
VANCE	GR-SL	C	0.15	6.00	6.00
VANCE	GRF-SL	C	0.24	6.00	6.00
VANCE	SL	C	0.24	6.00	6.00
VARINA	FSL	C	0.15	4.00	5.00
VARINA	GR-SL	C	0.17	4.00	5.00
VARINA	SL	C	0.17	4.00	5.00
VAUCLUSE	SL	C	0.24	6.00	6.00
VERTREES	CR-SIL	B	0.24	6.00	6.00
VERTREES	SIL	B	0.37	6.00	6.00
VERY ROCKY LAND		D		6.00	6.00
WADESBORO	CL	B	0.32	6.00	6.00
WADESBORO	FSL	B	0.24	6.00	6.00
WADESBORO	FSL	B	0.37	6.00	6.00
WADESBORO	SIL	B	0.24	6.00	6.00
WADESBORO	SIL	B	0.37	6.00	6.00
WAHEE	FSL	D	0.24	0.50	1.50
WAHEE	L	D	0.28	0.50	1.50
WAHEE	SIL	D	0.28	0.50	1.50
WAHEE	SL	D	0.24	0.50	1.50
WAKULLA	LS	A	0.10	6.00	6.00
WALLEN	CN-SL	B	0.17	6.00	6.00
WALLEN	STV-SL	B	0.17	6.00	6.00
WALLEN	STX-SL	B	0.17	6.00	6.00
WARMINSTER	L	C	0.37	6.00	6.00
WATAUGA	CB-SIL	B	0.17	6.00	6.00
WATAUGA	SIL	B	0.24	6.00	6.00
WATER			0.28		
WATEREE	FSL	B	0.20	6.00	6.00
WATT	CN-SIL	D	0.32	6.00	6.00
WATT	SIL	D	0.32	6.00	6.00
WATT VARIANT	SIL	D	0.32	6.00	6.00
WAXPOOL	SIL	D	0.43	0.00	1.00
WEAVER	SIL	C	0.32	1.50	2.50
WEAVERTON*	FLV-L	C	0.10	1.50	3.00
WEBBTOWN	CN-SIL	C	0.32	6.00	6.00
WEDOWEE	CL	B	0.28	6.00	6.00
WEDOWEE	FSL	B	0.24	6.00	6.00
WEDOWEE	GR-FSL	B	0.15	6.00	6.00
WEDOWEE	GR-SL	B	0.15	6.00	6.00
WEDOWEE	SCL	B	0.28	6.00	6.00
WEDOWEE	SL	B	0.24	6.00	6.00
WEEKSVILLE	SIL	B/D	0.43	0.00	1.00

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
WEHADKEE	FSL	D	0.24	0.00	1.00
WEHADKEE	L	C	0.28	1.50	2.00
WEHADKEE	L	D	0.24	0.00	1.00
WEHADKEE	L	D	0.24	0.00	2.50
WEHADKEE	L	D	0.49	0.00	0.50
WEHADKEE	SIL	D	0.32	0.00	1.00
WEHADKEE	SIL	D	0.32	0.00	2.50
WEHADKEE	SIL	D	0.49	0.00	0.50
WEHADKEE	VFSL	D	0.24	0.00	2.50
WEIKERT	CN-SIL	C/D	0.28	6.00	6.00
WEIKERT	CNV-SIL	C/D	0.28	6.00	6.00
WEIKERT	SHV-SIL	C/D	0.28	6.00	6.00
WEIKERT	SIL	C/D	0.37	6.00	6.00
WEIKERT	STV-SIL	C/D	0.20	6.00	6.00
WEKERT	CNV-SIL	C/D	0.28	6.00	6.00
WESTMORELAND	L	B	0.37	6.00	6.00
WESTMORELAND	SIL	B	0.37	6.00	6.00
WESTON	FSL	D	0.24	0.00	1.00
WESTON	SL	D	0.24	0.50	1.50
WESTPHALIA	LVFS	B	0.49	6.00	6.00
WEVERTON	FLV-L	B	0.15	6.00	6.00
WHEELING	FSL	B	0.28	6.00	6.00
WHEELING	FSL	B	0.37	6.00	6.00
WHEELING	GR-L	B	0.28	6.00	6.00
WHEELING	L	B	0.37	6.00	6.00
WHEELING	SIL	B	0.37	6.00	6.00
WHEELING	SL	B	0.37	6.00	6.00
WHITE STORE	FSL	D	0.28	1.00	1.50
WHITE STORE	L	D	0.43	1.00	1.50
WHITE STORE VARIANT	L	D	0.43	1.00	1.50
WHITEFORD	SIL	B	0.32	6.00	6.00
WICHKAM	FSL	B	0.24	6.00	6.00
WICKHAM	FSL	B	0.24	6.00	6.00
WICKHAM	L	B	0.24	6.00	6.00
WICKHAM	LFS	B	0.15	6.00	6.00
WICKHAM	SL	B	0.24	6.00	6.00
WICKHAM VARIANT	L	B	0.24	6.00	6.00
WICKHAM VARIANT	SL	B	0.24	6.00	6.00
WILKES	CL	C	0.28	6.00	6.00
WILKES	FSL	C	0.24	6.00	6.00
WILKES	GR-FSL	C	0.17	6.00	6.00
WILKES	L	C	0.24	6.00	6.00
WILKES	SL	C	0.24	6.00	6.00
WINTON	SL	C	0.20	2.00	4.00
WOLFGAP	CL	B	0.32	6.00	6.00
WOLFGAP	FSL	B	0.17	6.00	6.00
WOLFGAP	L	B	0.32	6.00	6.00
WOODINGTON	FSL	B/D	0.20	0.50	1.00
WOODSTOWN	FSL	C	0.24	1.50	2.50
WORSHAM	FSL	D	0.28	0.00	1.00
WORSHAM	L	D	0.37	0.00	1.00
WORSHAM	L	D	0.43	0.00	0.50
WORSHAM	SIL	D	0.37	0.00	1.00
WORSHAM	SIL	D	0.43	0.00	0.50

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
WORSHAM	SL	D	0.28	0.00	1.00
WORSHAM VARIANT	FSL	D	0.28	0.00	1.00
WRIGHTSBORO	FSL	C	0.28	2.00	3.00
WRIGHTSBORO	FSL	D	0.43	1.50	3.00
WRYICK	L	B	0.32	6.00	6.00
WURNO	CN-L	C	0.28	6.00	6.00
WURNO	CN-SIL	C	0.28	6.00	6.00
WURNO	SIL	C	0.28	6.00	6.00
WYRICK	L	B	0.32	6.00	6.00
WYRICK	SIL	B	0.32	6.00	6.00
YADKIN	L	C/D	0.32	6.00	6.00
YEMASSEE	FSL	C	0.20	1.00	1.50
YEMASSEE	SL	C	0.20	1.00	1.50
YEOPIM	SIL	B	0.37	1.50	3.00
YORK	SIL	C	0.43	1.50	3.00
ZEPP	STV-L	B	0.17	6.00	6.00
ZEPP	STV-SL	B	0.10	6.00	6.00
ZEPP	STX-L	B	0.15	6.00	6.00
ZEPP	STX-SL	B	0.10	6.00	6.00
ZION		C	0.37	6.00	6.00
ZION	L	C	0.37	6.00	6.00
ZION	SIL	C	0.37	6.00	6.00
ZION	SIL	D	0.43	1.00	2.50
ZION SILT LOAM	SIL	C	0.37	6.00	6.00
ZION VARIANT	L	C	0.37	6.00	6.00
ZOAR	L	C	0.43	1.50	2.50
ZOAR	SIL	C	0.43	1.50	2.50

CHAPTER 7

Administrative Guidelines

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CHAPTER 7

ADMINISTRATIVE GUIDELINES

The Virginia Erosion and Sediment Control Law (VESCL) provides the authority and administrative guidelines for the Virginia Erosion and Sediment Control Program. Counties, cities, and towns are authorized to administer a local erosion and sediment control (E&S) program which is consistent with the state program. These local E&S programs have jurisdiction over land-disturbing activities except for those activities which are otherwise provided for by the VESCL.

The VESCL contains several provisions which place certain land-disturbing activities under the jurisdiction of the Board or the Department of Conservation and Recreation's Division of Soil and Water Conservation (DSWC). Generally, these activities include land-disturbing activities undertaken by state agencies and other activities which are multijurisdictional in nature. (Part II of this chapter contains a thorough presentation of these activities.)

A minimum level of consistency for state and local E&S programs is provided by state guidelines, regulations, and other publications such as the Virginia Erosion and Sediment Handbook. In addition, DSWC functions in an oversight capacity to insure the acceptability of state and local programs. DSWC is directly involved in individual project regulation only when such projects are undertaken by state agencies or other institutions specified in VESCL (Sec. 10.1-563), or if they are multijurisdictional in nature and the applicant requests DSWC involvement.

This chapter is divided into two parts in order to present the administrative guidelines which are applicable to local and state level programs:

PART I - Local Programs: Provides information concerning the minimum administrative criteria which must be met in all local programs, along with ideas and suggestions which may be used to improve local program effectiveness. Also, procedures for multijurisdictional land-disturbing activities are presented.

PART II - State Agency Projects: Provides basic information and administrative guidelines which apply to state agencies and institutions that propose to undertake land-disturbing activities.

The guidelines and standards contained in this chapter are based upon provisions of the VESCL as amended through 1991, including the Erosion and Sediment Control Regulations. Later amendments may affect the applicability of this chapter. Handbook users should therefore be aware of all subsequent amendments to the VESCL and Regulations.

PART I: LOCAL PROGRAMS

There are 170 separate local E&S programs which were adopted by 95 counties, 41 cities, 34 incorporated towns, and one Soil and Water Conservation District (district). Every county, city, and incorporated town in the state is covered by one of these programs. Before local adoption, each of these programs was reviewed by DSWC and deemed to be in compliance with the state program. Each program included a set of administrative procedures which outlined specific local implementation mechanisms.

Local administrative procedures are often subject to variation due to turnover in personnel, changes in governmental structure, amendments to the state program, and other factors. For these reasons, the local programs are reviewed periodically to ensure consistency with the state program and their relevance and effectiveness under current local conditions. Even if the original procedures are being implemented as originally adopted, local conditions may have changed to the degree that the program is no longer serving its intended purpose.

Local administrative procedures may be changed without the permission or approval of DSWC. However, such changes should be documented, and they must be consistent with the criteria set forth in the VESCL. Localities are therefore advised to keep DSWC informed of significant program changes and to seek advice when there is a question of compatibility with the state program.

Local Program Reviews

DSWC periodically reviews and evaluates each local program. These reviews provide assistance to localities in maintaining effective E&S programs which are consistent with the state program and to provide state oversight of the local programs. Program reviews are conducted by the DSWC regional E&S Specialists who visit localities and meet with the appropriate personnel involved with the erosion and sediment control program.

The first part of a program review consists of a meeting with local program officials. Administrative aspects of the program are reviewed and discussed. Discussion topics include the local ordinance, plan review, inspection, and enforcement procedures. Also, revisions in the state program and available options which may be beneficial to the locality are discussed.

The second part consists of a field tour to assess the implementation of the program in the field. Sample plans are reviewed and, if possible, current construction sites are inspected.

Finally, DSWC prepares a program review letter that documents the findings of the program review. This letter outlines the local program and makes recommendations in order to achieve consistency with the state program and to improve local program effectiveness. DSWC intends to review all local programs on a periodic basis.

Funding and Staffing Local Programs

The problem of funding local E&S programs has been brought to the attention of the General Assembly a number of times since the passage of the VESCL in 1973. The Assembly's response has been to adopt amendments to the VESCL allowing localities to charge plan review or permit fees to cover the cost of program administration. A 1976 amendment, Section 21-89.5(e), allowed localities to charge applicants a fee of up to $25.00. This section was amended again in 1978 to allow a maximum $150.00 fee. The most recent amendment in 1988, Section 10.1-562(e), allows localities to charge a fee up to $1000.00. However, these fees must not exceed the actual costs of the services provided. It is apparent by these amendments that the local programs are intended to be funded by revenues from fees charged to persons who undertake land-disturbing activities.

Many rural localities have difficulty funding and staffing their programs. The small number of plans reviewed each year does not usually generate sufficient revenue to support a separate position to run the program. Consequently, most rural localities have given this responsibility to an existing local official such as the building inspector. Many of these local officials do not feel qualified or do not have the time to carry out the additional responsibilities of the E&S program.

Fortunately, there are sources of assistance available. Many localities utilize the expertise of Soil and Water Conservation Districts. The role of the districts in the local E&S programs varies according to mutual agreements between the district and the locality. Frequently, the districts are involved with plan review and inspection. Oftentimes, this arrangement also includes the technical expertise of the Soil Conservation Service (SCS).

Enforcement of a local program is, at least, partially the responsibility of the local Commonwealth's Attorney. According to Section 10.1-569(g) of the VESCL, the local Commonwealth's Attorney shall take legal action against violators upon request of the locality. If the services of the districts and the Commonwealth's Attorney are fully utilized, the burden of administering the E&S program will be greatly reduced.

Local officials can learn to perform inspections adequately with proper training. Such training is made available periodically by DSWC through statewide seminars. Oftentimes, a local training seminar can be arranged through the cooperative efforts of the local government, the DSWC regional E&S Specialist and the district. Training may also be available through local community colleges which can offer erosion and sediment control courses if sufficient local interest is shown.

The following suggestions are made to rural localities which are attempting to carry out local E&S programs on limited budgets:

1. Send local program officials to statewide training seminars or to any applicable courses available through the community college system.

2. Increase plan review or permit fees to cover a greater portion of administrative costs.

3. Fully utilize the services of districts for plan review and/or inspection assistance where available.

Certification Program

DSWC offers a program for certification of Erosion and Sediment Control Inspectors, Stormwater Management Inspectors, and Program Administrators. The objectives of this program are to encourage a higher standard of performance of duties, to promote updated education and training, to promote employer and public awareness of necessary skills, and to establish a code of consistency and competency among administrators and inspectors. Specific requirements for certification include experience and/or education in addition to a passing score on the examination. DSWC recommends that at least one E&S official in each local program be certified.

LOCAL PROGRAM ADMINISTRATION

The remainder of Part I is devoted to discussion of various elements of local program administration. The requirements of the VESCL and the Virginia Erosion and Sediment Control Regulations are outlined and referenced. Also, there are suggestions which may improve local program effectiveness. Appendix 7A contains sample forms which may be modified for use in the local E&S program.

Plan Submission

Requirements

VESCL Sec. 10.1-563(A): *... no person may engage in any land-disturbing activity until he has submitted to the district or locality an erosion and sediment control plan for the land-disturbing activity and the plan has been reviewed and approved by the plan-approving authority.*

VESCL Sec. 10.1-563(F): *... the preparation, submission, and approval of an erosion and sediment control plan shall be the responsibility of the owner.*

Discussion

The following items are recommended:

1. The public should be informed of the requirements for plan submission. It is advisable to prepare a brochure or handout sheet which lists the procedures necessary for land development. Include names, addresses and telephone numbers

of local government bodies involved, number of plans to be submitted, time required for review, and schedules of fees. (See Appendix 7A-1.)

2. Provide information on how to obtain copies of the appropriate handbooks or other technical information such as the Virginia E&S Handbook or local E&S handbook. Include a "Checklist for Plan Preparation" (Appendix 7A-2).

3. When the applicant first contacts the locality concerning a proposed development, a screening form may be used to determine whether an E&S plan is required for the project site (Appendix 7A-3).

4. At the time of plan submission, the applicant should fill out an application for a land-disturbing permit or for plan approval, if the locality does not issue such a permit. This application will eventually constitute an agreement between the applicant and the locality. The following items should be included:

   a. Identification of the landowner of record and the person responsible for carrying out the plan.

   b. Certification that the plan will be carried out as approved.

   c. A statement granting right-of-entry to the locality's inspectors or other personnel concerned with the plan (Appendix 7A-4).

5. At the time of plan submission, the E&S plan should be dated, stamped or marked with the date received to establish the 45-day deadline date.

Plan Review and Approval

Requirements

VESCL Sec. 10.1-563(B): ... *The plan-approving authority shall review the conservation plans submitted to it and grant written approval within forty-five days of the receipt of the plan if it determines that the plan meets the requirements of the Board's regulations. ...*

When a plan is determined to be inadequate, written notice of disapproval stating the specific reasons for disapproval shall be communicated to the applicant within forty-five days. The notice shall specify such modifications, terms, and conditions that will permit approval of the plan. If no action is taken by the plan-approving authority within the time specified above, the plan shall be deemed approved and the person authorized to proceed with the proposed activity.

E&S Regulations Sec. 50: *The plan approving authority may waive or modify any of the regulations that are deemed inappropriate or too restrictive for site conditions, by granting a variance. A variance may be granted under these conditions:*

1. *At the time of plan submission, an applicant may request a variance to become part of the approved erosion and sediment control plan. The applicant shall explain the reasons for requesting variances in writing. Specific variances which are allowed by the plan approving authority shall be documented in the plan.*

2. *During construction ... the plan approving authority shall respond in writing either approving or disapproving such a request. If the plan approving authority does not approve a variance within 10 days of receipt of the request, the request shall be considered to be disapproved. ...*

3. *The plan approving authority shall consider variance requests judiciously, keeping in mind both the need of the applicant to maximize cost effectiveness and the need to protect off-site properties and resources from damage.*

Note: The minimum standards contained in the E&S Regulations (or other more stringent regulations adopted by the locality) should be satisfied on all E&S plans. These regulations also apply to any land-disturbing activity which might evolve from a construction project (e.g., borrow site, disposal areas, etc.).

Discussion

1. When reviewing a plan, use the "Checklist for Plan Preparation" (Appendix 7A-2) to be sure that no items are overlooked. Variances must be requested in writing with reasons to support the variance.

   Note: A site plan without a narrative is usually unacceptable. The narrative may be on separate sheets or may be included as notes on the site plan. Construction specifications usually are not acceptable substitutes for the E&S Narrative.

2. Plan review by more than one reviewer is encouraged. Utilize the expertise and knowledge of other departments or staff. Make plans available to other reviewers quickly and streamline procedures to facilitate meeting the 45-day deadline.

3. On-site inspection of the project location (pre-approval site visit) should be an integral part of the review process.

4. If the plan is adequate, the plan sheet should be stamped or marked "APPROVED," signed and dated.

5. If the plan is inadequate, the applicant must be notified in writing within 45 days of what changes should be made to render the plan acceptable. To expedite the review and any subsequent revisions, the plan reviewer may prefer to discuss the plan with the applicant. **However, the law requires a written communication either approving or disapproving the plan with reasons for disapproval within 45 days.**

6. Consider developing a procedure to abbreviate the re-submitting process so that the plan can reach the reviewer quickly and not delay the applicant for an undue period of time.

   Note: At the time of re-submission, another 45-day review period is begun.

7. Appropriate fees may be charged to cover the costs of permit issuance, plan review and inspection. The VESCL limits the total fee to a maximum of $1000 (Sec. 10.1-562(e), 1990). Many localities charge a fee amount based on the size of the project.

Activities Under State Jurisdiction

Requirements
VESCL Sec. 10.1-563 (D): *Electric and telephone utility companies and railroad companies shall file general erosion and sediment control specifications annually with the Board for review and written comments. The specifications shall apply to:*

> *1. Construction, installation and maintenance of electric and telephone utility lines; and*
> *2. Construction of the tracks, rights-of-ways, bridges, communication facilities and other related structures and facilities of the railroad company. ...*

VESCL Sec. 10.1-564: *Any state agency that undertakes a project involving a land-disturbing activity shall file specifications annually or a conservation plan for each project with the Department for review and written comments. ...*

Discussion
These agencies/institutions submit either annual E&S specifications or individual plans to DSWC. Approval of individual projects is not necessary when the approved annual specifications are followed. The activities listed above are not subject to the requirements of local E&S programs. Projects not included in subsections 1 and 2 (above) must comply with the local program requirements.

DSWC staff oversees the implementation of the E&S program on state agency projects.

Residential Subdivisions

VESCL Sec. 10.1-560: Definitions

> *"Land-Disturbing Activity" means any land change ... except that the term shall not include: ... Preparation for single-family residences separately built, unless in conjunction with multiple construction in subdivision development; however, the governing body of any county which has adopted the urban county executive form of government, any city adjacent to such county, and any county contiguous to such county with the county*

executive form of government or any town within the contiguous county, and any city completely surrounded by such county, and portions of the Counties of Bedford, Franklin, and Pittsylvania which lie in the Smith Mountain Lake drainage area may regulate land-disturbing activities related to single-family residences separately built whether or not they are developed in conjunction with multiple construction in subdivision development. ...

Discussion
Preparation for single-family residences NOT IN A SUBDIVISION are exempt from E&S law, except as ~~provided for above.~~ [To date, the County of Fairfax is the only county in Virginia with the urban executive form of government.] The portions of the counties of Bedford, Franklin and Pittsylvania that drain into Smith Mountain Lake may regulate single-family residences which are not in a subdivision.

Requirements
E&S Regulations Sec. 1.8:

B. *If individual lots or sections in a residential development are being developed by different property owners, all land-disturbing activities related to the building construction shall be covered by an erosion and sediment control plan or an "Agreement in Lieu of a Plan" signed by the property owner.*

C. *Land-disturbing activity of less than 10,000 square feet on individual lots in a residential development shall not be considered exempt from the provisions of the act and these regulations.*

D. *The construction of permanent roads or driveways that disturb in excess of 10,000 square feet and that serve more than one single-family residence separately built is not exempt. ...*

Discussion
Land-disturbing activities on individual lots of a residential development (subdivision) must have an erosion control plan or an agreement in lieu of a plan signed by the lot owner and the locality.

Usually, E&S plans are developed in two phases. The first plan addresses the initial construction of the infrastructure for the development. This plan would include the construction of roads, storm sewers, utilities, and any grading activity that involves more than one lot. The plan would also include stormwater runoff considerations based on the expected final development.

The second phase of construction begins with the construction of houses or buildings on individual lots. Individual E&S plans are required for land-disturbing activities on individual lots; however, many times an "agreement in lieu of an E&S plan" is acceptable. (See Appendix 7A-5.) This agreement reduces the burden on the homeowner of having to prepare an individual plan. The agreement states the conditions to be maintained during construction, such as keeping public streets clean, maintaining perimeter controls, and establishing permanent stabilization.

This requirement applies to land-disturbing activities of less than 10,000 square feet when the activity occurs in a residential development. The intent is to regulate activities which would be considered a part of the development process such as construction of individual houses, outbuildings, garages, driveways, etc.

Agricultural Activities

Requirement

VESCL Sec. 10.1-560(7): *Tilling, planting, harvesting of agricultural, horticultural, or forest crops, or livestock feedlot operations; including engineering operations as follows: construction of terraces, terrace outlets, check dams, desilting basins, dikes, ponds, ditches, strip cropping, lister furrowing, contour cultivating, contour furrowing, land drainage and land irrigation.*

Discussion

The definition of land-disturbing activities specifies which agricultural activities are exempted. The construction of agricultural buildings is not included. Therefore, the agricultural exemption does not apply to the construction of farm buildings, such as barns, livestock houses, etc. The reference to ponds applies to ponds that are used primarily for agricultural purposes such as irrigating crops, watering livestock, etc.

Requirement

E&S Regulations Sec. 1.9:

A. *A property owner who disturbs 10,000 square feet, or more, of land and claims that the activity is exempted from the requirements ... shall have one year from the date of commencement of the activity to demonstrate to the erosion and sediment control enforcement authority that the activity is exempt. As soon as a nonexempt status is determined, the requirements of the Act shall be immediately enforced.*

Discussion

Many agricultural and forestry activities require a reasonable period of time to clearly establish the intent of the activity. Therefore, the one year period was provided.

Claims that an activity is exempt should be consistent with landuse regulations, zoning or other regulations. Several of the exemptions from the E&S program are regulated by another program. For example, surface mining and oil and gas operations are regulated by programs administered by the Department of Mines, Minerals, and Energy. Projects claiming an exemption such as surface mining should be able to substantiate the claim with documentation from the appropriate agency.

Issuing Permits

Requirements

VESCL Sec. 10.1-565: *Agencies authorized ... to issue grading, building, or other permits for activities involving land-disturbing activities may not issue any such permit unless the applicant* *submits with his application an approved erosion and sediment control plan and certification that the plan will be followed.*

Discussion

It is strongly recommended that a land-disturbing permit be issued. The permit clearly defines the land disturbance as a separate activity from building construction. By issuing a separate permit for the land-disturbing activity, the agency prevents any misunderstanding that the land-disturbing activity was permitted under another permit. Performance guarantees (e.g., bonds, credit, etc.) and certification should be made specifically for the land-disturbing activity, or at least a specified portion of the overall guarantee should be for the land-disturbing activity.

Changing An Approved Plan

Requirements

VESCL Sec.10.1-563(C): *An approved plan may be changed by the authority that approved the plan in the following cases:*

1. *Where inspection has revealed that the plan is inadequate to satisfy applicable regulations; or*
2. *Where the person responsible for carrying out the approved plan finds that because of changed circumstances or for other reasons the approved plan cannot be effectively carried out, and proposed amendments to the plan, consistent with the requirements of this article, are agreed to by the plan-approving authority and the person responsible for carrying out the plan.*

Discussion

Even though these procedures allow plans to be changed after initial approval, it is often difficult and troublesome to make changes in the field. Change orders are usually costly and time-consuming. Therefore, the original plan should be as thorough as possible.

Performance Guarantees

Requirements

VESCL Sec. 10.1-565: ... *Prior to issuance of any permit, the agency may also require an applicant to submit a reasonable performance bond with surety, cash escrow, letter of credit, any combination thereof, or such other legal arrangement acceptable to the agency, to ensure that measures could be taken by the agency at the applicant's expense should he fail, after proper notice, ... to initiate or maintain appropriate conservation action. ... If the agency takes such conservation action upon such failure by the permittee, the agency may collect from the permittee for the difference should the amount of the reasonable cost of such action exceed the amount of the security held. Within sixty days of the achievement of adequate stabilization of the land-disturbing activity, such bond, ... shall be refunded to the applicant or terminated.*

Discussion

The amount of coverage required as a guarantee for a project should be based on what it would cost the locality to implement the plan, should the applicant fail to do so. If the cost of the unfinished work is more than the amount of the performance guarantee, the locality may collect the additional cost from the permittee. A performance guarantee may be required for issuance of building, grading, land disturbing, or other permits. It is recommended that an E&S performance guarantee be collected separately from other guarantees.

Chapter Two of this handbook contains cost figures which may be used to help determine the amount of performance guarantee needed. At a minimum, the guarantee should be sufficient provide permanent stabilization for the entire disturbance in the event that the proposed development is not completed. The locality is responsible for determining the bond, escrow, etc. and administering these requirements unless stated otherwise in the local E&S ordinance.

Following are brief descriptions of various types of performance guarantees:

a. Bonding - If a bond is used, the bonding company agrees to complete the erosion and sediment control requirements of the plan, should the applicant fail to do so.

b. Escrow Accounts - Under an escrow arrangement, the applicant would pay funds into a bank under an agreement among the applicants, the permit issuing authority, and the bank. If the E&S plan was properly carried out, the applicant and the authority would sign a joint letter to the bank directing the bank to pay the money back to the applicant as specified in the agreement. Otherwise, the money would go to the permit issuing authority to pay for completing the unfinished portion of the plan, with any excess money being returned to the applicant.

c. Letters of Credit - A letter of credit is an agreement by a bank to pay a fixed sum of money upon the happening of a specified contingency. While a letter of credit is sometimes used alone, it is frequently used where a bonding company refuses to issue a bond unless it is provided with a letter of credit. The advantage of having a letter of credit in favor of a bonding company instead of the permit issuing authority is that if the work is not done, the bonding company will undertake to have it finished.

Localities should keep in mind the risk involved in accepting personal checks as performance guarantees. Checks should be deposited into escrow as soon as possible.

The performance guarantee must be returned to the applicant within 60 days of the achievement of adequate stabilization of the land-disturbing activity. Adequate stabilization should be determined by the Program Administrator or his designated agent. Localities should have a means of tracking the expiration dates of bonds and letters of credit. Extensions should be obtained when needed.

Inspections

Requirements

VESCL Sec. 10.1-566(A): *The plan-approving authority or, ... the permit-issuing authority (i) shall provide for periodic inspections of land-disturbing activity and (ii) may require monitoring and reports from the person responsible for carrying out the plan, to ensure compliance with the approved plan and to determine whether the measures required in the plan are effective in controlling erosion and sediment. The owner, occupier or operator shall be given notice of the inspection and an opportunity to accompany the inspectors.*

E&S Regulations Sec. 1.7:

A. All erosion and sediment control structures and systems shall be maintained, inspected and repaired as needed to insure continued performance of their intended function. A statement describing the maintenance responsibilities of the permittee shall be included in the approved erosion and sediment control plan.

B. Periodic inspections are required on all projects by the enforcement authority. An inspection shall be made during or immediately following initial installation of erosion and sediment controls, at least once in every two-week period, within 48 hours following any runoff producing storm event, and at the completion of the project prior to the release of any performance bonds.

Discussion

1. Pre-construction conferences are recommended, especially for large projects. During this meeting, the plan should be discussed, any problems or misconceptions resolved, and a basis for clear communication and good working relations established. Installation and maintenance of E&S control measures should be discussed.

2. All inspections should be documented by a written report or log. (See Appendix 7A-6 and 7A-7.) These reports should contain the date and time of inspection, comments concerning compliance or non-compliance, and notes on any verbal communications concerning the project. Localities may require the contractor to maintain an inspection log that can be reviewed by the local staff.

Violations And Enforcement

Requirements

VESCL Sec. 10.1-562(F): *The governing body of any [locality which has adopted its own local program] may adopt an ordinance establishing a uniform schedule of civil penalties for violations. ... [T]he civil penalty for any one violation shall not exceed $100. [I]n no event shall specified violations arising from the same operative set of facts be charged more frequently than once in any ten-day period, and in no event shall a series of specified violations arising from the same operative set of facts result in civil penalties which exceed a total of $3,000. ...*

VESCL Sec. 10.1-566(A): *... If the permit issuing authority or plan-approving authority determines that there is a failure to comply with the plan, notice shall be served upon the* *permittee. ... The notice shall specify the measures needed to comply with the plan and shall specify the time within which such measures shall by completed. Upon failure to comply within the time specified, the permit may be revoked and the permittee or person responsible for carrying out the plan shall be deemed to be in violation of this article and shall be subject to the penalties provided in Sec. 10.1-569.*

VESCL Sec. 10.1-569:

(A): *Violators ... shall be guilty of a misdemeanor and subject to a fine not exceeding $1,000 or thirty days imprisonment for each violation or both.*

(B): *If a locality has adopted an ordinance establishing a uniform schedule of civil penalties ... any [violator] shall, upon a finding of an appropriate general district court, be assessed a civil penalty in accordance with the schedule. ...*

(C): *The appropriate permit-issuing authority ... may apply to the circuit court in any jurisdiction wherein the land lies to enjoin a violation or a threatened violation ... without the necessity of showing that an adequate remedy at law does not exist.*

(D): *In addition to any criminal or civil penalties provided under this chapter, any person who violates any provision of this chapter may be liable to the locality, or the Board, as appropriate, in a civil action for damages.*

(E): *Without limiting the remedies which may be obtained in this section, any person violating or failing, neglecting or refusing to obey any injunction, mandamus or other remedy obtained pursuant to this section shall be subject, in the discretion of the court, to a civil penalty not to exceed $2,000 for each violation. ...*

(F): *With the consent of any person who has violated or failed, neglected or refused to obey any regulation or order of the Board, or any condition of a permit or any provision of this article, the ... authority may provide ... for the payment of civil charges for violations in specific sums, not to exceed the limit specified in subsection D of this section. Such civil charges shall be instead of any appropriate civil penalty which could be imposed under subsection E. ...*

<u>Discussion</u>

Violations include, but are not limited to, failure to comply with an approved plan or undertaking a land-disturbing activity without an approved plan. When a violation is noted, the following steps should be considered to secure compliance: (Also see "Enforcement Flow Chart" in Appendix 7B.)

1. <u>Informal Contact/Verbal Warning</u> - The inspector should complete a standard inspection report form detailing the observed violation and circumstances pertaining to it. (See Appendix 7A-7.) The report should specify the measures needed for compliance and a time frame for completion. The on-site job superintendent should be notified verbally, if possible, and asked to sign the inspection report to verify that

verbal notification has been given. Copies of the inspection report should be given or sent to the permittee and other concerned parties.

2. Notice to Comply - If the informal contact is unsuccessful, the plan approving or permit issuing authority should issue a "Notice to Comply" as required by Sec. 10.1-566(a). This notice should specify the measures required for compliance and the deadline for completion. The notice must be sent to the permittee by registered or certified mail (return receipt requested) to the address specified by the permittee in his application (Appendix 7A-8) or the notice can be delivered to the person supervising the activity.

3. Enforcement Options - If the permittee fails to respond adequately to the "Notice to Comply," the locality should consider the following actions:

   a. Utilize Performance Guarantee (where applicable) - The local authorities may utilize the performance guarantee to complete the required work according to the terms specified in the guarantee. Many times, a letter of intent to utilize the guarantee, sent by certified mail to the permittee, is sufficient to prompt the desired results. Such a letter should be cleared by the locality's attorney. If the cost of the unfinished work is more than the amount of the performance guarantee, the locality may also collect the additional amount from the permittee.

   b. Permit Revocation - Upon failure to complete the measures within the deadlines specified in the notice to comply, the land-disturbing permit can be revoked and the permittee can be considered in violation of the law.

   c. Stop Work Order - This highly recommended enforcement option allows the chief administrative officer of the locality to issue an order requiring all or part of the land-disturbing activities on the site be stopped until the specified corrective measures have been taken. (See Appendix 7A-9.) This order is issued either with or after a "Notice to Comply." The order shall be in effect for seven days allowing the locality time to pursue other means of legal action if problems are not corrected. A notice or card may be posted at the site notifying the public that a Stop Work Order has been issued for the project.

   d. Legal Action - Legal action against the violator is recommended when other enforcement options have failed or if a land disturbance poses a serious threat of damage to downstream or downslope property owners or the environment. There are four types of legal action which may be considered by the locality:

      1) Criminal Penalties - A misdemeanor charge subject to a fine up to $1000 or thirty days imprisonment for each violation;

2) Civil Penalties - (1) Civil penalties in accordance with the schedule of penalties up to $3,000; (2) Civil action charge subject to a fine up to $2000 for each violation;

3) Administrative Fines - With the consent of the violator, the payment of a civil charge for violations instead of the civil penalty;

4) Injunctive Relief - A suit for an injunction is a civil action, but it is possible to ask for an injunction and for penalties in the same action. Because of the length of time needed to decide the penalty question, <u>it is advisable to always file for an injunction as well as a penalty unless the land-disturbing activity has already been completed</u>.

   There are principally three types of injunctions, depending upon the amount of speed required:

   a) <u>Temporary Restraining Order</u> - This is the quickest form of injunction, usually issued for a limited time. It is issued to prevent irreparable harm to the plaintiff by preserving the status quo until the defendant can be notified and a preliminary hearing held.

   b) <u>Preliminary or Temporary Injunction</u> - This injunction provides a short period of notice to the defendant and is issued on a temporary basis until a full hearing and decision can be made.

   c) <u>Permanent Injunction</u> - This finally disposes of the matter at issue. It is issued only after a full hearing of the evidence and argument has occurred.

   An injunction will not be issued automatically. The court will probably weigh the damage to the environment against the damage to the builder. If it is just a question of enforcing the law with no great danger of sediment damage, the court might refuse the injunction and leave the enforcement to the penalty provisions of the law.

Projects Commenced Without an Approved Plan

<u>Requirement</u>

VESCL Sec 10.1-563(E): ... [No] person may engage in any land-disturbing activity until he has submitted to ... [the] locality an erosion and sediment control plan for the land-disturbing activity and the plan has been reviewed and approved by the plan-approving authority.

Discussion
If a land-disturbing activity is detected for which no E&S plan has been approved, an attempt should be made to contact the owner and advise him that he is in violation of the VESCL. He should be asked to stop all land disturbance until an approved plan is obtained, unless he agrees to perform work toward satisfactorily controlling erosion and sedimentation. A "Notice of Permit Requirement" should be sent to the owner by certified mail to establish that a warning was given. (See Appendix 7A-10.) Since there may be no permits issued or performance guarantees for the project at this early stage of development, the only enforcement options may be a stop work order or legal action. It is advisable to seek an injunction in accordance with Sec. 10.1-569(c) so that the problem will be addressed quickly.

Erosion Impact Area

Requirements
VESCL Sec. 10.1-560: *"Erosion Impact Area" means an area of land not associated with current land-disturbing activity but subject to persistent soil erosion resulting in the delivery of sediment onto neighboring properties or into state waters. This definition shall not apply to any lot or parcel of land of one acre or less used for residential purposes or to shorelines where the erosion results from wave action or other coastal processes.*

VESCL Sec. 10.1-563(E): *In order to prevent further erosion a local program may require approval of a conservation plan for any land identified in the local program as an erosion impact area.*

Discussion
A locality may declare a site to be an Erosion Impact Area and require the property owner to submit an E&S plan. A formal notice should be sent to the owner informing him of this requirement with a deadline for compliance. (See Appendix 7A-11.) Upon failure to comply with this notice, appropriate legal actions should be taken.

Records And Files

Discussion
1. For each project requiring an E&S plan, there should be a project file containing the following:

   a. permit application
   b. records of performance guarantee (bond, etc.)
   c. approved plan
   d. reviewer's comments
   e. inspection reports
   f. any photos taken
   g. any correspondence

2. Assign a project number to each plan, record the project number on each item in the file and cross-reference to other departments. The project number might also be the permit number (if permits are issued). This procedure will prevent confusion caused by changes in the name of the project or other projects with similar names.

Citizen Complaints

Discussion
Being involved in controlling a highly visible form of pollution, local program personnel will be recipients of many complaints and comments concerning drainage, erosion, stormwater, flooding, and sediment problems.

Develop procedures or steps to handle these inquiries efficiently. If the problem is related to a project under the jurisdiction of the local program, keep a record of all activity pertaining to the problem in the project file or provide a cross-reference to the appropriate file. If the problem pertains to some other program or agency, refer it to that organization. If the problem is not regulated, make that clear to the citizen and suggest legal alternatives or some means by which the citizen can obtain more information. (See Appendix 7A-12.)

The DSWC and districts are also available for technical assistance on E&S complaints.

Education And Information

Discussion
Local programs should consider the following steps:

1. Inform developers and other land disturbers of the requirements of the local program and develop printed material for this purpose. (See Appendix 7A-1 and 2.) Some localities hold annual meetings that address local development concerns and requirements for developers, consultants, contractors, etc.

2. Prepare training sessions or workshops for developers, engineers, landscape architects, consultants, contractors, excavators and others involved in the technical aspects of the program. Community college courses may be available for this purpose. Check with your local college for more information.

3. Conduct periodic workshops for local government and district personnel having responsibilities in the program, such as inspection, plan review or administrative duties. Inspectors and administrators should be certified by the state E&S certification program.

4. Prepare an orientation program for new employees and for cross-training inspectors in other departments. Assistance in training programs is available from the DSWC,

districts, SCS, other state agencies and other sources. These programs may be conducted on a regional or local basis.

Multijurisdictional Projects

Requirements

VESCL Sec. 10.1-563(A): *Where land-disturbing activities involve lands under the jurisdiction of more than one local control program an erosion and sediment control plan may, at the option of the applicant, be submitted to the Board for review and approval rather than to each jurisdiction concerned.*

Discussion

When a land-disturbing activity involves two or more local programs, the person responsible for plan submission has the option of submitting the plan for review and approval to: (1) each local program in which the project lies; or, (2) to DSWC.

1. Submission of Plans to Localities for Review - If this option is chosen, the applicant must contact each locality in which the project lies and comply with each set of local administrative procedures separately.

2. Submission of Plans to DSWC for Review - Under this option, the following procedures will apply:

   a. Plan Submission and Review

      Plans shall be submitted to the DSWC Central Office in Richmond or to the appropriate Regional Office. (See Appendix 7C.) Four copies of the plan must be provided. After the plan is approved, additional copies of the approved plan, if necessary, will be requested by DSWC (one for each locality). The plan should include the name, address and phone number of the landowner, the person responsible for implementing the plan, and the person preparing the plan.

      The plan should be prepared according to the guidelines in Chapter 6 of this handbook. The plan should include a precise location of the project and a listing of all localities in which it lies.

      DSWC shall review the plan within 45 days of submission. Localities will have the opportunity to review the plan and comment. Where localities have adopted more stringent standards in accordance with Section 10.1-570, DSWC will consider and apply those standards where deemed appropriate for local conditions.

      If the plan is not approved, the applicant will be notified in writing of the modifications needed to gain approval. If DSWC takes no action to approve or disapprove the plan within 45 days, the plan is automatically approved as submitted.

DSWC will notify all localities in which the project lies of any action it takes for approval or disapproval of the plan. If the plan is finally approved, each locality will receive a copy of the approved plan. Upon receipt of the approved plan, each locality may issue applicable permits, collect appropriate fees for permits, and obtain performance guarantees as provided under local administrative procedures.

Approved plans may be changed under the following conditions:

1) Where inspection (by the locality or localities) has revealed the inadequacy of the plan to accomplish the erosion and sediment control objectives of the plan, and proposed amendments are agreed to by the locality or DSWC;

or,

2) Where the person responsible for carrying out the approved plan finds that, because of changed circumstances or for other reasons, the approved plan cannot be effectively carried out, and proposed amendments to the plan, consistent with the requirements of the VESCL, are agreed to by the locality or DSWC.

b. Inspections

Inspections shall be the responsibility of the locality (or localities). The person responsible for implementing the plan shall notify the localities when land disturbing commences. DSWC may also periodically monitor the project to ensure that the plan is properly implemented. Before making any on-site visits, DSWC will notify the locality involved.

c. Enforcement

Responsibility for enforcement of the approved plan rests with the locality (or localities). The locality may require performance bonds, cash escrow accounts, letters of credit or other appropriate guarantees to ensure that the plan is properly carried out.

d. Appeals

Appeals shall be carried out in the following manner:

1) Appeals on acts or decisions of a locality shall be filed in accordance with the E&S ordinance of that locality.

2) Appeals on the requirements of the plan or other action or proposed action by DSWC shall be subject to the review of the Board, provided an appeal is filed within thirty days from the date of the written decision.

3) Final decisions of the Board shall be subject to judicial review in accordance with the provisions of the Administrative Process Act (Sec. 9-6.14:1 et seq.).

Discussion

Some localities have agreements with adjacent localities regarding multijurisdictional projects. Frequently, the locality which contains the greater portion of the project area will handle all or part of the E&S administrative procedures (plan review, permit issuance, fee collection, inspection and enforcement).

Conclusions

To help localities reduce erosion and sedimentation from urban construction, DSWC recommends the following measures*:

1. Ensure that no land-disturbing activity is allowed to commence grading or receive any other permits for construction prior to the approval of the project's E&S plan.

2. Provide the necessary staff and resources, including adequate education and training for program personnel, to effectively implement the local E&S Program.

3. Conduct periodic inspections of all active construction projects to ensure that the Law, program regulations and approved E&S plans are being followed.

4. Establish a clear, efficient enforcement procedure to ensure that E&S violations and other problems are corrected quickly. Enlist the support of the Commonwealth and municipal attorneys and local judges in enforcing the program.

5. Periodically conduct information programs for the general public as well as for those in the land-development industry to explain program requirements and promote compliance.

6. Ensure that all local government-funded construction (schools, fire stations, industrial parks, landfills, etc.) have approved E&S plans that are effectively implemented. Generally conduct E&S activities in an exemplary manner to provide a model of compliance for private sector projects.

7. Ensure that at least one, preferably all, local E&S officials become certified under the DSWC's certification program.

8. Identify all "erosion impact areas" (as defined in the VESCL) and require them to be stabilized.

* From Nonpoint Source Pollution Management Program, Revised 1989.

PART II: STATE AGENCY PROJECTS

The VESCL requires that DSWC must review E&S plans or specifications for all state-sponsored land-disturbing activities. This may be accomplished in one of two ways: (1) annual E&S specifications, or (2) E&S plans for each project.

Submission of Annual E&S Specifications

State agencies may prepare their own standards and specifications for erosion and sediment control. These standards and specifications must be reviewed and approved annually by DSWC. The agency is then responsible for the preparation of plans for individual projects and the inspection and enforcement of the plans.

State agencies which choose this option must submit standards and specifications at least annually for review by DSWC. The standards and specifications should be submitted by November 1 of each year. DSWC will promptly review the standards and specifications and notify the agency within 60 days of its approval or disapproval.

To use this option, the agency must have sufficient capabilities to prepare E&S plans for each land-disturbing activity and to properly inspect and enforce the plans. DSWC will periodically inspect active construction sites to ensure that the program is effective and administered adequately.

Submission of Erosion and Sediment Control Plans

State agencies which have not submitted annual standards and specifications must submit an E&S plan for each land-disturbing activity to DSWC for approval. This E&S plan requirement applies to capital improvement projects as well as other land-disturbing activities as defined by VESCL (Sec. 10.1-560).

Note: When determining the amount of land disturbance for a project, the agency should include the project site, staging areas and any off-site areas such as borrow sites and surplus material disposal areas. In the event that off-site areas were not included in the original site plan, contact the appropriate DSWC regional office for approval before commencing the off-site activity.

The E&S plan should be prepared in accordance with the guidelines in Chapter 6 of this handbook. Plans should be sent to the appropriate regional office. (See Appendix 7C.) Four copies of the plan must be submitted by the agency or by its designated representative, such as an engineer or architect. All replies will be made to the person submitting the plan.

To facilitate planning, preliminary plans may also be submitted to DSWC. Comments will be made concerning erosion and sediment controls on the plan; however, the comments will not be binding and final approval will be granted only on final working drawings.

Minimum Standards - When determining plan adequacy, DSWC will generally apply the Minimum Standards contained in the E&S Regulations. The standards and specifications in Chapter 3 of this handbook (with standard symbols and abbreviations) should be used in the design of the E&S plan.

Note: State agency projects must comply with the Virginia Stormwater Management Program (SWM). With regard to stormwater runoff, the plan shall comply with the more stringent regulation of either the E&S or SWM program as determined by DSWC.

Approval or Disapproval - DSWC will promptly review all E&S plans submitted. Reviews will be conducted expeditiously, and, in all cases, the review will be completed within 60 days. The person submitting the plan will be notified in writing of its approval or disapproval. If the project is disapproved, the applicant will be notified of the modifications necessary to obtain approval. DSWC will provide copies of all final correspondence concerning each project to the Department of General Services' Division of Engineering and Buildings and the local E&S program administrator.

Modifications to an Approved Plan - An approved E&S plan may be changed under the following circumstances:

a. Where inspection has revealed the inadequacy of the plan to accomplish the erosion and sediment control objectives of the plan;

or

b. Where the agency responsible for carrying out the approved plan finds that because of changed circumstances or for other reasons the approved plan cannot be effectively carried out, and proposed amendments to the plan, consistent with the requirements of the E&S program, are agreed to by DSWC.

Inspection - A state agency which engages in a land-disturbing activity is responsible for inspection and enforcement of each E&S plan. This task may be delegated to someone such as an engineer or architect, but the agency retains the ultimate responsibility. The DSWC's Regional E&S Specialists will monitor state-sponsored construction sites to ensure that the plans are being properly carried out.

DSWC Assistance - DSWC will assist state agencies in formulating E&S plans on both capital and non-capital improvement projects upon request. As time and manpower permit, DSWC will also make its personnel and other resources available for inspections, workshops, research, and other activities to improve the effectiveness of erosion and sediment control on state construction projects.

Appeals - Appeals of any final decisions of DSWC shall be reviewed by the Soil and Water Conservation Board (Board). Appeals must be filed with the Board within 30 days from the date of the written decision. Decisions by the Board are subject to the appeals process provided by VESCL (Sec. 10.1-568 (c)).

APPENDIX 7A

SAMPLE ADMINISTRATIVE FORMS

The following sample forms are intended to streamline and improve efficiency of program administration. They are intended as suggestions, not requirements. Most localities have already developed forms for some of these procedures. We suggest that you review these and incorporate them into your program. Each one may be modified to fit your local program.

1. Brochure - "Obtaining a Land-Disturbing Permit" (for land developers/general public).

2. Checklist for Erosion and Sediment Control Plans (to assist with plan preparation and review).

3. Screening Form for Land-Disturbing Permit (for determining whether or not an E&S plan is required).

4. Application for Land-Disturbing Permit (or E&S Plan Approval) (for those submitting E&S plans).

5. Agreement in Lieu of an E&S Plan (option for those disturbing individual lots in residential subdivision development).

6. Inspector's Daily Log Entry (for E&S inspectors).

7. Inspection Report Form - Erosion and Sediment Control.

8. Notice to Comply (to be sent to violators).

9. Stop Work Order (to be sent to violators).

10. Notice of Permit Requirement (to be sent to violators).

11. Erosion Impact Area (to officially declare property such).

12. Citizen Request for Assistance (to record pertinent information).

OBTAINING A LAND-DISTURBING PERMIT

Before you grade, excavate, fill, or clear land, you may have to obtain a Land-Disturbing Permit. To find out if you need one, contact:

(Local Program Administrator)
(Address)
(Phone Number)

You will be asked what type of project you plan, location, and the total area of the property and number of square feet to be disturbed.

If Your Project Requires an Erosion and Sediment Control Plan:

You must:

a. Fill out an application;

b. Submit a plan, consisting of a narrative and site plan. (Obtain a copy of the E&S Handbook; it will tell you how to prepare a plan);

c. Pay a plan review fee of ________________.

Your plan will be reviewed and evaluated. If changes are required, you will be notified and advised of them. A revised plan may be required.

Upon final approval of the plan, you will be required to post a bond (surety bond, cash escrow, letter of credit) and sign certain agreements connected with the permit.

Your land-disturbing permit will then be issued. Building permits can be issued and the approved construction may commence.

CHECKLIST

FOR EROSION AND SEDIMENT CONTROL PLANS

______ Minimum Standards - All applicable Minimum Standards must be addressed.

NARRATIVE

______ Project description - Briefly describes the nature and purpose of the land-disturbing activity, and the area (acres) to be disturbed.

______ Existing site conditions - A description of the existing topography, vegetation and drainage.

______ Adjacent areas - A description of neighboring areas such as streams, lakes, residential areas, roads, etc., which might be affected by the land disturbance.

______ Off-site areas - Describe any off-site land-disturbing activities that will occur (including borrow sites, waste or surplus areas, etc.). Will any other areas be disturbed?

______ Soils - A brief description of the soils on the site giving such information as soil name, mapping unit, erodibility, permeability, depth, texture and soil structure.

______ Critical areas - A description of areas on the site which have potentially serious erosion problems (e.g., steep slopes, channels, wet weather/ underground springs, etc.).

______ Erosion and sediment control measures - A description of the methods which will be used to control erosion and sedimentation on the site. (Controls should satisfy minimum standards in Chapter 3.)

______ Permanent stabilization - A brief description, including specifications, of how the site will be stabilized after construction is completed.

______ Stormwater runoff considerations - Will the development site cause an increase in peak runoff rates? Will the increase in runoff cause flooding or channel degradation downstream? Describe the strategy to control stormwater runoff.

______ Calculations - Detailed calculations for the design of temporary sediment basins, permanent stormwater detention basins, diversions, channels, etc. Include calculations for pre- and post-development runoff.

SITE PLAN

_____ Vicinity map - A small map locating the site in relation to the surrounding area. Include any landmarks which might assist in locating the site.

_____ Indicate north - The direction of north in relation to the site.

_____ Limits of clearing and grading - Areas which are to be cleared and graded.

_____ Existing contours - The existing contours of the site.

_____ Final contours - Changes to the existing contours, including final drainage patterns.

_____ Existing vegetation - The existing tree lines, grassed areas, or unique vegetation.

_____ Soils - The boundaries of different soil types.

_____ Existing drainage patterns - The dividing lines and the direction of flow for the different drainage areas. Include the size (acreage) of each drainage area.

_____ Critical erosion areas - Areas with potentially serious erosion problems. (See Chapter 6 for criteria.)

_____ Site Development - Show all improvements such as buildings, parking lots, access roads, utility construction, etc.

_____ Location of practices - The locations of erosion and sediment control and stormwater management practices used on the site. Use the standard symbols and abbreviations in Chapter 3 of the E&S Handbook.

_____ Off-site areas - Identify any off-site land-disturbing activities (e.g., borrow sites, waste areas, etc.). Show location of erosion controls. (Is there sufficient information to assure adequate protection and stabilization?)

_____ Detail drawings - Any structural practices used that are not referenced to the E&S Handbook or local handbooks should be explained and illustrated with detail drawings.

_____ Maintenance - A schedule of regular inspections and repair of erosion and sediment control structures should be set forth.

SCREENING FORM

Project: ______________________ Project File#: ________

Applicant: ______________________________________
(Name)

____
(Address)

Will project require grading, excavating, clearing, filling, or other land-disturbing activity of any kind? YES NO

If YES, complete this form:

Purpose: ______________________________________

____

Location: ______________________________________

____

Area to be disturbed: ________ acres; ____________ sq. ft.

Total area of the property: ________ acres; ____________ sq. ft.

Is structure a single family dwelling? YES NO

If yes, is it located in a residential subdivision? YES NO

= =

(FOR OFFICE USE ONLY)

Checked by ______________________ Date ____________

________ Requires an Erosion and Sediment Control Plan

________ Requires an Agreement in Lieu of an E&S Plan

________ Exempt

APPLICATION FOR LAND-DISTURBING PERMIT

Project File#: ____________________
Date of Application: ____________________
Permit Effective Date: ____________________
Permit Expires: ____________________

Applicant: ____
(Name) (Business Phone)

____
(Address)

Landowner: ____
(Name) (Business Phone)

____
(Address)

Plan prepared by: ____

Project: ____
(Name and Description)

Location: ____

Tax Map: ____________ Parcel ____________ Area = ____________sq.ft.

I, __**[applicant]**__, hereby certify that I fully understand the provisions of the __**[locality]**__ Erosion and Sediment Control Ordinance and Program, and that I accept responsibility for carrying out the Erosion and Sediment Control Plan for the above-referenced project as approved.

I further grant the right-of-entry onto this property, as described above, to the designated personnel of __**[locality]**__ for the purpose of inspecting and monitoring for compliance with the aforesaid Ordinance.

The following general statements shall apply to all permits:

1. All projects shall conform to the standards and specifications and other criteria adopted by **[locality]** unless a variance has been granted in writing by this locality.

2. This permit must be kept on the work site and shown on request.

3. The locality must be notified when work commences and when the project is completed.

4. Other work (grading, excavating, construction) on the project shall not commence until the appropriate erosion and sediment controls are in-place as specified on the plan.

5. Applicant agrees to be responsible for any and all damages to any other conservation measures already in-place as a result of work covered by this permit.

6. Applicant agrees to maintain the conservation measures in satisfactory operating condition until final, permanent stabilization is achieved.

7. The land-disturbing permit may be revoked, should the locality determine that the project is not in compliance with the conditions of the approved plan.

I, applicant, certify that I have read and understand the above requirements of this permit.

Section ________ of the ________________________ Code requires that a Performance Guarantee be posted with the Commonwealth's Attorney in the amount determined by the Program Administrator. Such Performance Guarantee shall be conditioned to conform any work to approved standards and specifications as specified in the approved Erosion and Sediment Control Plan.

Final inspection of the project shall be made by the Program Administrator or designated agent. The release of any Performance Guarantee is contingent upon the findings of such inspection. Release of the Performance Guarantee shall occur within 60 days after the project site is deemed adequately stabilized by the Program Administrator. The amount of such Performance Guarantee is hereby set at $____________. The fee for plan review and inspection for this project is hereby stated to be $__________.

SUBMITTED:

______________________________________ ____________________
(Applicant signature) (Date)

APPROVED:

______________________________________ ____________________
(Program Administrator) (Date)

______________________________________ ____________________
(Plan Approving Authority) (Date)

Attachments: ( ) copies of E&S plan
Fee Payment
Performance Guarantee

AGREEMENT IN LIEU OF AN EROSION AND SEDIMENT CONTROL PLAN FOR A SINGLE FAMILY RESIDENCE

Land-Disturbing Permit No.: ____________________
Building Permit Number: ____________________
Subdivision: ____________________
Lot Number: ____________________

In lieu of submission of an erosion and sediment control plan for the construction of this single family dwelling, I agree to comply with any reasonable requirements determined necessary by employees of ____**[Locality]**_______, representing the Erosion and Sediment Control Program Administrator. Such requirements shall be based on the conservation standards contained in the ____**[Locality]**____ Erosion and Sediment Control Ordinance, and shall represent the minimum practices necessary to provide adequate control of erosion and sedimentation on or resulting from this project.

As a minimum, all denuded areas on the lot shall be stabilized within 7 days of final grading with permanent vegetation or a protective ground cover suitable for the time of year.

I further understand that failure to comply with such requirements within three working days following notice by the representatives of ____**[Locality]**____ could result in citation for violation of the ____**[Locality]**____ Erosion and Sediment Control Ordinance.

Measures Specified by the Plan Approving Authority: ______________________________

____

____

____

Signature of Landowner: ____

Party Responsible for Erosion and
Sediment Control (if different from landowner): ______________________________

Approved By: ______________________________ Date: ____________________

INSPECTOR'S DAILY LOG ENTRY

Date: ______________

Time: ______________

Project: ____

Stage of Project:

Condition of Site:

Verbal Comments (Violations, potential problems, etc.):

Initialed _____

INSPECTION REPORT

Sheet ____ of ____

Project Name: ______________________________ File No. ______________

Inspection Date: ______________ Time: ____________ Inspected by: ______________

STAGE OF CONSTRUCTION

____ Pre-Construction Conference
____ Clearing and Grubbing
____ Rough Grading
____ Building Construction
____ Finish Grading
____ Final Stabilization

INSPECTION CHECKLIST

Yes	No	NA		
☐	☐	☐	*MS-1	Have all denuded areas requiring temporary or permanent stabilization been stabilized? Seeded? yes/no Mulched? yes/no Graveled? yes/no
☐	☐	☐	MS-2	Are soil stockpiles adequately stabilized with seeding and/or sediment trapping measures?
☐	☐	☐	MS-3	Does permanent vegetation provide adequate stabilization?
☐	☐	☐	MS-4	Have sediment trapping facilities been constructed as a first step in LDA?
☐	☐	☐	MS-5	For perimeter sediment trapping measures, are earthen structures stabilized?
☐	☐	☐	MS-6	Are sediment basins installed where needed?
☐	☐	☐	MS-7	Are finished cut and fill slopes adequately stabilized?
☐	☐	☐	MS-8&9	Are on-site channels and outlets adequately stabilized?
☐	☐	☐	MS-10	Do all operational storm sewer inlets have adequate inlet protection?
☐	☐	☐	MS-11	Are stormwater conveyance channels adequately stabilized with channel lining and/or outlet protection?
☐	☐	☐	MS-12	Is in-stream construction conducted using measures to minimize channel damage?
☐	☐	☐	MS-13	Are temporary stream crossings of non-erodible material installed where applicable?
☐	☐	☐	MS-15	Is necessary restabilization of in-stream construction complete?
☐	☐	☐	MS-16	Are utility trenches stabilized properly?
☐	☐	☐	MS-17	Are soil and mud kept off public roadways at intersections with site access roads?
☐	☐	☐	MS-18	Have all temporary control structures that are no longer needed been removed?
☐	☐	☐		Have all control structure repairs and sediment removal been performed?
☐	☐	☐	MS-19	Are properties and waterways downstream from development adequately protected from erosion and sediment deposition due to increases in peak stormwater runoff?

*** Refers to the minimum standards of the Virginia Erosion and Sediment Control Regulations (VR 625-02-00).**

Comments: ____

____

____

____

Verbal/Written notification given to: ______________________________

Report by: ______________________________ Date: ______________

NOTICE TO COMPLY

Project File #: __________

Date: __________

To: ____

Re: ____
(Project Name)

An inspection of the above-referenced project on [date] revealed that the following violations are present: ____

____

____

The following recommendations are made regarding the necessary corrections:

____

____

____

Notice is hereby given that these violations shall be corrected in accordance with the approved Erosion and Sediment Control Plan on or before [date]. The site will be re-inspected at that time.

Failure to comply with this notice will result in necessary legal enforcement action by the locality to effect the implementation of the approved plan. Please contact this department if there are any questions.

Inspector: ____
(Signature)

Program Administrator: ____
(Signature)

Copies to: Commonwealth's Attorney
Board of Supervisors/Town or City Council
Plan Approving Authority

STOP WORK ORDER

To: ______________________________ Date: __________

Address: ____

____

Project File#: ____________ Name: ______________________

Project Location: ______________________________________

The above-referenced project is in violation of the __[locality]__ Erosion and Sediment Control Ordinance. A "Notice to Comply" was issued on __[date]__. Corrective measures specified for compliance were not performed.

This order requires that all land-disturbing activities on the above-referenced site be stopped until the specified corrective measures have been taken. If work is not begun to correct this violation by __[date]__, further legal action will be taken. Upon completion of the corrective action, the order shall immediately be lifted.

Program Administrator ____________________ Date ______________

Chief Administrative
Officer **[of locality]** ____________________ Date ______________

cc: Commonwealth's Attorney
Plan Approving Authority

7A-10

NOTICE OF PERMIT REQUIREMENT

Date:________

To: ____
(Name)

____
(Address)

Re: ____
(Project Name)

It has come to the attention of this department that a land-disturbing activity is occurring on your property located at __**[location]**__.

This activity requires a Land-Disturbing Permit. Pursuing the activity without such a permit is a violation of the ____**[locality]**_____ Erosion and Sediment Control Ordinance.

It is hereby requested that you cease the land-disturbing activity until a permit has been obtained from this office. Contact us as soon as possible so that we may assist you in bringing your project into compliance with the Law.

Signed: ________________________________
(Program Administrator)

cc: Commonwealth's Attorney
Board of Supervisors/Town or City Council
Plan Approving Authority

EROSION IMPACT AREA

To: ______________________________ Date: ____________

Address: ____

____

[Locality] has identified the property located ______________________________ as an Erosion Impact Area. You, as the property owner, are required to submit an Erosion and Sediment Control Plan to this office by _[date]_. Failure to comply with this notice is a violation of the _[locality]_ Erosion and Sediment Control Ordinance.

If you have any questions regarding the content of the required Erosion and Sediment Control Plan, please contact the Program Administrator as listed below.

Program Administrator ______________________ Date ___________
(signature)

cc: Commonwealth's Attorney
Plan Approving Authority

* An Erosion Impact Area is defined as "an area of land not associated with current land-disturbing activity but subject to persistent soil erosion resulting in the delivery of sediment onto neighboring properties or into state waters" (Sec. 10.1-560 in the Virginia Erosion and Sediment Control Law, Code of Virginia).

REQUEST FOR ASSISTANCE

Received By: ______________________ Date: ______________

Referred To: ______________________ Date: ______________

Assistance Requested By: ____

Street Address/P. O. Box: ____

City/Town/Zip: ____

Telephone:

Location of Problem: ____

Description of Problem: ____

____

____

____

Is the problem related to a land-disturbing activity? ____________________

If yes, Project File# ______________

Problem Satisfactorily Resolved? __________________ Date ___________

Chronological Summary of Actions Taken: ______________________________

____

____

____

____

APPENDIX 7C

DCR/DSWC URBAN PROGRAMS CONTACT INFORMATION
Erosion and Sediment Control (ESC) and Stormwater Management (SWM) Programs
URBAN PROGRAMS HOME PAGES

http://www.state.va.us/~dcr/sw/e&s.htm http://www.state.va.us/~dcr/sw/stormwat.htm

TRAINING & CERTIFICATION HOME PAGE

http://www.state.va.us/~dcr/sw/estr&crt.htm

LINKS TO LOCAL GOVERNMENTS

http://www.vipnet.org/vipnet/government/local-government.html

DCR CENTRAL OFFICE

203 Governor Street, Suite 206
Richmond, VA 23219

Program Support Technician **Regina Greene** (804) 371-7533 fax 786-1978	**Assistant Program Support Technician** **Nicole Gordon** (804) 371-7489 fax 786-1978
Urban Programs Training/Certification Coordinator VACANT (804)371-7532 fax 786-1978	**Urban Programs Regulatory Coordinator** Michael C. Gerel (804) 371-7440 fax 786-1978
Urban Programs Engineer - VACANT (804) 786-4508 fax 371-2630	
Stormwater Management Program Manager Joseph G. Battiata (804) 371-7492 fax 371-2630	**Erosion and Sediment Control Program Manager** Jacob A. Porter (804) 786-3997 fax 371-2630

DCR WATERSHED OFFICES*
Urban Program Compliance Engineer (UPCE), Urban Program Engineer (UPE), and Urban Program Planner (UPP) Field Representatives

Shenandoah Watershed Office <u>Manager</u> - Charlie Wade Tamara Keeler (UPCE) John S. Mlnarcik (UPE) Lynn A. Snyder (UPCE – Shen-James West) Route 4, Box 99-J **Staunton**, VA 24401 (540) 332-9991 fax: 332-8956	**James Watershed Office** <u>Manager</u> - Michael Bowman Robert E. Cooper (UPE) John McCutcheon (UPCE - James East) David Aho (UPCE - James Central) 3800 Stillman Parkway, Suite 102 **Richmond**, VA 23233 (804) 527-4484 fax: 527-4483	**Potomac Watershed Office** <u>Manager</u> - Mary Apostolico VACANT (UPCE) Jamie B. Lowery (UPE) 98 Alexandria Pike, Suite 33 **Warrenton**, VA 22186 (540) 347-6420 fax: 347-6423
Rappahannock Watershed Office <u>Manager</u> - Matthew Criblez VACANT (UPP) Michael J. Lee (UPCE) Commonwealth Building, 2601Princess Anne St., Suite 101 **Fredericksburg**, VA 24401 (540) 899-4074 fax 899-4389	**York Watershed Office** <u>Manager</u> - Darryl Glover Kenny W. Harper (UPCE) Post Office Box 1425 **Tappahannock**, VA 22560 (804) 443-6752 fax: 443-4534	**Upper Tennessee & Big Sandy (UTBS) Watershed Office** <u>Manager</u> - Neal Kilgore Phyllis A. Hinch (UPCE) 252 W. Main St., Suite 3 **Abingdon**, VA 24210 (540) 676-5529 fax: 676-5527
Roanoke Watershed Office <u>Manager</u> - Tim Ott VACANT (UPP) Clarence F. Huff (UPCE) 411 Boyd Street **Chase City**, VA 23924 (804) 372-2191/2192 fax: 372-4962	**New River Watershed Office** <u>Manager</u> – Charlotte Burnett Vacant (UPE) Vacant (UPCE) Post Office Box 1506 148 Broad Street **Dublin**, VA 24084 (540) 643-2590 fax: 643-2597	**Chowan & Albermarle Watersheds Office** <u>Manager</u> - Ernie Brown Vacant (UPE) Jeffrey T. Hancock (UPCE) 1548-A Holland Road **Suffolk**, VA 23434 (757) 925-2468 fax: 925-2388

APPENDIX 7C
LOCAL GOVERNMENT JURSIDICTIONS AND CORRESPONDING URBAN PROGRAMS CONTACTS

COUNTIES

County	Watershed Office*	County	Watershed Office*
Accomack	Chowan/Albermarle	King & Queen	York
Albemarle	James Central	King William	York
Alleghany	Shen – James West	Lancaster	Rappahannock
Amelia	James East	Lee	UTBS
Amherst	James Central	Loudoun	Potomac
Appomattox	James Central	Louisa	James Central
Arlington	Potomac	Lunenburg	Roanoke
Augusta	Shen – James West	Madison	Rappahannock
Bath	Shen - James West	Mathews	York
Bedford	Roanoke	Mecklenburg	Roanoke
Bland	New River	Middlesex	York
Botetourt	Shen - James West	Montgomery	New River
Brunswick	Roanoke	Nelson	James Central
Buchanan	UTBS	New Kent	York
Buckingham	James Central	Northampton	Chowan/Albermarle
Campbell	James Central	Northumberland	Rappahannock
Caroline	York	Nottoway	James East
Carroll	New River	Orange	Rappahannock
Charles City	York	Page	Shenandoah
Charlotte	Roanoke	Patrick	New River
Chesterfield	James East	Pittsylvania	Roanoke
Clarke	Shenandoah	Powhatan	James East
Craig	Shen - James West	Prince Edward	James East
Culpeper	Rappahannock	Prince George	James East
Cumberland	James East	Prince William	Potomac
Dickenson	UTBS	Pulaski	New River
Dinwiddie	Chowan/Albermarle	Rappahannock	Rappahannock
Essex	York	Richmond	Rappahannock
Fairfax	Potomac	Roanoke	Roanoke
Fauquier	Potomac	Rockbridge	Shen - James West
Floyd	New River	Rockingham	Shenandoah
Fluvanna	James Central	Russell	UTBS
Franklin	Roanoke	Scott	UTBS
Frederick	Shenandoah	Shenandoah	Shenandoah
Giles	New River	Smyth	UTBS
Gloucester	York	Southampton	Chowan/Albermarle
Goochland	James East	Spotsylvania	Rappahannock
Grayson	New River	Stafford	Rappahannock
Greene	Rappahannock	Surry	Chowan/Albermarle
Greensville	Chowan/Albermarle	Sussex	Chowan/Albermarle
Halifax	Roanoke	Tazewell	New River
Hanover	York	Warren	Shenandoah
Henrico	James East	Washington	UTBS
Henry	Roanoke	Westmoreland	Rappahannock
Highland	Shen – James West	Wise	UTBS
Isle of Wight	Chowan/Albermarle	Wythe	New River
James City	York	York	York
King George	Rappahannock		

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APPENDIX 7C

LOCAL GOVERNMENT JURSIDICTIONS AND CORRESPONDING URBAN PROGRAMS CONTACTS

CITIES

City	Watershed Office*	City	Watershed Office*
Alexandria	Potomac	Manassas	Potomac
Bedford	Roanoke	Manassas Park	Potomac
Bristol	UTBS	Martinsville	Roanoke
Buena Vista	Shen – James West	Newport News	Chowan/Albermarle
Charlottesville	James Central	Norfolk	Chowan/Albermarle
Chesapeake	Chowan/Albermarle	Norton	UTBS
Clifton Forge	Shen – James West	Petersburg	Chowan/Albermarle
Colonial Heights	James East	Poquoson	York
Covington	Shen – James West	Portsmouth	Chowan/Albermarle
Danville	Roanoke	Radford	New River
Emporia	Chowan/Albermarle	Richmond	James East
Fairfax	Potomac	Roanoke	Roanoke
Falls Church	Potomac	Salem	Roanoke
Franklin	Chowan/Albermarle	Staunton	Shen - James West
Fredericksburg	Rappahannock	Suffolk	Chowan/Albermarle
Galax	New River	Virginia Beach	Chowan/Albermarle
Hampton	Chowan/Albermarle	Waynesboro	Shen - James West
Harrisonburg	Shenandoah	Williamsburg	York
Hopewell	James East	Winchester	Shenandoah
Lexington	Shen – James West		
Lynchburg	James Central		

TOWNS

Town	Watershed Office*	Town	Watershed Office*
Abingdon	UTBS	Haymarket	Potomac
Alta Vista	Roanoke	Herndon	Potomac
Ashland	York	Narrows	New River
Berryville	Shenandoah	Occoquan	Potomac
Blacksburg	New River	Pearisburg	New River
Bluefield	New River	Pulaski	New River
Bridgewater	Shenandoah	Scottsville	James Central
Cape Charles	Chowan/Albermarle	South Boston	Roanoke
Chase City	Roanoke	South Hill	Roanoke
Christiansburg	New River	Stephens City	Shenandoah
Culpeper	Rappahannock	Tappahannock	York
Dayton	Shenandoah	Vienna	Potomac
Dublin	New River	Warrenton	Potomac
Dumfries	Potomac	West Point	York
Farmville	James East	Woodstock	Shenandoah
		Wytheville	New River

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Appendix 7B

CHAPTER 8

Virginia
Erosion and Sediment Control
Law and Regulations

COMMONWEALTH of VIRGINIA

Virginia Erosion and Sediment Control Law

Virginia Erosion and Sediment Control Regulations and Certification Regulations

FY 2014

Department of Environmental Quality
629 East Main Street
P.O. Box 1105
Richmond, VA 23218
Website: http://www.deq.virginia.gov

Virginia Department of Environmental Quality

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The following is a unofficial copy of the Virginia Erosion and Sediment Control Law Please refer to the Code of Virginia for an official copy of the Law.

§ 62.1-44.15:51. Definitions.

As used in this article, unless the context requires a different meaning:

"Agreement in lieu of a plan" means a contract between the plan-approving authority and the owner that specifies conservation measures that must be implemented in the construction of a single-family residence; this contract may be executed by the plan-approving authority in lieu of a formal site plan.

"Applicant" means any person submitting an erosion and sediment control plan for approval or requesting the issuance of a permit, when required, authorizing land-disturbing activities to commence.

"Certified inspector" means an employee or agent of a VESCP authority who (i) holds a certificate of competence from the Board in the area of project inspection or (ii) is enrolled in the Board's training program for project inspection and successfully completes such program within one year after enrollment.

"Certified plan reviewer" means an employee or agent of a VESCP authority who (i) holds a certificate of competence from the Board in the area of plan review, (ii) is enrolled in the Board's training program for plan review and successfully completes such program within one year after enrollment, or (iii) is licensed as a professional engineer, architect, landscape architect, land surveyor pursuant to Article 1 (§ 54.1-400 et seq.) of Chapter 4 of Title 54.1, or professional soil scientist as defined in § 54.1-2200.

"Certified program administrator" means an employee or agent of a VESCP authority who (i) holds a certificate of competence from the Board in the area of program administration or (ii) is enrolled in the Board's training program for program administration and successfully completes such program within one year after enrollment.

"Department" means the Department of Environmental Quality.

"Director" means the Director of the Department of Environmental Quality.

"District" or "soil and water conservation district" means a political subdivision of the Commonwealth organized in accordance with the provisions of Article 3 (§ 10.1-506 et seq.) of Chapter 5 of Title 10.1.

"Erosion and sediment control plan" or "plan" means a document containing material for the conservation of soil and water resources of a unit or group of units of land. It may include appropriate maps, an appropriate soil and water plan inventory and management information with needed interpretations, and a record of decisions contributing to conservation treatment. The plan shall contain all major conservation decisions to ensure that the entire unit or units of land will be so treated to achieve the conservation objectives.

"Erosion impact area" means an area of land not associated with current land-disturbing activity but subject to persistent soil erosion resulting in the delivery of sediment onto neighboring properties or into state waters. This definition shall not apply to any lot or parcel of land of 10,000 square feet or less used for residential purposes or to shorelines where the erosion results from wave action or other coastal processes.

"Land-disturbing activity" means any man-made change to the land surface that may result in soil erosion from water or wind and the movement of sediments into state waters or onto lands in the Commonwealth, including, but not limited to, clearing, grading, excavating, transporting, and filling of land, except that the term shall not include:

1. Minor land-disturbing activities such as home gardens and individual home landscaping, repairs, and maintenance work;

2. Individual service connections;

3. Installation, maintenance, or repair of any underground public utility lines when such activity occurs on an existing hard surfaced road, street, or sidewalk, provided the land-disturbing activity is confined to the area of the road, street, or sidewalk that is hard surfaced;

4. Septic tank lines or drainage fields unless included in an overall plan for land-disturbing activity relating to construction of the building to be served by the septic tank system;

5. Permitted surface or deep mining operations and projects, or oil and gas operations and projects conducted pursuant to Title 45.1;

6. Tilling, planting, or harvesting of agricultural, horticultural, or forest crops, livestock feedlot operations, or as additionally set forth by the Board in regulation, including engineering operations as follows: construction of terraces, terrace outlets, check dams, desilting basins, dikes, ponds, ditches, strip cropping, lister furrowing, contour cultivating, contour furrowing, land drainage, and land irrigation; however, this exception shall not apply to harvesting of forest crops unless the area on which harvesting occurs is reforested artificially or naturally in accordance with the provisions of Chapter 11 (§ 10.1-1100 et seq.) of Title 10.1 or is converted to bona fide agricultural or improved pasture use as described in subsection B of § 10.1-1163;

7. Repair or rebuilding of the tracks, rights-of-way, bridges, communication facilities, and other related structures and facilities of a railroad company;

8. Agricultural engineering operations, including but not limited to the construction of terraces, terrace outlets, check dams, desilting basins, dikes, ponds not required to comply with the provisions of the Dam Safety Act (§ 10.1-604 et seq.), ditches, strip cropping, lister furrowing, contour cultivating, contour furrowing, land drainage, and land irrigation;

9. Disturbed land areas of less than 10,000 square feet in size or 2,500 square feet in all areas of the jurisdictions designated as subject to the Chesapeake Bay Preservation Area Designation and Management Regulations; however, the governing body of the program authority may reduce this exception to a smaller area of disturbed land or qualify the conditions under which this exception shall apply;

10. Installation of fence and sign posts or telephone and electric poles and other kinds of posts or poles;

11. Shoreline erosion control projects on tidal waters when all of the land-disturbing activities are within the regulatory authority of and approved by local wetlands boards, the Marine Resources Commission, or the United States Army Corps of Engineers; however, any associated land that is disturbed outside of this exempted area shall remain subject to this article and the regulations adopted pursuant thereto; and

12. Emergency work to protect life, limb, or property, and emergency repairs; however, if the land-disturbing activity would have required an approved erosion and sediment control plan, if the activity were not an emergency, then the land area disturbed shall be shaped and stabilized in accordance with the requirements of the VESCP authority.

"Natural channel design concepts" means the utilization of engineering analysis and fluvial geomorphic processes to create, rehabilitate, restore, or stabilize an open conveyance system for the purpose of creating or recreating a stream that conveys its bankfull storm event within its banks and allows larger flows to access its bankfull bench and its floodplain.

"Owner" means the owner or owners of the freehold of the premises or lesser estate therein, mortgagee or vendee in possession, assignee of rents, receiver, executor, trustee, lessee, or other person, firm, or corporation in control of a property.

"Peak flow rate" means the maximum instantaneous flow from a given storm condition at a particular location.

"Permittee" means the person to whom the local permit authorizing land-disturbing activities is issued or the person who certifies that the approved erosion and sediment control plan will be followed.

"Person" means any individual, partnership, firm, association, joint venture, public or private corporation, trust, estate, commission, board, public or private institution, utility, cooperative, county, city, town, or other political subdivision of the Commonwealth, governmental body, including a federal or state entity as applicable, any interstate body, or any other legal entity.

"Runoff volume" means the volume of water that runs off the land development project from a prescribed storm event.

"Town" means an incorporated town.

"Virginia Erosion and Sediment Control Program" or "VESCP" means a program approved by the Board that has been established by a VESCP authority for the effective control of soil erosion, sediment deposition, and nonagricultural runoff associated with a land-disturbing activity to prevent the unreasonable degradation of properties, stream channels, waters, and other natural resources and shall include such items where applicable as local ordinances, rules, permit requirements, annual standards and specifications, policies and guidelines, technical materials, and requirements for plan review, inspection, enforcement where authorized in this article, and evaluation consistent with the requirements of this article and its associated regulations.

"Virginia Erosion and Sediment Control Program authority" or "VESCP authority" means an authority approved by the Board to operate a Virginia Erosion and Sediment Control Program. An authority may include a state entity, including the Department; a federal entity; a district, county, city, or town; or for linear projects subject to annual standards and specifications, electric, natural gas, and telephone utility companies, interstate and intrastate natural gas pipeline companies, railroad companies, or authorities created pursuant to § 15.2-5102.

"Water quality volume" means the volume equal to the first one-half inch of runoff multiplied by the impervious surface of the land development project.

62.1-44.15:52. Virginia erosion and sediment control program.

A. The Board shall develop a program and adopt regulations in accordance with the Administrative Process Act (§ 2.2-4000 et seq.) for the effective control of soil erosion, sediment deposition, and nonagricultural runoff that shall be met in any control program to prevent the unreasonable degradation of properties, stream channels, waters, and other natural resources. Stream restoration and relocation projects that incorporate natural channel design concepts are not man-made channels and shall be exempt from any flow rate capacity and velocity requirements for natural or man-made channels as defined in any regulations promulgated pursuant to this section or § 62.1-44.15:54 or 62.1-44.15:65. Any plan approved prior to July 1, 2014, that provides for stormwater management that addresses any flow rate capacity and velocity requirements for natural or man-made channels shall satisfy the flow rate capacity and velocity requirements for natural or man-made channels if the practices are designed to (i) detain the water quality volume and to release it over 48 hours; (ii) detain and release over a 24-hour period the expected rainfall resulting from the one-year, 24-hour storm; and (iii) reduce the allowable peak flow rate resulting from the 1.5-year, two-year, and 10-year, 24-hour storms to a level that is less than or equal to the peak flow rate from the site assuming it was in a good forested condition, achieved through multiplication of the forested peak flow rate by a reduction factor that is equal to the runoff volume from the site when it was in a good forested condition divided by the runoff volume from the site in its proposed condition, and shall be exempt from any flow rate capacity and velocity requirement for natural or man-made channels as defined in regulations promulgated pursuant to § 62.1-44.15:54 or 62.1-44.15:65. For plans approved on and after July 1, 2014, the flow rate capacity and velocity requirements of this subsection shall be satisfied by compliance with water quantity requirements in the Stormwater Management Act (§ 62.1-44.15:24 et seq.) and attendant regulations, unless such land-disturbing activities are in accordance with the grandfathering provisions of the Virginia Stormwater Management Program (VSMP) Permit Regulations.

The regulations shall:

1. Be based upon relevant physical and developmental information concerning the watersheds and drainage basins of the Commonwealth, including, but not limited to, data relating to land use, soils, hydrology, geology, size of land area being disturbed, proximate water bodies and their characteristics, transportation, and public facilities and services;

2. Include such survey of lands and waters as may be deemed appropriate by the Board or required by any applicable law to identify areas, including multijurisdictional and watershed areas, with critical erosion and sediment problems; and

3. Contain conservation standards for various types of soils and land uses, which shall include criteria, techniques, and methods for the control of erosion and sediment resulting from land-disturbing activities.

B. The Board shall provide technical assistance and advice to, and conduct and supervise educational programs for VESCP authorities.

C. The Board shall adopt regulations establishing minimum standards of effectiveness of erosion and sediment control programs, and criteria and procedures for reviewing and evaluating the effectiveness of VESCPs. In developing minimum standards for program effectiveness, the Board shall consider information and standards on which the regulations promulgated pursuant to subsection A are based.

D. The Board shall approve VESCP authorities and shall periodically conduct a comprehensive program compliance review and evaluation to ensure that all VESCPs operating under the jurisdiction of this article meet minimum standards of effectiveness in controlling soil erosion, sediment deposition, and nonagricultural runoff. The Department shall develop a schedule for conducting periodic reviews and evaluations of the effectiveness of VESCPs unless otherwise directed by the Board. Such reviews where applicable shall be coordinated with those being implemented in accordance with the Stormwater Management Act (§ 62.1-44.15:24 et seq.) and associated regulations and the Chesapeake Bay Preservation Act (§ 62.1-44.15:67 et seq.) and associated regulations. The Department may also conduct a comprehensive or partial program compliance review and evaluation of a VESCP at a greater frequency than the standard schedule.

E. The Board shall issue certificates of competence concerning the content, application, and intent of specified subject areas of this article and accompanying regulations, including program administration, plan review, and project inspection, to personnel of program authorities and to any other persons who have completed training programs or in other ways demonstrated adequate knowledge. The Department shall administer education and training programs for specified subject areas of this article and accompanying regulations, and is authorized to charge persons attending such programs reasonable fees to cover the costs of administering the programs. Such education and training programs shall also contain expanded components to address plan review and project inspection elements of the Stormwater Management Act (§ 62.1-44.15:24 et seq.) and attendant regulations in accordance with § 62.1-44.15:30.

F. Department personnel conducting inspections pursuant to this article shall hold a certificate of competence as provided in subsection E.

§ 62.1-44.15:53. Certification of local program personnel.

A. The minimum standards of VESCP effectiveness established by the Board pursuant to subsection C of § 62.1-44.15:52 shall provide that (i) an erosion and sediment control plan shall not be approved until it is reviewed by a certified plan reviewer; (ii) inspections of land-disturbing activities shall be conducted by a certified inspector; and (iii) a VESCP shall contain a certified program administrator, a certified plan reviewer, and a certified project inspector, who may be the same person.

B. Any person who holds a certificate of competence from the Board in the area of plan review, project inspection, or program administration that was attained prior to the adoption of the mandatory certification provisions of subsection A shall be deemed to satisfy the requirements of that area of certification.

C. Professionals registered in the Commonwealth pursuant to Article 1 (§ 54.1-400 et seq.) of Chapter 4 of Title 54.1 or a professional soil scientist as defined in § 54.1-2200 shall be deemed to satisfy the certification requirements for the purposes of renewals.

§ 62.1-44.15:54. Establishment of Virginia erosion and sediment control programs.

A. Counties and cities shall adopt and administer a VESCP.

Any town lying within a county that has adopted its own VESCP may adopt its own program or shall become subject to the county program. If a town lies within the boundaries of more than one county, the town shall be considered for the purposes of this article to be wholly within the county in which the larger portion of the town lies.

B. A VESCP authority may enter into agreements or contracts with soil and water conservation districts, adjacent localities, or other public or private entities to assist with carrying out the provisions of this article, including the review and determination of adequacy of erosion and sediment control plans submitted for land-disturbing activities on a unit or units of land as well as for monitoring, reports, inspections, and enforcement where authorized in this article, of such land-disturbing activities.

C. Any VESCP adopted by a county, city, or town shall be approved by the Board if it establishes by ordinance requirements that are consistent with this article and associated regulations.

D. Each approved VESCP operated by a county, city, or town shall include provisions for the integration of the VESCP with Virginia stormwater management, flood insurance, flood plain management, and other programs requiring compliance prior to authorizing a land-disturbing activity in order to make the submission and approval of plans, issuance of permits, payment of fees, and coordination of inspection and enforcement activities more convenient and efficient both for the local governments and those responsible for compliance with the programs.

E. The Board may approve a state entity, federal entity, or, for linear projects subject to annual standards and specifications, electric, natural gas, and telephone utility companies, interstate and intrastate natural gas pipeline companies, railroad companies, or authorities created pursuant to § 15.2-5102 to operate a VESCP consistent with the requirements of this article and its associated regulations and the VESCP authority's Department-approved annual standards and specifications. For these programs, enforcement shall be administered by the Department and the Board where applicable in accordance with the provisions of this article.

F. Following completion of a compliance review of a VESCP in accordance with subsection D of § 62.1-44.15:52, the Department shall provide results and compliance recommendations to the Board in the form of a corrective action agreement if deficiencies are found; otherwise, the Board may find the program compliant. If a comprehensive or partial program compliance review conducted by the Department of a VESCP indicates that the VESCP authority has not administered, enforced where authorized to do so, or conducted its VESCP in a manner that satisfies the minimum standards of effectiveness established pursuant to subsection C of § 62.1-44.15:52, the Board shall establish a schedule for the VESCP authority to come into compliance. The Board shall provide a copy of its decision to the VESCP authority that specifies the deficiencies, actions needed to be taken, and the approved compliance schedule required to attain the minimum standard of effectiveness and shall include an offer to provide technical assistance to implement the corrective action. If the VESCP authority has not implemented the necessary compliance actions identified by the Board within 30 days following receipt of the corrective action agreement, or such additional period as is granted to complete the implementation of the corrective action, then the Board shall have the authority to (i) issue a special order to any VESCP, imposing a civil penalty not to exceed $5,000 per day with the maximum amount not to exceed $20,000 per violation for noncompliance with the state program, to be paid into the state treasury and deposited in the Virginia Stormwater Management Fund established by § 62.1-44.15:29 or (ii) revoke its approval of the VESCP. The Administrative Process Act (§ 2.2-4000 et seq.) shall govern the activities and proceedings of the Board and the judicial review thereof.

In lieu of issuing a special order or revoking the program, the Board is authorized to take legal action against a VESCP to ensure compliance.

G. If the Board revokes its approval of the VESCP of a county, city, or town, and the locality is in a district, the district, upon approval of the Board, shall adopt and administer a VESCP for the locality. To carry out its program, the district shall adopt regulations in accordance with the Administrative Process Act (§ 2.2-4000 et seq.) consistent with this article and associated regulations. The regulations may be revised from time to time as necessary. The program and regulations shall be available for public inspection at the principal office of the district.

H. If the Board (i) revokes its approval of a VESCP of a district, or of a county, city, or town not in a district, or (ii) finds that a local program consistent with this article and associated regulations has not been adopted by a district or a county, city, or town that is required to adopt and administer a VESCP, the Board shall find the VESCP authority provisional, and have the

Department assist with the administration of the program until the Board finds the VESCP authority compliant with the requirements of this article and associated regulations. "Assisting with administration" includes but is not limited to the ability to review and comment on plans to the VESCP authority, to conduct inspections with the VESCP authority, and to conduct enforcement in accordance with this article and associated regulations.

I. If the Board revokes its approval of a state entity, federal entity, or, for linear projects subject to annual standards and specifications, electric, natural gas, and telephone utility companies, interstate and intrastate natural gas pipeline companies, railroad companies, or authorities created pursuant to § 15.2-5102, the Board shall find the VESCP authority provisional, and have the Department assist with the administration of the program until the Board finds the VESCP authority compliant with the requirements of this article and associated regulations. "Assisting with administration" includes the ability to review and comment on plans to the VESCP authority and to conduct inspections with the VESCP authority in accordance with this article and associated regulations.

J. Any VESCP authority that administers an erosion and sediment control program may charge applicants a reasonable fee to defray the cost of program administration. Such fee may be in addition to any fee charged for administration of a Virginia Stormwater Management Program, although payment of fees may be consolidated in order to provide greater convenience and efficiency for those responsible for compliance with the programs. A VESCP authority shall hold a public hearing prior to establishing a schedule of fees. The fee shall not exceed an amount commensurate with the services rendered, taking into consideration the time, skill, and the VESCP authority's expense involved.

K. The governing body of any county, city, or town, or a district board that is authorized to administer a VESCP, may adopt an ordinance or regulation where applicable providing that violations of any regulation or order of the Board, any provision of its program, any condition of a permit, or any provision of this article shall be subject to a civil penalty. The civil penalty for any one violation shall be not less than $100 nor more than $1,000. Each day during which the violation is found to have existed shall constitute a separate offense. In no event shall a series of specified violations arising from the same operative set of facts result in civil penalties that exceed a total of $10,000, except that a series of violations arising from the commencement of land-disturbing activities without an approved plan for any site shall not result in civil penalties that exceed a total of $10,000. Adoption of such an ordinance providing that violations are subject to a civil penalty shall be in lieu of criminal sanctions and shall preclude the prosecution of such violation as a misdemeanor under subsection A of § 62.1-44.15:63. The penalties set out in this subsection are also available to the Board in its enforcement actions.

§ 62.1-44.15:55. Regulated land-disturbing activities; submission and approval of erosion and sediment control plan.

A. Except as provided in § 62.1-44.15:56 for state agency and federal entity land-disturbing activities, no person shall engage in any land-disturbing activity until he has submitted to the VESCP authority an erosion and sediment control plan for the land-disturbing activity and the plan has been reviewed and approved. Upon the development of an online reporting system by the Department, but no later than July 1, 2014, a VESCP authority shall then be required to obtain evidence of Virginia Stormwater Management Program permit coverage where it is required prior to providing approval to begin land disturbance. Where land-disturbing activities involve lands under the jurisdiction of more than one VESCP, an erosion and sediment control plan may, at the request of one or all of the VESCP authorities, be submitted to the Department for review and approval rather than to each jurisdiction concerned. The Department may charge the jurisdictions requesting the review a fee sufficient to cover the cost associated with conducting the review. A VESCP may enter into an agreement with an adjacent VESCP regarding the administration of multijurisdictional projects whereby the jurisdiction that contains the greater portion of the project shall be responsible for all or part of the administrative procedures. Where the land-disturbing activity results from the construction of a single-family residence, an agreement in lieu of a plan may be substituted for an erosion and sediment control plan if executed by the VESCP authority.

B. The VESCP authority shall review erosion and sediment control plans submitted to it and grant written approval within 60 days of the receipt of the plan if it determines that the plan meets the requirements of this article and the Board's regulations and if the person responsible for carrying out the plan certifies that he will properly perform the erosion and sediment control measures included in the plan and shall comply with the provisions of this article. In addition, as a prerequisite to engaging in the land-disturbing activities shown on the approved plan, the person responsible for carrying out the plan shall provide the name of an individual holding a certificate of competence to the VESCP authority, as provided by § 62.1-44.15:52, who will be in charge of and responsible for carrying out the land-disturbing activity. However, any VESCP authority may waive the certificate of competence requirement for an agreement in lieu of a plan for construction of a single-family residence. If a violation occurs during the land-disturbing activity, then the person responsible for carrying out the agreement in lieu of a plan shall correct the violation and provide the name of an individual holding a certificate of competence, as provided by § 62.1-44.15:52. Failure to provide the name of an individual holding a certificate of competence prior to engaging in land-disturbing activities may result in revocation of the approval of the plan and the person responsible for carrying out the plan shall be subject to the penalties provided in this article.

When a plan is determined to be inadequate, written notice of disapproval stating the specific reasons for disapproval shall be communicated to the applicant within 45 days. The notice shall specify the modifications, terms, and conditions that will permit approval of the plan. If no action is taken by the VESCP authority within the time specified in this subsection, the plan shall be deemed approved and the person authorized to proceed with the proposed activity. The VESCP authority shall act on any erosion and sediment control plan that has been previously disapproved within 45 days after the plan has been revised, resubmitted for approval, and deemed adequate.

C. The VESCP authority may require changes to an approved plan in the following cases:

1. Where inspection has revealed that the plan is inadequate to satisfy applicable regulations; or

2. Where the person responsible for carrying out the approved plan finds that because of changed circumstances or for other reasons the approved plan cannot be effectively carried out, and

proposed amendments to the plan, consistent with the requirements of this article and associated regulations, are agreed to by the VESCP authority and the person responsible for carrying out the plan.

D. Electric, natural gas, and telephone utility companies, interstate and intrastate natural gas pipeline companies, and railroad companies shall, and authorities created pursuant to § 15.2-5102 may, file general erosion and sediment control standards and specifications annually with the Department for review and approval. Such standards and specifications shall be consistent with the requirements of this article and associated regulations and the Stormwater Management Act (§ 62.1-44.15:24 et seq.) and associated regulations where applicable. The specifications shall apply to:

1. Construction, installation, or maintenance of electric transmission, natural gas, and telephone utility lines and pipelines, and water and sewer lines; and

2. Construction of the tracks, rights-of-way, bridges, communication facilities, and other related structures and facilities of the railroad company.

The Department shall have 60 days in which to approve the standards and specifications. If no action is taken by the Department within 60 days, the standards and specifications shall be deemed approved. Individual approval of separate projects within subdivisions 1 and 2 is not necessary when approved specifications are followed. Projects not included in subdivisions 1 and 2 shall comply with the requirements of the appropriate VESCP. The Board shall have the authority to enforce approved specifications and charge fees equal to the lower of (i) $1,000 or (ii) an amount sufficient to cover the costs associated with standard and specification review and approval, project inspections, and compliance.

E. Any person engaging, in more than one jurisdiction, in the creation and operation of a wetland mitigation or stream restoration bank or banks, which have been approved and are operated in accordance with applicable federal and state guidance, laws, or regulations for the establishment, use, and operation of wetlands mitigation or stream restoration banks, pursuant to a mitigation banking instrument signed by the Department of Environmental Quality, the Marine Resources Commission, or the U.S. Army Corps of Engineers, may, at the option of that person, file general erosion and sediment control standards and specifications for wetland mitigation or stream restoration banks annually with the Department for review and approval consistent with guidelines established by the Board.

The Department shall have 60 days in which to approve the specifications. If no action is taken by the Department within 60 days, the specifications shall be deemed approved. Individual approval of separate projects under this subsection is not necessary when approved specifications are implemented through a project-specific erosion and sediment control plan. Projects not included in this subsection shall comply with the requirements of the appropriate local erosion and sediment control program. The Board shall have the authority to enforce approved specifications and charge fees equal to the lower of (i) $1,000 or (ii) an amount sufficient to cover the costs associated with standard and specification review and approval, projection inspections, and compliance. Approval of general erosion and sediment control specifications by the Department does not relieve the owner or operator from compliance with any other local ordinances and regulations including requirements to submit plans and obtain permits as may be required by such ordinances and regulations.

F. In order to prevent further erosion, a VESCP authority may require approval of an erosion and sediment control plan for any land identified by the VESCP authority as an erosion impact area.

G. For the purposes of subsections A and B, when land-disturbing activity will be required of a contractor performing construction work pursuant to a construction contract, the preparation, submission, and approval of an erosion and sediment control plan shall be the responsibility of the owner.

§ § 62.1-44.15:56**. State agency and federal entity projects.**

A. A state agency shall not undertake a project involving a land-disturbing activity unless (i) the state agency has submitted annual standards and specifications for its conduct of land-disturbing activities that have been reviewed and approved by the Department as being consistent with this article and associated regulations or (ii) the state agency has submitted an erosion and sediment control plan for the project that has been reviewed and approved by the Department. When a federal entity submits an erosion and sediment control plan for a project, land disturbance shall not commence until the Department has reviewed and approved the plan.

B. The Department shall not approve an erosion and sediment control plan submitted by a state agency or federal entity for a project involving a land-disturbing activity (i) in any locality that has not adopted a local program with more stringent regulations than those of the state program or (ii) in multiple jurisdictions with separate local programs, unless the erosion and sediment control plan is consistent with the requirements of the state program.

C. The Department shall not approve an erosion and sediment control plan submitted by a state agency or federal entity for a project involving a land-disturbing activity in one locality with a local program with more stringent ordinances than those of the state program unless the erosion and sediment control plan is consistent with the requirements of the local program. If a locality has not submitted a copy of its local program regulations to the Department, the provisions of subsection B shall apply.

D. The Department shall have 60 days in which to comment on any standards and specifications or erosion and sediment control plan submitted to it for review, and its comments shall be binding on the state agency and any private business hired by the state agency.

E. As onsite changes occur, the state agency shall submit changes in an erosion and sediment control plan to the Department.

F. The state agency responsible for the land-disturbing activity shall ensure compliance with an approved plan, and the Department and Board, where applicable, shall provide project oversight and enforcement as necessary.

G. If the state agency or federal entity has developed, and the Department has approved, annual standards and specifications, and the state agency or federal entity has been approved by the Board to operate a VESCP as a VESCP authority, erosion and sediment control plan review and approval and land-disturbing activity inspections shall be conducted by such entity. The Department and the Board, where applicable, shall provide project oversight and enforcement as necessary and comprehensive program compliance review and evaluation. Such standards and specifications shall be consistent with the requirements of this article and associated regulations and the Stormwater Management Act (§ 62.1-44.15:24 et seq.) and associated regulations when applicable.

§ 62.1-44.15:57. Approved plan required for issuance of grading, building, or other permits; security for performance.

Agencies authorized under any other law to issue grading, building, or other permits for activities involving land-disturbing activities regulated under this article shall not issue any such permit unless the applicant submits with his application an approved erosion and sediment control plan and certification that the plan will be followed and, upon the development of an online reporting system by the Department but no later than July 1, 2014, evidence of Virginia Stormwater Management Program permit coverage where it is required. Prior to issuance of any permit, the agency may also require an applicant to submit a reasonable performance bond with surety, cash escrow, letter of credit, any combination thereof, or such other legal arrangement acceptable to the agency, to ensure that measures could be taken by the agency at the applicant's expense should he fail, after proper notice, within the time specified to initiate or maintain appropriate conservation action that may be required of him by the approved plan as a result of his land-disturbing activity. The amount of the bond or other security for performance shall not exceed the total of the estimated cost to initiate and maintain appropriate conservation action based on unit price for new public or private sector construction in the locality and a reasonable allowance for estimated administrative costs and inflation, which shall not exceed 25 percent of the estimated cost of the conservation action. If the agency takes such conservation action upon such failure by the permittee, the agency may collect from the permittee the difference should the amount of the reasonable cost of such action exceed the amount of the security held. Within 60 days of the achievement of adequate stabilization of the land-disturbing activity in any project or section thereof, the bond, cash escrow, letter of credit, or other legal arrangement, or the unexpended or unobligated portion thereof, shall be refunded to the applicant or terminated based upon the percentage of stabilization accomplished in the project or section thereof. These requirements are in addition to all other provisions of law relating to the issuance of such permits and are not intended to otherwise affect the requirements for such permits.

§ 62.1-44.15:58. Monitoring, reports, and inspections.

A. The VESCP authority (i) shall provide for periodic inspections of the land-disturbing activity and require that an individual holding a certificate of competence, as provided by § 62.1-44.15:52, who will be in charge of and responsible for carrying out the land-disturbing activity and (ii) may require monitoring and reports from the person responsible for carrying out the erosion and sediment control plan, to ensure compliance with the approved plan and to determine whether the measures required in the plan are effective in controlling erosion and sediment.

However, any VESCP authority may waive the certificate of competence requirement for an agreement in lieu of a plan for construction of a single-family residence. The owner, permittee, or person responsible for carrying out the plan shall be given notice of the inspection. If the VESCP authority, where authorized to enforce this article, or the Department determines that there is a failure to comply with the plan following an inspection, notice shall be served upon the permittee or person responsible for carrying out the plan by mailing with confirmation of delivery to the address specified in the permit application or in the plan certification, or by delivery at the site of the land-disturbing activities to the agent or employee supervising such activities. The notice shall specify the measures needed to comply with the plan and shall specify the time within which such measures shall be completed. Upon failure to comply within the time specified, the permit may be revoked and the VESCP authority, where authorized to enforce this article, the Department, or the Board may pursue enforcement as provided by § 62.1-44.15:63.

B. Notwithstanding the provisions of subsection A, a VESCP authority is authorized to enter into agreements or contracts with districts, adjacent localities, or other public or private entities to assist with the responsibilities of this article, including but not limited to the review and determination of adequacy of erosion and sediment control plans submitted for land-disturbing activities as well as monitoring, reports, inspections, and enforcement where an authority is granted such powers by this article.

C. Upon issuance of an inspection report denoting a violation of this section, § 62.1-44.15:55 or 62.1-44.15:56, in conjunction with or subsequent to a notice to comply as specified in subsection A, a VESCP authority, where authorized to enforce this article, or the Department may issue an order requiring that all or part of the land-disturbing activities permitted on the site be stopped until the specified corrective measures have been taken or, if land-disturbing activities have commenced without an approved plan as provided in § 62.1-44.15:55, requiring that all of the land-disturbing activities be stopped until an approved plan or any required permits are obtained. Where the alleged noncompliance is causing or is in imminent danger of causing harmful erosion of lands or sediment deposition in waters within the watersheds of the Commonwealth, or where the land-disturbing activities have commenced without an approved erosion and sediment control plan or any required permits, such an order may be issued whether or not the alleged violator has been issued a notice to comply as specified in subsection A. Otherwise, such an order may be issued only after the alleged violator has failed to comply with a notice to comply. The order for noncompliance with a plan shall be served in the same manner as a notice to comply, and shall remain in effect for seven days from the date of service pending application by the VESCP authority, the Department, or alleged violator for appropriate relief to the circuit court of the jurisdiction wherein the violation was alleged to have occurred or other appropriate court. The order for disturbance without an approved plan or permits shall be served upon the owner by mailing with confirmation of delivery to the address specified in the land records of the locality, shall be posted on the site where the disturbance is occurring, and shall remain in effect until such time as permits and plan approvals are secured, except in such situations where an agricultural exemption applies. If the alleged violator has not obtained an approved erosion and sediment control plan or any required permit within seven days from the date of service of the order, the Department or the chief administrative officer or his designee on behalf of the VESCP authority may issue a subsequent order to the owner requiring that all construction and other work on the site, other than corrective measures, be stopped until an approved erosion and sediment control plan and any required permits have been obtained. The subsequent order shall be served upon the owner by mailing with confirmation of delivery to the address specified in the permit application or the land records of the locality in which the site is located. The owner may appeal the issuance of any order to the circuit court of the jurisdiction wherein the violation was alleged to have occurred or other appropriate court. Any person violating or failing, neglecting, or refusing to obey an order issued by the Department or the chief administrative officer or his designee on behalf of the VESCP authority may be compelled in a proceeding instituted in the circuit court of the jurisdiction wherein the violation was alleged to have occurred or other appropriate court to obey same and to comply therewith by injunction, mandamus, or other appropriate remedy. Upon completion and approval of corrective action or obtaining an approved plan or any required permits, the order shall immediately be lifted. Nothing in this section shall prevent the Department, the Board, or the chief administrative officer or his designee on behalf of the VESCP authority from taking any other action specified in § 62.1-44.15:63.

§ 62.1-44.15:59. Reporting.

Each VESCP authority shall report to the Department, in a method such as an online reporting system and on a time schedule established by the Department, a listing of each land-disturbing activity for which a plan has been approved by the VESCP under this article.

§ 62.1-44.15:60. Right of entry.

The Department, the VESCP authority, where authorized to enforce this article, or any duly authorized agent of the Department or such VESCP authority may, at reasonable times and under reasonable circumstances, enter any establishment or upon any property, public or private, for the purpose of obtaining information or conducting surveys or investigations necessary in the enforcement of the provisions of this article.

In accordance with a performance bond with surety, cash escrow, letter of credit, any combination thereof, or such other legal arrangement, a VESCP authority may also enter any establishment or upon any property, public or private, for the purpose of initiating or maintaining appropriate actions that are required by the permit conditions associated with a land-disturbing activity when a permittee, after proper notice, has failed to take acceptable action within the time specified.

§ 62.1-44.15:61. Cooperation with federal and state agencies.

A VESCP authority and the Board are authorized to cooperate and enter into agreements with any federal or state agency in connection with the requirements for erosion and sediment control with respect to land-disturbing activities.

§ 62.1-44.15:62. Judicial appeals.

A. A final decision by a county, city, or town, when serving as a VESCP authority under this article, shall be subject to judicial review, provided that an appeal is filed within 30 days from the date of any written decision adversely affecting the rights, duties, or privileges of the person engaging in or proposing to engage in land-disturbing activities.

B. Final decisions of the Board, Department, or district shall be subject to judicial review in accordance with the provisions of the Administrative Process Act (§ 2.2-4000 et seq.).

§ 62.1-44.15:63. Penalties, injunctions and other legal actions.

A. Violators of § 62.1-44.15:55, 62.1-44.15:56, or 62.1-44.15:58 shall be guilty of a Class 1 misdemeanor.

B. Any person who has violated or failed, neglected, or refused to obey any regulation or order of the Board, any order, notice, or requirement of the Department or VESCP authority, any condition of a permit, or any provision of this article or associated regulation shall, upon a finding of an appropriate court, be assessed a civil penalty. If a locality or district serving as a VESCP authority has adopted a uniform schedule of civil penalties as permitted by subsection K of § 62.1-44.15:54, such assessment shall be in accordance with the schedule. The VESCP authority or the Department may issue a summons for collection of the civil penalty. In any trial for a scheduled violation, it shall be the burden of the locality or Department to show the liability of the violator by a preponderance of the evidence. An admission or finding of liability shall not be a criminal conviction for any purpose. Any civil penalties assessed by a court shall be paid into the treasury of the locality wherein the land lies, except that where the violator is the locality itself, or its agent, or where the Department is issuing the summons, the court shall direct the penalty to be paid into the state treasury.

C. The VESCP authority, the Department, or the owner of property that has sustained damage or which is in imminent danger of being damaged may apply to the circuit court in any jurisdiction wherein the land lies or other appropriate court to enjoin a violation or a threatened violation under § 62.1-44.15:55, 62.1-44.15:56, or 62.1-44.15:58 without the necessity of showing that an adequate remedy at law does not exist; however, an owner of property shall not apply for injunctive relief unless (i) he has notified in writing the person who has violated the VESCP, the Department, and the VESCP authority that a violation of the VESCP has caused, or creates a probability of causing, damage to his property, and (ii) neither the person who has violated the VESCP, the Department, nor the VESCP authority has taken corrective action within 15 days to eliminate the conditions that have caused, or create the probability of causing, damage to his property.

D. In addition to any criminal or civil penalties provided under this article, any person who violates any provision of this article may be liable to the VESCP authority or the Department, as appropriate, in a civil action for damages.

E. Without limiting the remedies that may be obtained in this section, any person violating or failing, neglecting, or refusing to obey any injunction, mandamus, or other remedy obtained pursuant to this section shall be subject, in the discretion of the court, to a civil penalty not to exceed $2,000 for each violation. A civil action for such violation or failure may be brought by the VESCP authority wherein the land lies or the Department. Any civil penalties assessed by a court shall be paid into the treasury of the locality wherein the land lies, except that where the violator is the locality itself, or its agent, or other VESCP authority, or where the penalties are assessed as the result of an enforcement action brought by the Department, the court shall direct the penalty to be paid into the state treasury.

F. With the consent of any person who has violated or failed, neglected, or refused to obey any regulation or order of the Board, any order, notice, or requirement of the Department or VESCP authority, any condition of a permit, or any provision of this article or associated regulations, the Board, the Director, or VESCP authority may provide, in an order issued by the Board or VESCP authority against such person, for the payment of civil charges for violations in specific sums, not to exceed the limit specified in subsection E. Such civil charges shall be instead of any appropriate civil penalty that could be imposed under subsection B or E.

G. Upon request of a VESCP authority, the attorney for the Commonwealth shall take legal action to enforce the provisions of this article. Upon request of the Board, the Department, or the district, the Attorney General shall take appropriate legal action on behalf of the Board, the Department, or the district to enforce the provisions of this article.

H. Compliance with the provisions of this article shall be prima facie evidence in any legal or equitable proceeding for damages caused by erosion or sedimentation that all requirements of law have been met and the complaining party must show negligence in order to recover any damages.

§ 62.1-44.15:64. Stop work orders by Department; civil penalties.

A. An aggrieved owner of property sustaining pecuniary damage resulting from a violation of an approved erosion and sediment control plan or required permit, or from the conduct of land-disturbing activities commenced without an approved plan or required permit, may give written notice of the alleged violation to the VESCP authority and to the Director.

B. Upon receipt of the notice from the aggrieved owner and notification to the VESCP authority, the Director shall conduct an investigation of the aggrieved owner's complaint.

C. If the VESCP authority has not responded to the alleged violation in a manner that causes the violation to cease and abates the damage to the aggrieved owner's property within 30 days following receipt of the notice from the aggrieved owner, the aggrieved owner may request that the Director require the violator to stop the violation and abate the damage to his property.

D. If (i) the Director's investigation of the complaint indicates that the VESCP authority has not responded to the alleged violation as required by the VESCP, (ii) the VESCP authority has not responded to the alleged violation within 30 days from the date of the notice given pursuant to subsection A, and (iii) the Director is requested by the aggrieved owner to require the violator to cease the violation, then the Director shall give written notice to the VESCP authority that the Department intends to issue an order pursuant to subsection E.

E. If the VESCP authority has not instituted action to stop the violation and abate the damage to the aggrieved owner's property within 10 days following receipt of the notice from the Director, the Department is authorized to issue an order requiring the owner, permittee, person responsible for carrying out an approved erosion and sediment control plan, or person conducting the land-disturbing activities without an approved plan or required permit to cease all land-disturbing activities until the violation of the plan or permit has ceased or an approved plan and required permits are obtained, as appropriate, and specified corrective measures have been completed. The Department also may immediately initiate a program review of the VESCP.

F. Such orders are to be issued after a hearing held in accordance with the requirements of the Administrative Process Act (§ 2.2-4000 et seq.), and they shall become effective upon service on the person by mailing with confirmation of delivery, sent to his address specified in the land records of the locality, or by personal delivery by an agent of the Director. Any subsequent identical mail or notice that is sent by the Department may be sent by regular mail. However, if the Department finds that any such violation is grossly affecting or presents an imminent and substantial danger of causing harmful erosion of lands or sediment deposition in waters within the watersheds of the Commonwealth, it may issue, without advance notice or hearing, an emergency order directing such person to cease all land-disturbing activities on the site immediately and shall provide an opportunity for a hearing, after reasonable notice as to the time and place thereof, to such person, to affirm, modify, amend, or cancel such emergency order.

G. If a person who has been issued an order or emergency order is not complying with the terms thereof, the Board may institute a proceeding in the appropriate circuit court for an injunction, mandamus, or other appropriate remedy compelling the person to comply with such order.

H. Any person violating or failing, neglecting, or refusing to obey any injunction, mandamus, or other remedy obtained pursuant to subsection G shall be subject, in the discretion of the court, to a civil penalty not to exceed $2,000 for each violation. Any civil penalties assessed by a court shall be paid into the state treasury.

§ 62.1-44.15:65. Authorization for more stringent regulations.

A. As part of a VESCP, a district or locality is authorized to adopt more stringent soil erosion and sediment control regulations or ordinances than those necessary to ensure compliance with the Board's regulations, provided that the more stringent regulations or ordinances are based upon factual findings of local or regional comprehensive watershed management studies or findings developed through the implementation of an MS4 permit or a locally adopted watershed management study and are determined by the district or locality to be necessary to prevent any further degradation to water resources, to address total maximum daily load requirements, to protect exceptional state waters, or to address specific existing water pollution including nutrient and sediment loadings, stream channel erosion, depleted groundwater resources, or excessive localized flooding within the watershed and that prior to adopting more stringent regulations or ordinances, a public hearing is held after giving due notice. The VESCP authority shall report to the Board when more stringent stormwater management regulations or ordinances are determined to be necessary pursuant to this section. However, this section shall not be construed to authorize any district or locality to impose any more stringent regulations for plan approval or permit issuance than those specified in §§ 62.1-44.15:55 and 62.1-44.15:57.

B. Any provisions of an erosion and sediment control program in existence before July 1, 2012, that contains more stringent provisions than this article shall be exempt from the analysis requirements of subsection A.

§ 62.1-44.15:66. No limitation on authority of Water Control Board or Department of Mines, Minerals and Energy.

The provisions of this article shall not limit the powers or duties of the Department of Mines, Minerals and Energy as they relate to strip mine reclamation under Chapters 16 (§ 45.1-180 et seq.) and 19 (§ 45.1-226 et seq.) of Title 45.1 or oil or gas exploration under the Virginia Gas and Oil Act (§ 45.1-361.1 et seq.).

The following is a complete, edited text (unofficial copy) of the Virginia Erosion and Sediment Control Regulations (4VAC50-30). Please refer to the Virginia Administrative Code for an official copy of the Regulations.

4VAC50-30-10. Definitions.

The following words and terms when used in this chapter shall have the following meanings unless the context clearly indicates otherwise. In addition, some terms not defined herein are defined in § 62.1-44.15:51of the Erosion and Sediment Control Law.

"Act" means the Erosion and Sediment Control Law, Article 4 62.1-44.15:51 et seq.) of Chapter 5 of Title 10.1 of the Code of Virginia.

"Adequate channel" means a watercourse that will convey the designated frequency storm event without overtopping its banks or causing erosive damage to the bed, banks and overbank sections of the same.

"Agreement in lieu of a plan" means a contract between the VESCP authority and the owner that specifies conservation measures that must be implemented in the construction of a single-family residence; this contract may be executed by the VESCP authority in lieu of an erosion and sediment control plan.

"Applicant" means any person submitting an erosion and sediment control plan or an agreement in lieu of a plan for approval or requesting the issuance of a permit, when required, authorizing land-disturbing activities to commence.

"Board" means the Virginia Soil and Water Conservation Board.

"Causeway" means a temporary structural span constructed across a flowing watercourse or wetland to allow construction traffic to access the area without causing erosion damage.

"Channel" means a natural stream or manmade waterway.

"Cofferdam" means a watertight temporary structure in a river, lake, etc., for keeping the water from an enclosed area that has been pumped dry so that bridge foundations, dams, etc., may be constructed.

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

"Denuded" means a term applied to land that has been physically disturbed and no longer supports vegetative cover.

"Department" means the Department of Environmental Quality.

"Development" means a tract or parcel of land developed or to be developed as a single unit under single ownership or unified control which is to be used for any business or industrial purpose or is to contain three or more residential dwelling units.

"Dike" means an earthen embankment constructed to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; levee.

"Director" means the Director of the Department of Environmental Quality.

"District" or "soil and water conservation district" means a political subdivision of the Commonwealth organized in accordance with the provisions of Article 3 (§ 10.1- 506 et seq.) of Chapter 5 of Title 10.1 of the Code of Virginia.

"Diversion" means a channel with a supporting ridge on the lower side constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

"Dormant" refers to denuded land that is not actively being brought to a desired grade or condition.

"Energy dissipator" means a nonerodible structure which reduces the velocity of concentrated flow to reduce its erosive effects.

"Erosion and Sediment Control Plan" or "plan" means a document containing material for the conservation of soil and water resources of a unit or group of units of land. It may include appropriate maps, an appropriate soil and water plan inventory and management information with needed interpretations, and a record of decisions contributing to conservation treatment. The plan shall contain all major conservation decisions and all information deemed necessary by the plan-approving authority to assure that the entire unit or units of land will be so treated to achieve the conservation objectives.

"Flume" means a constructed device lined with erosion-resistant materials intended to convey water on steep grades.

"Live watercourse" means a definite channel with bed and banks within which concentrated water flows continuously.

"Locality" means a county, city or town.

"Natural stream" means nontidal waterways that are part of the natural topography. They usually maintain a continuous or seasonal flow during the year and are characterized as being irregular in cross-section with a meandering course. Constructed channels such as drainage ditches or swales shall not be considered natural streams.

"Nonerodible" means a material, e.g., riprap, concrete, plastic, etc., that will not experience surface wear due to natural forces.

"Person" means any individual, partnership, firm, association, joint venture, public or private corporation, trust, estate, commission, board, public or private institution, utility, cooperative, county, city, town or other political subdivision of the Commonwealth, governmental body, including a federal or state entity as applicable, any interstate body, or any other legal entity.

"Post-development" refers to conditions that may be reasonably expected or anticipated to exist after completion of the land development activity on a specific site or tract of land.

"Program administrator" means the person or persons responsible for administering and enforcing the erosion and sediment control program of a VESCP authority.

"Pre-development" refers to conditions at the time the erosion and sediment control plan is submitted to the VESCP authority. Where phased development or plan approval occurs (preliminary grading, roads and utilities, etc.), the existing conditions at the time the erosion and sediment control plan for the initial phase is submitted for approval shall establish pre-development conditions.

"Sediment basin" means a temporary impoundment built to retain sediment and debris with a controlled stormwater release structure.

"Sediment trap" means a temporary impoundment built to retain sediment and debris which is formed by constructing an earthen embankment with a stone outlet.

"Sheet flow" (also called overland flow) means shallow, unconcentrated and irregular flow down a slope. The length of strip for overland flow usually does not exceed 200 feet under natural conditions.

"Shore erosion control project" means an erosion control project approved by local wetlands boards, the Virginia Marine Resources Commission, the Virginia Department of Environmental Quality or the United States Army Corps of Engineers and located on tidal waters and within nonvegetated or vegetated wetlands as defined in Title 28.2 of the Code of Virginia.

"Slope drain" means tubing or conduit made of nonerosive material extending from the top to the bottom of a cut or fill slope with an energy dissipator at the outlet end.

"Stabilized" means land that has been treated to withstand normal exposure to natural forces without incurring erosion damage.

"Storm sewer inlet" means a structure through which stormwater is introduced into an underground conveyance system.

"Stormwater detention" means the process of temporarily impounding runoff and discharging it through a hydraulic outlet structure to a downstream conveyance system.

"Temporary vehicular stream crossing" means a temporary nonerodible structural span installed across a flowing watercourse for use by construction traffic. Structures may include bridges, round pipes or pipe arches constructed on or through nonerodible material.

"Ten-year storm" means a storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in 10 years. It may also be expressed as an exceedence probability with a 10% chance of being equaled or exceeded in any given year.

"Two-year storm" means a storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in two years. It may also be expressed as an exceedence probability with a 50% chance of being equaled or exceeded in any given year.

"Twenty-five-year storm" means a storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in 25 years. It may also be expressed as exceedence probability with a 4.0% chance of being equaled or exceeded in any given year.

"Virginia Erosion and Sediment Control Program" or "VESCP" means a program approved by the board that has been established by a VESCP authority for the effective control of soil erosion, sediment deposition, and nonagricultural runoff associated with a land-disturbing activity to prevent the unreasonable degradation of properties, stream channels, waters, and other natural resources and shall include such items where applicable as local ordinances, rules, permit requirements, annual standards and specifications, policies and guidelines, technical materials, and requirements for plan review, inspection, enforcement where authorized in this article, and evaluation consistent with the requirements of the Act and this chapter.

"Virginia Erosion and Sediment Control Program authority" or "VESCP authority" means an authority approved by the board to operate a Virginia Erosion and Sediment Control Program. An authority may include a state entity, including the department; a federal entity; a district, county, city, or town; or for linear projects subject to annual standards and specifications, electric, natural gas and telephone utility companies, interstate and intrastate natural gas pipeline companies, railroad companies, or authorities created pursuant to § 15.2-5102 of the Code of Virginia.

9VAC25-840-20**. Purpose.**

The purpose of this chapter is to form the basis for the administration, implementation and enforcement of the Act. The intent of this chapter is to establish the framework for compliance with the Act while at the same time providing flexibility for innovative solutions to erosion and sediment control concerns.

9VAC25-840-30**. Scope and applicability.**

A. This chapter sets forth minimum standards for the effective control of soil erosion, sediment deposition, and nonagricultural runoff that must be met:

1. In VESCPs adopted under § 62.1-44.15:54 of the Act;

2. In erosion and sediment control plans that may be submitted directly to the department pursuant to § 62.1-44.15:55 A of the Act;

3. In annual general erosion and sediment control standards and specifications that electric, natural gas, and telephone utility companies, interstate and intrastate natural gas pipeline companies, and railroad companies are required to file, and authorities created pursuant to § 15.2-5102 of the Code of Virginia may file with the department pursuant to § 62.1-44.15:55 D of the Act;

4. In erosion and sediment control plans or annual standards and specifications that state agencies are required to file with the department pursuant to § 62.1-44.15:56 of the Act; and

5. In erosion and sediment control plans or annual standards and specifications that federal agencies may submit to the department pursuant to § 62.1-44.15:56 of the Act.

B. The submission of annual standards and specifications to the department does not eliminate the need where applicable for a project specific Erosion and Sediment Control Plan.

C. In accordance with Item 360 I1 of Chapter 3 of the 2012 Virginia Acts of Assembly, Special Session 1, public institutions of higher education, including community colleges, colleges, and universities, shall be subject to project review and compliance for state erosion and sediment control requirements by the VESCP authority of the locality within which the land-disturbing activity is located, unless such institution submits annual specifications to the Department in accordance with § 62.1-44.15:56 A (i) of the Code of Virginia.

D. Any VESCP authority that administers a VESCP may charge applicants a reasonable fee to defray the costs of program administration. Such fee may be in addition to any fee charged for administration of a Virginia stormwater management program, although payment of fees may be consolidated in order to provide greater convenience and efficiency for those responsible for compliance with the programs. A VESCP authority shall hold a public hearing prior to establishing a schedule of fees. The fee shall not exceed an amount commensurate with the services rendered, taking into consideration the time, skill, and the VESCP authority's expense involved.

9VAC25-840-40**. Minimum standards.**

A VESCP must be consistent with the following criteria, techniques and methods:

1. Permanent or temporary soil stabilization shall be applied to denuded areas within seven days after final grade is reached on any portion of the site. Temporary soil stabilization shall be applied within seven days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization shall be applied to areas that are to be left dormant for more than one year.

2. During construction of the project, soil stock piles and borrow areas shall be stabilized or protected with sediment trapping measures. The applicant is responsible for the temporary

protection and permanent stabilization of all soil stockpiles on site as well as borrow areas and soil intentionally transported from the project site.

3. A permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized. Permanent vegetation shall not be considered established until a ground cover is achieved that is uniform, mature enough to survive and will inhibit erosion.

4. Sediment basins and traps, perimeter dikes, sediment barriers and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

5. Stabilization measures shall be applied to earthen structures such as dams, dikes and diversions immediately after installation.

6. Sediment traps and sediment basins shall be designed and constructed based upon the total drainage area to be served by the trap or basin.

a. The minimum storage capacity of a sediment trap shall be 134 cubic yards per acre of drainage area and the trap shall only control drainage areas less than three acres.

b. Surface runoff from disturbed areas that is comprised of flow from drainage areas greater than or equal to three acres shall be controlled by a sediment basin. The minimum storage capacity of a sediment basin shall be 134 cubic yards per acre of drainage area. The outfall system shall, at a minimum, maintain the structural integrity of the basin during a 25-year storm of 24-hour duration. Runoff coefficients used in runoff calculations shall correspond to a bare earth condition or those conditions expected to exist while the sediment basin is utilized.

7. Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. Slopes that are found to be eroding excessively within one year of permanent stabilization shall be provided with additional slope stabilizing measures until the problem is corrected.

8. Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

9. Whenever water seeps from a slope face, adequate drainage or other protection shall be provided.

10. All storm sewer inlets that are made operable during construction shall be protected so that sediment-laden water cannot enter the conveyance system without first being filtered or otherwise treated to remove sediment.

11. Before newly constructed stormwater conveyance channels or pipes are made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and receiving channel.

12. When work in a live watercourse is performed, precautions shall be taken to minimize encroachment, control sediment transport and stabilize the work area to the greatest extent possible during construction. Nonerodible material shall be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by nonerodible cover materials.

13. When a live watercourse must be crossed by construction vehicles more than twice in any six-month period, a temporary vehicular stream crossing constructed of nonerodible material shall be provided.

14. All applicable federal, state and local requirements pertaining to working in or crossing live watercourses shall be met.

15. The bed and banks of a watercourse shall be stabilized immediately after work in the watercourse is completed.

16. Underground utility lines shall be installed in accordance with the following standards in addition to other applicable criteria:

a. No more than 500 linear feet of trench may be opened at one time.

b. Excavated material shall be placed on the uphill side of trenches.

c. Effluent from dewatering operations shall be filtered or passed through an approved sediment trapping device, or both, and discharged in a manner that does not adversely affect flowing streams or off-site property.

d. Material used for backfilling trenches shall be properly compacted in order to minimize erosion and promote stabilization.

e. Restabilization shall be accomplished in accordance with this chapter.

f. Applicable safety requirements shall be complied with.

17. Where construction vehicle access routes intersect paved or public roads, provisions shall be made to minimize the transport of sediment by vehicular tracking onto the paved surface. Where sediment is transported onto a paved or public road surface, the road surface shall be cleaned thoroughly at the end of each day. Sediment shall be removed from the roads by shoveling or sweeping and transported to a sediment control disposal area. Street washing shall be allowed only after sediment is removed in this manner. This provision shall apply to individual development lots as well as to larger land-disturbing activities.

18. All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization or after the temporary measures are no longer needed, unless otherwise authorized by the VESCP authority. Trapped sediment and the disturbed soil areas resulting from

the disposition of temporary measures shall be permanently stabilized to prevent further erosion and sedimentation.

19. Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff for the stated frequency storm of 24-hour duration in accordance with the following standards and criteria. Stream restoration and relocation projects that incorporate natural channel design concepts are not man-made channels and shall be exempt from any flow rate capacity and velocity requirements for natural or man-made channels:

a. Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe or storm sewer system. For those sites where runoff is discharged into a pipe or pipe system, downstream stability analyses at the outfall of the pipe or pipe system shall be performed.

b. Adequacy of all channels and pipes shall be verified in the following manner:

(1) The applicant shall demonstrate that the total drainage area to the point of analysis within the channel is one hundred times greater than the contributing drainage area of the project in question; or

(2)(a) Natural channels shall be analyzed by the use of a two-year storm to verify that stormwater will not overtop channel banks nor cause erosion of channel bed or banks.

(b) All previously constructed man-made channels shall be analyzed by the use of a ten-year storm to verify that stormwater will not overtop its banks and by the use of a two-year storm to demonstrate that stormwater will not cause erosion of channel bed or banks; and

(c) Pipes and storm sewer systems shall be analyzed by the use of a ten-year storm to verify that stormwater will be contained within the pipe or system.

c. If existing natural receiving channels or previously constructed man-made channels or pipes are not adequate, the applicant shall:

(1) Improve the channels to a condition where a ten-year storm will not overtop the banks and a two-year storm will not cause erosion to channel the bed or banks; or

(2) Improve the pipe or pipe system to a condition where the ten-year storm is contained within the appurtenances;

(3) Develop a site design that will not cause the pre-development peak runoff rate from a two-year storm to increase when runoff outfalls into a natural channel or will not cause the pre-development peak runoff rate from a ten-year storm to increase when runoff outfalls into a man-made channel; or

(4) Provide a combination of channel improvement, stormwater detention or other measures which is satisfactory to the VESCP authority to prevent downstream erosion.

d. The applicant shall provide evidence of permission to make the improvements.

e. All hydrologic analyses shall be based on the existing watershed characteristics and the ultimate development condition of the subject project.

f. If the applicant chooses an option that includes stormwater detention, he shall obtain approval from the VESCP of a plan for maintenance of the detention facilities. The plan shall set forth the maintenance requirements of the facility and the person responsible for performing the maintenance.

g. Outfall from a detention facility shall be discharged to a receiving channel, and energy dissipators shall be placed at the outfall of all detention facilities as necessary to provide a stabilized transition from the facility to the receiving channel.

h. All on-site channels must be verified to be adequate.

i. Increased volumes of sheet flows that may cause erosion or sedimentation on adjacent property shall be diverted to a stable outlet, adequate channel, pipe or pipe system, or to a detention facility.

j. In applying these stormwater management criteria, individual lots or parcels in a residential, commercial or industrial development shall not be considered to be separate development projects. Instead, the development, as a whole, shall be considered to be a single development project. Hydrologic parameters that reflect the ultimate development condition shall be used in all engineering calculations.

k. All measures used to protect properties and waterways shall be employed in a manner which minimizes impacts on the physical, chemical and biological integrity of rivers, streams and other waters of the state.

l. Any plan approved prior to July 1, 2014, that provides for stormwater management that addresses any flow rate capacity and velocity requirements for natural or man-made channels shall satisfy the flow rate capacity and velocity requirements for natural or man-made channels if the practices are designed to (i) detain the water quality volume and to release it over 48 hours; (ii) detain and release over a 24-hour period the expected rainfall resulting from the one year, 24-hour storm; and (iii) reduce the allowable peak flow rate resulting from the 1.5, 2, and 10-year, 24-hour storms to a level that is less than or equal to the peak flow rate from the site assuming it was in a good forested condition, achieved through multiplication of the forested peak flow rate by a reduction factor that is equal to the runoff volume from the site when it was in a good forested condition divided by the runoff volume from the site in its proposed condition, and shall be exempt from any flow rate capacity and velocity requirements for natural or man-made channels as defined in any regulations promulgated pursuant to § 62.1-44.15:54 or 62.1-44.15:65 of the Act.

m. For plans approved on and after July 1, 2014, the flow rate capacity and velocity requirements of § 62.1-44.15:52 A of the Act and this subsection shall be satisfied by compliance with water quantity requirements in the Stormwater Management Act (§62.1-44.15:24 et seq. of the Code of Virginia) and attendant regulations, unless such land-disturbing activities are in accordance with 9VAC25-870-48 of the Virginia Stormwater Management Program (VSMP) Permit Regulations.

n. Compliance with the water quantity minimum standards set out in 9VAC25-870-66 of the Virginia Stormwater Management Program (VSMP) Permit Regulations shall be deemed to satisfy the requirements of Minimum Standard 19.

9VAC25-840-50. Variances.

The VESCP authority may waive or modify any of the requirements that are deemed inappropriate or too restrictive for site conditions, by granting a variance. A variance may be granted under these conditions:

1. At the time of plan submission, an applicant may request a variance to become part of the approved erosion and sediment control plan. The applicant shall explain the reasons for requesting variances in writing. Specific variances which are allowed by the VESCP authority shall be documented in the plan.

2. During construction, the person responsible for implementing the approved plan may request a variance in writing from the VESCP authority. The VESCP authority shall respond in writing either approving or disapproving such a request. If the VESCP authority does not approve a variance within 10 days of receipt of the request, the request shall be considered to be disapproved. Following disapproval, the applicant may resubmit a variance request with additional documentation.

3. The VESCP authority shall consider variance requests judiciously, keeping in mind both the need of the applicant to maximize cost effectiveness and the need to protect off-site properties and resources from damage.

9VAC25-840-60. Maintenance and inspections.

A. All erosion and sediment control structures and systems shall be maintained, inspected and repaired as needed to insure continued performance of their intended function. A statement describing the maintenance responsibilities of the permittee shall be included in the approved erosion and sediment control plan.

B. Periodic inspections are required on all projects by the VESCP authority. The VESCP authority shall either:

1. Provide for an inspection during or immediately following initial installation of erosion and sediment controls, at least once in every two-week period, within 48 hours following any runoff producing storm event, and at the completion of the project prior to the release of any performance bonds; or

2. Establish an alternative inspection program which ensures compliance with the approved erosion and sediment control plan. Any alternative inspection program shall be:

a. Approved by the board prior to implementation;

b. Established in writing;

c. Based on a system of priorities that, at a minimum, address the amount of disturbed project area, site conditions and stage of construction; and

d. Documented by inspection records.

9VAC25-840-65. Reporting.

Each VESCP authority shall report to the department, in a method such as an online reporting system and on a time schedule established by the department, a listing of each land-disturbing activity for which a plan has been approved by the VESCP authority under the Act and this chapter.

9VAC25-840-70. Developments.

A. An erosion and sediment control plan shall be filed for a development and the buildings constructed within, regardless of the phasing of construction.

B. If individual lots or sections in a residential development are being developed by different property owners, all land-disturbing activities related to the building construction shall be covered by an erosion and sediment control plan or an "Agreement in Lieu of a Plan" signed by the property owner.

C. Land-disturbing activity of less than 10,000 square feet on individual lots in a residential development shall not be considered exempt from the provisions of the Act and this chapter if the total land-disturbing activity in the development is equal to or greater than 10,000 square feet.

9VAC25-840-80. Criteria for determining status of land-disturbing activity.

A. The program administrator shall determine the validity of a claim of exempt status by a property owner who disturbs 10,000 square feet or more or 2,500 square feet or more in areas of jurisdictions designated as subject to the Chesapeake Bay Preservation Area Designation and Management Regulations (9VAC25-830). As soon as a nonexempt status is determined, the requirements of the Act shall be immediately enforced.

B. Should a land-disturbing activity not begin during the 180-day period following plan approval or cease for more than 180 days, the VESCP authority may evaluate the existing approved erosion and sediment control plan to determine whether the plan still satisfies local and state erosion and sediment control criteria and to verify that all design factors are still valid. If the

VESCP authority finds the previously filed plan to be inadequate, a modified plan shall be submitted and approved prior to the resumption of land-disturbing activity.

C. Shore erosion control projects are not subject to this chapter. However, land-disturbing activity immediately outside the limits of the shore erosion project is subject to the Act and this chapter.

D. Whenever land-disturbing activity involves activity at a separate location (including but not limited to borrow and disposal areas), the VESCP authority may either:

1. Consider the off-site activity as being part of the proposed land-disturbing activity; or

2. If the off-site activity is already covered by an approved erosion and sediment control plan, the VESCP authority may require the applicant to provide proof of the approval and to certify that the plan will be implemented in accordance with a the Act and this chapter.

9VAC25-840-90. Review and evaluation of VESCPs: minimum program standards.

A. This section sets forth the criteria that will be used by the department to determine whether a VESCP operating under authority of the Act, satisfies minimum standards of effectiveness, as follows.

Each VESCP must contain an ordinance or other appropriate document or documents adopted by the VESCP authority. Such document or documents must be consistent with the Act and this chapter, including the following criteria:

1. The document or documents shall include or reference the definition of land-disturbing activity including exemptions, as well as any other significant terms, as necessary to produce an effective VESCP.

2. The document or documents shall identify the VESCP authority and any soil and water conservation district, adjacent locality, or other public or private entities that the VESCP authority entered into agreements or contracts with to assist with carrying out the provisions of the Act and this chapter, and must include the requirements and design standards to be used in the program.

3. The document or documents shall include procedures for submission and approval of plans, issuance of permits, monitoring and inspections of land-disturbing activities. The position, agency, department, or other party responsible for conducting inspections shall be identified. The VESCP authority shall maintain, either on-site or in VESCP files, a copy of the approved plan and a record of inspections for each active land-disturbing activity.

4. Each VESCP operated by a county, city, or town shall include provisions for the integration of the VESCP with Virginia stormwater management, flood insurance, flood plain management, and other programs requiring compliance prior to authorizing a land-disturbing activity in order to make the submission and approval of plans, issuance of permits, payment of fees, and

coordination of inspection and enforcement activities more convenient and efficient both for the local governments and those responsible for compliance with the programs.

5. The VESCP authority must take appropriate enforcement actions, where authorized to do so, to achieve compliance with the program and maintain a record of enforcement actions for all active land-disturbing activities.

B. The department will coordinate the review with its other program reviews for the same entity to avoid redundancy. The review and evaluation of a local program shall consist of the following: (i) consultation with the local program administrator or designee or designees; (ii) review of the local ordinance and other applicable documents; (iii) review of plans approved by the program; (iv) inspection of regulated activities; and (v) review of enforcement actions where authorized to do so. The department is also authorized to conduct a partial program compliance review.

C. Local programs shall be reviewed and evaluated for effectiveness in carrying out the Act and this chapter using the criteria in this section.

D. If deficiencies noted in the review will cause the erosion and sediment control program to be inconsistent with the state program and this chapter, the board shall provide the VESCP authority with a copy of its decision that specifies the deficiencies, action needed to be taken, and an approved corrective action plan and schedule required to attain the minimum standard of effectiveness. If the VESCP authority has not implemented the necessary compliance actions identified by the board within the corrective action schedule, or such additional period as is granted to complete the implementation of the corrective action, then the board shall have the authority to (i) issue a special order to any VESCP imposing a civil penalty set out in § 62.1-44.15:54 F of the Act or (ii) revoke its approval of the VESCP. The Administrative Process Act (§ 2.2-4000 et seq. of the Code of Virginia) shall govern the activities and proceedings of the board and the judicial review thereof. In lieu of issuing a special order or revoking the program, the board is authorized to take legal action against a VESCP to ensure compliance.

E. Review and evaluation of VESCPs shall be conducted according to a schedule adopted by the department.

9VAC25-840-100. State agency projects.

A. All state agency land-disturbing activities that are not exempt and that have commenced without an approved erosion and sediment control plan shall immediately cease until the state agency has submitted annual standards and specifications for its conduct of land-disturbing activities which has been reviewed and approved by the department as being consistent with the Act and this chapter, or an erosion and sediment control plan has been submitted to and approved by the department. A formal "Notice of Plan Requirement" will be sent to the state agency under whose purview the project lies since that agency is responsible for compliance with the Act and this chapter.

B. Where inspections by department personnel reveal deficiencies in carrying out an approved plan, the person responsible for carrying out the plan, as well as the state agency responsible, will be issued a notice to comply with specific actions and the deadlines that shall be met. Failure to meet the prescribed deadlines can result in the issuance of a stop work order for all land-disturbing activities on the project at the discretion of the department. The stop work order will be lifted once the required erosion and sediment control measures are in place and inspected by department staff.

C. Whenever the Commonwealth or any of its agencies fails to comply within the time provided in an appropriate final order, the director of the department may petition for compliance as follows: For violations in the Natural Resources Secretariat, to the Secretary of Natural Resources; for violations in other secretariats, to the appropriate Secretary; for violations in other state agencies, to the head of such agency. Where the petition does not achieve timely compliance, the director shall bring the matter to the Governor for resolution. The board or the department may also pursue enforcement as provided by § 62.1-44.15:63 of the Act.

D. Where compliance will require the appropriation of funds, the director shall cooperate with the appropriate agency head in seeking such an appropriation; where the director determines that an emergency exists, he shall petition the Governor for funds from the Civil Contingency Fund or other appropriate source.

The following is a complete, edited text (unofficial copy) of the Virginia Erosion and Sediment Control and Stormwater Management Certification Regulations (4VAC50-50). Please refer to the Virginia Administrative Code for an official copy of the Certification Regulations.

4VAC50-50-10. Definitions.

The following words and terms, when used in this chapter, shall have the following meanings, unless the context clearly indicates otherwise.

"Applicant" means any person submitting a request to be considered for certification.

"Board" means the Virginia Soil and Water Conservation Board.

"Certification" means the process whereby the board, on behalf of the Commonwealth, issues a certificate to persons who have completed board-approved training programs and met any additional eligibility requirements of 4VAC50-50-50 related to the specified classifications (4VAC50-50-40) within the areas of ESC or SWM or in other ways demonstrated adequate knowledge and experience in accordance with the eligibility requirements of 4VAC50-50-50 in the specified classifications within the areas of ESC or SWM.

"Certified combined administrator for ESC" means an employee or agent of a VESCP authority who holds a certificate of competence from the board in the combined ESC classifications of program administrator, plan reviewer, and project inspector in the area of ESC. "Certified combined administrator for SWM" means an employee or agent of a VSMP authority who holds a certificate of competence from the board in the combined classifications of program administrator, plan reviewer, and project inspector in the area of SWM.

"Certified project inspector for ESC" means an employee or agent of a VESCP authority who holds a certificate of competence from the board in the classification of project inspector in the area of ESC.

"Certified project inspector for SWM" means an employee or agent of a VSMP authority who holds a certificate of competence from the board in the classification of project inspector in the area of SWM.

"Certified plan reviewer for ESC" means an employee or agent of a VESCP authority who: (i) holds a certificate of competence from the board in the classification of plan reviewer in the area of ESC; (ii) is licensed as a professional engineer, architect, certified landscape architect, or land surveyor pursuant to Article 1 (§ 54.1-400 et seq.) of Chapter 4 of Title 54.1 of the Code of Virginia; or (iii) is a professional soil scientist as defined in Chapter 22 (§ 54.1-2200 et seq.) of Title 54.1 of the Code of Virginia.

"Certified plan reviewer for SWM" means an employee or agent of a VSMP authority who holds a certificate of competence from the board in the classification of plan reviewer in the area of SWM.

"Certified program administrator for ESC" means an employee or agent of a VESCP authority who holds a certificate of competence from the board in the classification of program administrator in the area of ESC.

"Certified program administrator for SWM" means an employee or agent of a VSMP authority who holds a certificate of competence from the board in the classification of program administrator in the area of SWM.

"Classification" refers to the four specific certificate of competence classifications within the areas of ESC or SWM that make up activities being performed (program administrator, plan reviewer, project inspector, and combined administrator).

"Combined administrator for ESC" means anyone who is responsible for performing the combined duties of a program administrator, plan reviewer and project inspector of a VESCP authority.

"Combined administrator for SWM" means anyone who is responsible for performing the combined duties of a program administrator, plan reviewer and project inspector of a VSMP authority.

"Department" means the Department of Conservation and Recreation.

"ESC" means erosion and sediment control.

"ESC Act" means the Erosion and Sediment Control Law, Article 4 (§62.1-44.15:51 et seq.) of Title 62.1 Waters of the State, Ports and Harbors, Chapter 3.1 State Water Control Law.

"Erosion and sediment control plan" or "ESC plan" means a document containing material for the conservation of soil and water resources of a unit or group of units of land. It may include appropriate maps, an appropriate soil and water plan inventory and management information with needed interpretations, and a record of all decisions contributing to conservation treatment. The plan shall contain all major conservation decisions to ensure that the entire unit or units of land will be so treated to achieve the conservation objective.

"Plan reviewer" means anyone who is responsible for determining the accuracy of ESC plans and supporting documents or SWM plans and supporting documents for approval by a VESCP authority or a VSMP authority as may be applicable in the areas of ESC or SWM.

"Program administrator" means the person or persons responsible for administering and enforcing the VESCP or VSMP of a VESCP authority or a VSMP authority as may be applicable in the areas of ESC or SWM.

"Project inspector" means anyone who, as a representative of a VESCP authority or a VSMP authority, is responsible for periodically examining the ESC or SWM activities and premises of a land-disturbing activity for compliance with the ESC Act and Regulations or the SWM Act and Regulations as may be applicable.

"Stormwater management plan" or "SWM plan" means a document containing material describing methods for complying with the requirements of a VSMP and the SWM Act and its attendant regulations.

"SWM" means stormwater management.

"SWM Act" means the Virginia Stormwater Management Act, (§62.1-44.15:24 et seq.) of Title 62.1 Waters of the State, Ports and Harbors, Chapter 3.1 State Water Control Law.

"Virginia Erosion and Sediment Control Program" or "VESCP" means a program approved by the board that has been established by a VESCP authority for the effective control of soil erosion, sediment deposition, and nonagricultural runoff associated with a land-disturbing activity to prevent the unreasonable degradation of properties, stream channels, waters, and other natural resources and shall include such items where applicable as local ordinances, rules, permit requirements, annual standards and specifications, policies and guidelines, technical materials, and requirements for plan review, inspection, enforcement where authorized in the ESC Act and this chapter, and evaluation consistent with the requirements of the ESC Act and this chapter.

"Virginia Erosion and Sediment Control Program authority" or "VESCP authority" means an authority approved by the board to operate a Virginia erosion and sediment control program. An authority may include a state entity, including the department; a federal entity; a district, county, city, or town; or for linear projects subject to annual standards and specifications, electric, natural gas and telephone utility companies, interstate and intrastate natural gas pipeline companies, railroad companies, or authorities created pursuant to § 15.2-5102 of the Code of Virginia.

"Virginia Stormwater Management Program" or "VSMP" means a program approved by the board after September 13, 2011, that has been established by a VSMP authority to manage the quality and quantity of runoff resulting from land-disturbing activities and shall include such items as local ordinances, rules, permit requirements, annual standards and specifications, policies and guidelines, technical materials, and requirements for plan review, inspection, enforcement, where authorized in the SWM Act and associated regulations, and evaluation consistent with the requirements of the SWM Act and associated regulations.

"Virginia Stormwater Management Program authority" or "VSMP authority" means an authority approved by the board after September 13, 2011, to operate a Virginia Stormwater Management Program or, until such approval is given, the department. An authority may include a locality; state entity, including the department; federal entity; or, for linear projects subject to annual standards and specifications in accordance with subsection B of § 10.1-603.5 of the Code of Virginia, electric, natural gas, and telephone utility companies, interstate and intrastate natural gas pipeline companies, railroad companies, or authorities created pursuant to § 15.2-5102 of the Code of Virginia.

4VAC50-50-20. Purpose.

The purpose of this chapter is to guide the issuance of certificates of competence required by §§ 10.1-561 E and 10.1-561.1 of the ESC Act and § 10.1-603.4:2 of the SWM Act.

4VAC50-50-30. Applicability.

This chapter is applicable to:

1. Every VESCP authority or VSMP authority that administers a VESCP or VSMP as may be applicable. Staff of a VESCP authority must be certified in accordance with §§ 10.1-560 E and 10.1-561.1 of the ESC Act. Staff of a VSMP authority must be certified in accordance with § 10.1-603.4:2 of the SWM Act.

2. Anyone who is contracted by a VESCP authority or a VSMP authority to perform any or all of the functions of that authority as may be applicable. This person will be subject to the same certification requirements as the authority.

3. Anyone voluntarily seeking certificates of competence from the board for classifications described in 4VAC50-50-40.

4VAC50-50-40. Certificates of competence.

A. Certificates of competence shall be issued by the board in accordance with the requirements of 4VAC50-50-50 for the following classifications:

1. Program administrator for ESC. The person employed as the VESCP administrator.

2. Plan reviewer for ESC. The person who reviews ESC plans to be approved by the VESCP authority.

3. Project inspector for ESC. The person responsible for inspecting erosion and sediment control practices to ensure compliance with the Virginia Erosion and Sediment Control Law and Regulations.

4. Combined administrator for ESC. The person responsible for performing the combined duties of program administrator, plan reviewer and project inspector for a VESCP authority.

5. Program administrator for SWM. The person employed as the VSMP administrator.

6. Plan reviewer for SWM. The person who reviews SWM plans to be approved by the VSMP authority.

7. Project inspector for SWM. The person responsible for inspecting regulated activities to ensure compliance with the SWM Act and Regulations.

8. Combined administrator for SWM. The person responsible for performing the combined duties of program administrator, plan reviewer, and project inspector for a VSMP authority.

B. Any person employed as a plan reviewer who is licensed as a professional engineer, architect, certified landscape architect, or land surveyor pursuant to Article 1 (§ 54.1-400 et seq.) of Chapter 4 of Title 54.1 of the Code of Virginia or as a professional soil scientist as defined in Chapter 22 (§ 54.1-2200 et seq.) of Title 54.1 of the Code of Virginia shall qualify as a certified plan reviewer for ESC and will not require a certificate of competence from the board. In lieu of a person holding this board certificate of competence, such person shall produce a current professional license or certification upon request of the department.

C. Any person who holds a valid and unexpired certificate of competence issued by the board in the classification of ESC or SWM, or who obtains such a certificate, and who later successfully obtains an additional certificate of competence from the board in the parallel ESC or SWM classification may surrender both certificates of competence to the board and request in writing issuance of a dual certificate showing certification in both classifications. Such a request must be made while both of the ESC and SWM certificates of competence obtained are valid and unexpired. The expiration date of the dual certificate shall be three years from the date of expiration of the additional certificate acquired.

4VAC50-50-50. Eligibility requirements.

A. Certification may be obtained by satisfactorily completing and submitting an application to the department for review and approval and:

1. By obtaining a total of 800 hours of experience as an ESC or SWM plan reviewer, project inspector, or combined administrator and obtaining a passing score on the certification examination administered by the department in the applicable ESC or SWM area; or

2. By enrolling in and completing a board-approved training program in the classifications of program administrator, plan reviewer, project inspector, or combined administrator and obtaining within one year of completion of the training program a passing score on the certification examination administered by the department in the applicable ESC or SWM area.

a. The training program for project inspectors for ESC will consist of attending and completing courses/seminars in "Basic Erosion and Sediment Control in Virginia" and "Erosion and Sediment Control for Inspectors."

b. The training program for plan reviewers for ESC will consist of attending and completing courses/seminars in "Basic Erosion and Sediment Control in Virginia" and "Erosion and Sediment Control for Plan Reviewers."

c. The training program for program administrators for ESC will consist of attending the seminar "Basic Erosion and Sediment Control in Virginia."

d. The training program for combined administrators for ESC will consist of attending the courses/seminars "Basic Erosion and Sediment Control in Virginia," "Erosion and Sediment Control for Inspectors," and "Erosion and Sediment Control for Plan Reviewers."

e. The training program for project inspectors for SWM will consist of attending and completing courses/seminars in "Basic Stormwater Management in Virginia" and "Stormwater Management for Inspectors."

f. The training program for plan reviewers for SWM will consist of attending and completing courses/seminars in "Basic Stormwater Management in Virginia" and "Stormwater Management for Plan Reviewers."

g. The training program for program administrators for SWM will consist of attending the seminar "Basic Stormwater Management in Virginia."

h. The training program for combined administrators for SWM will consist of attending the courses/seminars "Basic Stormwater Management in Virginia," "Stormwater Management for Inspectors," and "Stormwater Management for Plan Reviewers."

B. Certification and recertification shall be valid for three years and will expire on the last day of the expiration month except as otherwise set out in 4VAC50-50-40 C or 4VAC50-50-90.

C. Recertification may be obtained for classifications outlined in 4VAC50-50-40 of this chapter prior to the expiration date of a certification by:

1. Obtaining a passing score on the certification examination;

2. Successfully completing a board-approved training program during the last 12 months of the term of the certificate but prior to its expiration date;

3. Being a professional registered in the Commonwealth pursuant to Article 1 (§ 54.1-400 et seq.) of Chapter 4 of Title 54.1 of the Code of Virginia or a professional soil scientist as defined in Chapter 22 (§ 54.1-2200 et seq.) of Title 54.1, and paying the required fee for recertification. Such professionals shall be deemed to satisfy the provisions of this subsection for classifications in subdivisions A 1 through 4 of 4VAC50-50-40. However, such professionals when in the classification of plan reviewer for ESC shall be exempt from the recertification requirements and fees of this chapter provided they maintain their professional license; or

4. Being a professional registered in the Commonwealth pursuant to Article 1 (§ 54.1-400 et seq.) of Chapter 4 of Title 54.1 of the Code of Virginia and paying the required fee for recertification. Such professionals shall be deemed to satisfy the provisions of this subsection for classifications in subdivisions A 5 through 8 of 4VAC50-50-40.

4VAC50-50-55. Classification acknowledgement for the purposes of program compliance reviews.

For the purposes of VESCP or VSMP compliance reviews and evaluations, the certification requirements of §§ 10.1-561.1 and 10.1-603.4:2 of the Code of Virginia shall be deemed to have been met if the VESCP or the VSMP authority has a person or persons enrolled in the board's ESC or SWM training programs for the necessary classifications and such person or persons obtains certification within one year of completing the necessary training programs.

4VAC50-50-60. Fees.

A. Application, recertification, and dual certificate issuance fees shall be collected to cover the administrative cost for the certification program.

B. A fee will also be charged to present education and training program courses/seminars which support the certification program.

C. Fees are nonrefundable and shall not be prorated.

4VAC50-50-70. Examination.

A. A board approved examination shall be administered at least twice a year.

B. An individual may take the certification examination for the desired certificate of competence after fulfilling the prerequisite experience requirement or completing a board-approved training program in accordance with 4VAC50-50-50.

C. An individual who is unable to take an examination at the time scheduled shall notify the department within 48 hours prior to the date of the examination; such an individual may be rescheduled for the next examination. Failure to notify the department may require an individual to submit a new application and payment of fees in accordance with this chapter.

D. An applicant who is unsuccessful in passing an examination will be allowed to pay the appropriate fee and retake the appropriate exam within one year without resubmitting an application. After the one-year period has elapsed, an applicant will be required to submit a new application with the appropriate fee in accordance with this chapter in order to take the examination. Application for examination must be received at least 60 days prior to the scheduled examination by the department to be eligible to sit for the examination.

E. A minimum passing score of 70% will be required on the appropriate certification exam(s).

F. All applicants will be notified in writing within 60 days of the results of the examination.

4VAC50-50-80. Application.

A. Any person seeking certification by a combination of experience and examination or by the combination of completion of the training program and examination shall submit a completed application with the appropriate fee(s) attached. The application shall contain the following:

1. The applicant's name, address, daytime phone number, and name and address of business as well as the date the application was filled out.

2. The classification of certification applying for as set forth in 4VAC50-50-40 of this chapter, and if applying for initial certification or recertification.

3. If any special arrangements must be provided for because of a handicap.

4. A verification of all work experience signed and dated by applicant's supervisor.

5. A signed and notarized affidavit confirming that all statements in the application are believed to be true.

Incomplete applications will be returned to the applicant. All applications must be received in the appropriate department office or by mail post marked at least 60 days prior to the scheduled examination date in order to be able to sit for the examination.

B. All applications of candidates will be reviewed by the department to determine eligibility for certification. All applicants will be notified of the results of the review within 30 days of receipt of the application. Any applicant may appeal the review, in writing, to the board within 30 days of the department's determination. No applicant will be approved for certification unless they meet all requirements of this chapter.

C. Applicants who have been found ineligible to sit for an examination may request further consideration by submitting a letter to the board with the necessary evidence of additional qualifications. No additional fee will be required provided that all requirements for certification are met within one year from the date of original application.

4VAC50-50-90. Discipline of certified personnel.

The board may suspend, revoke or refuse to grant or renew the certification of any person if the board, in an informational fact finding under § 2.2-4019 of the Code of Virginia, finds that:

1. The certification was obtained or renewed thorough fraud or misinterpretation;

2. The certified person has violated or cooperated with others in violating any provision of this chapter;

3. The certified person has not demonstrated reasonable care, judgment, or application of his knowledge and ability in the performance of his duties; or

4. The certified person has made any material misrepresentation in the course of performing his duties.

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GLOSSARY

GLOSSARY

The list of terms that follows is representative of those used by public works officials, planners and other urban specialists, water pollution specialists, engineers, developers, soil scientists, conservationist planners, etc. Not all the terms are necessarily used in the text, but they are in common use in urban conservation and environmental matters. The aim of this glossary is representativeness, not completeness.

AASHTO classification - The official classification of soil materials and soil aggregate mixtures for highway construction used by the American Association of State Highway and Transportation Officials.

Acid soil - A soil with a preponderance of hydrogen ions, and probably of aluminum in proportion to hydroxyl ions. Specifically, soil with a pH value less than 7.0. For most practical purposes, a soil with a pH value less than 6.6.

Acre-foot - The volume of water that will cover 1 acre to a depth of 1 foot.

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

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

Alluvial land - Areas of unconsolidated alluvium, generally stratified and varying widely in texture, recently deposited by streams, and subject to flooding.

Alluvial soils - Soils developed from transported and relatively recently deposited material (alluvium) characterized by a weak modification (or none) of the original material by soil-forming processes.

Alluvium - A general term for all detrital material deposited or in transit by streams, including gravel, sand, silt, clay and all variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated.

Annual flood - The highest peak discharge which can be expected in any given year.

Antecedent Moisture Conditions (AMC) - The degree of wetness of a watershed at the beginning of a storm.

Antecedent Precipitation Index (API) - An indicator of the amount of water (in inches) present in the soil at any given time. The calculation of the API is based on the assumption that, during time periods of no precipitation, the soil moisture decreases logarithmically with time.

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

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

Aquifer - An underground porous, water-bearing geological formation. The term is generally restricted to materials capable of yielding an appreciable supply of water.

Artificial Recharge - The addition of water to the groundwater reservoir by activities of man, such as irrigation or induced infiltration from streams, wells or spreading basins.

Base flow - Stream discharge derived from groundwater sources. Sometimes considered to include flows from regulated lakes or reservoirs. Fluctuates much less than storm runoff.

Bearing capacity - The maximum load that a material can support before failing.

Bedrock - The more or less solid rock in place either on or beneath the surface of the earth. It may be soft, medium or hard and have a smooth or irregular surface.

Benthic region - The bottom of a body of water which supports the benthos.

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

Bentonite - A highly plastic clay consisting of the minerals montmorillonite and beidellite that swells extensively when wet.

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

Borrow area - A source of earth fill material used in the construction of embankments or other earth fill structures.

California bearing ratio (CBR) - The load-supporting capacity of a soil as compared to that of a standard crushed limestone, expressed as a ratio and multiplied by 100; first standardized in California. A soil with a ratio of 16 will support 16 percent of the load that would be supported by the standard crushed limestone per unit area and with the same degree of distortion.

Capillary action - In hydrology, the tendency of dry soil particles to attract moisture from wetter portions of soil.

Castellated - Built or formed like a castle, with "battlements."

Catch basin - A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Catchment - Surface drainage area.

Channel - A natural stream that conveys water. A ditch or channel excavated for the flow of water. VESCR: A natural stream or manmade waterway.

Channel stabilization - Erosion prevention and stabilization of velocity distribution in a channel using drops, revetments, vegetation and other measures.

Channel storage - Water temporarily stored in channels while en route to an outlet.

Channelization - Alteration of a stream channel by widening, deepening, straightening, cleaning, or paving certain areas to improve flow characteristics.

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

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

Cohesion - The capacity of a soil to resist shearing stress, exclusive or functional resistance.

Cohesive soil - A soil that, when unconfined, has considerable strength when air-dried and significant cohesion when submerged.

Compost - Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.

Composting - A controlled process of degrading organic matter by micro-organisms. Present-day composting is the aerobic, thermophilic decomposing of organic waste to relatively stable humus. Humus with no more than 25 percent dead or living organisms is stable enough not to reheat or cause odor or fly problems. It can undergo further, slower decay.

Comprehensive planning - Planning that takes into account all aspects of water, air and land resources and their uses and limits.

Cone of depression - Cone-shaped depression in the water table created by pumping at a well head.

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

Conservation district - A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries, usually a subdivision of state government with a local governing body and always with limited authorities. Often called a soil conservation district or a soil and water conservation district. VESCL: a political subdivision of this Commonwealth organized in accordance with the provisions of Article 3 (§ 10.1-506 et. seq.) of this chapter.

Contour - An imaginary line on the surface of the earth connecting points of the same elevation.

Cool season grasses - In Virginia, a grass which experiences most of its growth in the spring and fall, but may remain green all year long. Cool season grasses tend to turn brown and become dormant during mid-summer.

Cut - Portion of land surface or area from which earth has been removed or will be removed by excavating; the depth below original ground surface of excavated surface.

Cutting - A leaf, stem or branch cut from a plant to establish a new plant.

Cut-and-fill - Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

Cutoff trench - A long, narrow excavation constructed along the center line of a dam, dike, levee or embankment and filled with relatively impervious material intended to reduce seepage of water through porous strata.

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

Debris dam - A barrier built across a stream channel to retain rock, sand, gravel, silt or other material.

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

Depression storage - Watershed capacity to retain in puddles, ditches, depressions or on foliage.

Design highwater - The elevation of the water surface as determined by the flow conditions of the design floods.

Design life - The period of time for which a facility is expected to perform its intended function.

Design storm - A selected rainfall pattern of specified amount, intensity, duration and frequency that is used as a basis for design.

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

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

Detention dam - A dam constructed for the purpose of temporary storage of streamflow or surface runoff and for releasing the stored water at controlled rates.

Detention time - The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Detritus - Loose material (soil and organic particles) that results from the disintegration, destruction or wearing away of the earth's surface: debris.

Dibble bar - A heavy metal tool with a blade and a foot pedal used to open holes for planting seeds or small seedlings.

Dike - (Engineering) An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee.

Discharge - Outflow; the flow of a stream, canal or aquifer. One may also speak of the discharge of a canal or stream into a lake, river or ocean. (Hydraulics) Rate of flow, especially fluid flow; a volume of fluid passing a point per unit time commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day.

Discharge coefficient (Hydraulics) - The ratio of actual rate of flow to the theoretical rate of flow through orifices, weirs or other hydraulic structures.

Dispersion, Soil - The breaking down of soil aggregates into individual particles, resulting in single-grain structure. Ease of dispersion is an important factor influencing the erodibility of soils. Generally speaking, the more easily dispersed the soil, the more erodible it is.

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

Diversion dam - A barrier built to divert part or all of the water from a stream into a different course.

Diversion terrace - Diversions, which differ from terraces in that they consist of individually designed channels across a hillside, may be used to protect bottomland from hillside runoff or may be needed above a terrace system for protection against runoff from an unterraced area. They may also divert water out of active gullies, protect buildings from runoff, or reduce the number of waterways, and are sometimes used in connection with stripcropping to shorten the length of slope so that the strips can effectively control erosion. See Terrace.

Divide, Drainage Divide - The boundary between one drainage basin and another.

Drain - A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or groundwater.

Drainage - The removal of excess surface water or groundwater from land by means of surface or subsurface drains. Soil characteristics that affect natural drainage.

Drainage basin - A geographical area or region that is so sloped and contoured that surface runoff from streams and other natural watercourses is carried away by a single drainage system by gravity to a common outlet or outlets. Also referred to as a watershed or drainage area.

Drainage, Soil - As a natural condition of the soil, soil drainage refers to the frequency and duration of periods when the soil is free of saturation; for example, in well-drained soils the water is removed readily but not rapidly; in poorly drained soils the root zone is waterlogged for long periods unless artificially drained, and the roots of ordinary crop plants cannot get enough oxygen; in excessively drained soils the water is removed so completely that most crop plants suffer from lack of water. Strictly speaking, excessively drained soils are a result of excessive runoff due to the steep slopes or low water-holding capacity due to small amounts of silt and clay in the soil material. The following classes are used to express soil drainage:

Well drained - Excess water drains away rapidly and no mottling occurs within 36 inches of the surface.

Moderately well drained - Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness. Mottling occurs between 18 and 36 inches.

Somewhat poorly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Mottling occurs between 8 and 18 inches.

Poorly drained - Water is removed so slowly that the soil is wet for a large part of the time. Mottling occurs between 0 and 8 inches.

Very poorly drained - Water is removed so slowly that the water table remains at or near the surface of the greater part of the time. There may also be periods of surface ponding. The soil has a black to gray surface layer with mottles up to the surface.

Drawdown - Lowering of the water surface (in open channel flow), water table or piezometric surface (in groundwater flow) resulting from a withdrawal of water.

Drop-inlet spillway - Overall structure in which the water drops through a vertical riser connected to a discharge conduit.

Drop spillway - Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

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

Dry storage - Volume within a basin (e.g., sediment basin) which is allotted for temporary ponding of stormwater runoff. It will undergo drawdown over a period of time, re-establishing the initial storage volume.

Dry weather flow - The combination of sanitary sewage, and industrial and commercial wastes normally found in the sanitary sewers during the dry weather season of the year. Also, that flow which exists in streams during dry seasons.

Earth dam - Dam constructed of compacted soil materials.

Effective precipitation - That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

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

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

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

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

Erodible - Susceptible to erosion.

Erosion - The wearing away of the land surface by running water, wind, ice or other geological agents, including such processes of gravitational creep. Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion:

Accelerated erosion - Erosion much rapid than normal or geologic erosion, primarily as a result of the influence of the activities of man, or, in some cases, of the animals or natural catastrophes that expose bare surfaces (e.g., fires).

Channel erosion - The erosion process whereby the volume and velocity of a concentrated flow wears away the bed and banks of well-defined channel.

Geological erosion - The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plans, etc. Synonymous to natural erosion.

Gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.

Natural erosion - Wearing away of the earth's surface by water, ice or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. Synonymous to geological erosion.

Normal erosion - The gradual erosion of land used by man which does not greatly exceed natural erosion. See <u>Erosion, natural</u>.

Rill erosion - An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils. See <u>Rill</u>.

Raindrop erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.

Sheet erosion - The removal of a fairly uniform layer of soil from the land surface by runoff water.

Erosion classes (soil survey) - A grouping of erosion conditions based on the degree of erosion or on characteristic patterns. Applied to accelerated erosion, not to normal, natural, or geological erosion. Four erosion classes are recognized for water erosion and three for wind erosion.

Estuary - Area where fresh water meets salt water, where the tide meets the river current (e.g., bays, mouths of rivers, salt marshes and lagoons). Estuaries serve as nurseries and spawning the feeding grounds for large groups of marine life and provide shelter and food for birds and wildlife.

Evapotranspiration - The combined loss of water from a given area and during a specific period of time, by evaporation from the soil surface and by transpiration from plants.

Excess rainfall - Direct runoff at the place where it originates.

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

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

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

First flush - The first portion of runoff generated by rainfall event and containing the main portion of the pollutant load resulting from the storm.

Flood - An overflow or inundation that comes from a river or other body of water. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream.

Flood control - Methods or facilities for reducing flood flows.

Floodgate - A gate placed in a channel or closed conduit to keep out floodwater or tidal backwater.

Flood peak - The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.

Flood plain - The lowland that borders a stream and is subject to flooding when the stream overflows its banks.

Flood routing - Determining the changes in the rise and fall of floodwater as it proceeds downstream through a valley or reservoir.

Flood stage - The stage at which overflow of the natural banks of a stream begins.

Floodwater retarding structure - A structure providing for temporary storage of floodwater and for its controlled release.

Floodway - A channel, either natural, excavated or bounded by dikes and levees, used to carry excessive flood flows to reduce flooding. Sometimes considered to be the transitional area between the active channel and the floodplain.

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

Fluvial sediment - Those deposits produced by stream or river action.

Foundation drain - A pipe or series of pipes which collects groundwater from the foundation or footing of structures and discharges this water into sewers or other points of disposal.

Fragipan - A natural subsurface soil horizon with high bulk density relative to the solum above, seemingly cemented when dry but showing a moderate to weak brittleness when moist. The layer is low in organic matter, mottled, slowly or very slowly permeable to water, and usually shows occasional or frequent bleached cracks forming polygons. It may be found in profiles of either cultivated or virgin soils, but not in calcareous material.

Freeboard - A vertical distance between the elevation of the design highwater and the top of a dam, levee or diversion ridge.

Frequency of storm (design storm frequency) - The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm or a given intensity and/or total volume will recur; thus a 10-year storm can be expected to occur on the average once every 10 years. Sewers designed to handle flows which occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

Froude number (F) - A calculated number of classifying water flow as critical ($F = 1$), supercritical ($F > 1$) or subcritical ($F < 1$).

Gabion - A rectangular or cylindrical wire mesh cage filled with rock and used as a protecting agent, revetment, etc., against erosion.

Gage or gauge - Device for registering precipitation, water level, discharge velocity, pressure, temperature, etc. A measure of the thickness of metal; e.g., diameter of wire, wall thickness of steel pipe.

Gaging station - A selected section of a stream channel equipped with a gage, recorder or other facilities for determining stream discharge.

Graduation (geology) - The bringing of a surface or a stream bed to grade, by running water. As used in connection with sedimentation and fragmental products for engineering evaluation, the term gradation refers to the frequency distribution of the various sized grains that constitute a sediment, soil or other material.

Grade - The slope of a road, channel, or natural ground. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction such as paving or the laying of a conduit.

(To) Grade - To finish the surface of a canal bed, top of embankment or bottom of excavation.

Graded stream - A stream in which, over a period of years, the slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for transportation of the load (of sediment) supplied from the drainage basin.

Graded stabilization structure - A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further head-cutting or lowering of the channel grade.

Gradient - Change of elevation, velocity, pressure or other characteristics per unit length; slope.

Grading - Any stripping, cutting, filling, stockpiling or any combination thereof, including the land in its cut-and-filled condition.

Grass - A member of the botanical family Gramineae, characterized by bladelike leaves arranged on the culm or stem in two ranks.

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

Greenbelt - A strip of land reserved around the periphery of an urban area by official authority for park land, farms, etc.

Groundwater infiltration - The seepage of groundwater into an opening in a sewer.

Groundwater recharge - Inflow to a groundwater reservoir.

Groundwater runoff - That part of groundwater that is discharged into a stream channel as spring or seepage water.

Groundwater table - The free surface of the groundwater. It is seldom static, generally rising and falling with the season, subject to atmospheric pressure under the ground, the rate of withdrawal, the rate of restoration, and other conditions.

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

Head (Hydraulics) - The height of water above any plain or reference. The energy either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head, velocity head and head loss.

Head gate - Water control structure; the gate at the entrance to a conduit.

Head loss - Energy loss due to friction, eddies, changes in velocity or direction of flow.

Headwater - The source of a stream. The water upstream from a structure or point on a stream.

Hydrograph - A graph showing for a given point on a stream or for a given point in any drainage system the discharge, stage (depth), velocity or other property of water with respect to time.

Hydrology - The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Hydrologic cycle - The circuit of water movement from the atmosphere to the earth and back to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation and transpiration.

Impact basin - A device used to dissipate the energy of flowing water. Generally constructed of concrete in the form of a partially depressed or partially submerge vessel, and may utilize baffles to dissipate velocities.

Impervious - Not allowing infiltration.

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

Indirect runoff - That portion of runoff that contributes to the runoff pollution that enters receiving water as point discharges from separate storm sewer systems and as general surface runoff.

Infiltration/inflow - A combination of infiltration and inflow waste water volumes in sewer lines that permits no distinction between the two basic sources which have the same effect of usurping the capacities of sewer systems and other sewerage system facilities.

Infiltration-percolation - An approach to wastewater treatment in which large volumes of wastewater are applied to the land, and subsequently, infiltrates the surface and percolates through the soil pores.

Infiltration rate - A soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions including the presence of an excess of water.

Initial abstraction - Initial precipitation loss including interception and depression storage.

Intercepted surface runoff - That portion of surface runoff that enters a sewer, either storm or combined, directly through catch basins, inlets, etc.

Interception (Hydraulics) - The process by which precipitation is caught and held by foliage, twigs and branches of trees, shrubs and other vegetation. Often used for "interception loss" or the amount of water evaporated from the precipitation intercepted.

Interception channel - A channel excavated at the top of earth cuts, at the foot of slopes or at other critical places to intercept surface flow; a catch basin. Synonymous to interception ditch.

Interflow - That portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface at some point downslope from its point of infiltration.

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

Internal soil drainage - The downward movement of water through the soil profile. The rate of movement is determined by the textile, structure and other characteristics of the soil profile and underlying layers and by the height of the water table, either permanent or perched. Relative terms for expressing internal drainage are: none, very slow, slow, medium, rapid, and very rapid.

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

Junction - In rivers, the point of connection of two upstream stretches or segments. In some estuary models, a junction is a segment of the estuary.

Lag time - The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff.

Land capability - The suitability of land for use without permanent damage. Land capability, as ordinarily used in the United States, is an expression of the effect of physical land conditions, including climate, on the total suitability for use without damage for crops that require regular tillage, for grazing, for woodland and for wildlife. Land capability involves consideration of (1) the risks of land damage from erosion and other causes and (2) the difficulties in land use owing to physical land characteristics, including climate.

Land capability classification - A grouping of kinds of soils into special units, classes, and subclasses according to their capability for intensive use and the treatments required for sustained use; prepared by the Soil Conservation Service, USDA.

Land capability map - A map showing land capability units, classes and subclasses, or a soil survey map colored to show land capability classes.

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

Legume - A member of the legume or pulse family, Leguminosae, one of the most important and widely distributed plant families. The fruit is a "legume" or pod that opens along two sutures when ripe. The flowers are usually papilionaceous (butterfly-like). Leaves are alternate, have stipules, and are usually compound. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Liquefaction, Spontaneous - The sudden large decrease of the shearing resistance of a cohesionless soil caused by a collapse of the structure from shock or other type of strain and associated with a sudden but temporary increase in the pore-fluid pressure. It involves a temporary transformation of the material into a fluid mass.

Liquid limit - The moisture content at which the soil passes from plastic to a liquid state. In engineering, a high liquid limit indicates that the soil has a high content of clay and low capacity for supporting loads.

Manning's equation (Hydraulics) - An equation used to predict the velocity of water flow in an open channel or pipelines:

$$V = \frac{1.486\, r^{2/3}\, S^{1/2}}{n}$$

where:

V = the mean velocity of flow in feet per second;
r = the hydraulic radius in feet;
S = the slope of the energy gradient or, for assumed uniform flow, the slope of the channel in feet per foot;
n = the roughness coefficient or retardance factor of the channel lining.

Mean depth (Hydraulics) - Average depth; cross-sectional area of a steam or channel divided by its surface or top width.

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

Merlon - In a castellated concrete grid pavement unit, one of the protruding portions which alternate with depressed portions (crenels) to form the surface geometry of the unit.

Mottled - A soil characteristic denoting spots or blotches of different colors.

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

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

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

Non-sewered urban runoff - Surface runoff in an urban drainage area which drains into a receiving stream without passing through a sewer system.

Normal depth - Depth of flow in an open conduit during uniform flow for the given conditions.

Nutrient(s) - A substance necessary for the growth and reproduction of organisms. In water, those substances that promote growth of algae and bacteria; chiefly nitrates and phosphates.

Open drain - Natural watercourse or constructed open channel that conveys drainage water.

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

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

Outlet channel - A waterway constructed or altered primarily to carry water from man-made structures, such as terraces, tile lines and diversions.

Overflow - A pipeline or conduit device, together with an outlet pipe, that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regular device has allowed the portion of the flow which can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

Overland flow irrigation - A process of land application of wastewater that provides spray distribution onto gently sloping soil of relatively impervious nature, such as clays, for the purpose of attaining aerobic bio-treatment of the exposed flow in contact with ground cover vegetation, followed by the collection of runoff waters in interception ditches or channels and the return of the wastewater back to the spray system or its discharge into receiving waters; sometimes called spray runoff.

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

Percolation - The movement of water through soil.

Percolation rate - The rate, usually expressed as a velocity, at which water moves through saturated granular material.

Percolation test - A determination of the rate of percolation or seepage of water through natural soils expressed as time in minutes for a 1-inch fall of water in a test hole.

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

Permeability coefficient - The volume of water, in cubic feet, under a head of one foot, that will pass through a square foot of porous surface in one day.

Permeability, Soil - The quality of a soil horizon that enable water or air to move through it. The permeability of a soil may be limited by the presence of one nearly impermeable horizon even though the others are permeable.

Permeability rate - The rate at which water will move through a saturated soil. Permeability rates are classified as follows:

(a) Very slow - Less than 0.06 inches per hour.
(b) Slow - 0.06 to 0.20 inches per hour.
(c) Moderately slow - 0.20 to 0.63 inches per hour.
(d) Moderate - 0.63 to 2.0 inches per hour.
(e) Moderately rapid - 2.0 to 6.3 inches per hour.
(f) Rapid - 6.3 to 20.0 inches per hour.
(g) Very rapid - More than 20.0 inches per hour.

Pervious - Allowing movement of water.

Pesticides - Chemical compounds used for the control of undesirable plants, animals or insects. The term includes insecticides, herbicides, algalcides, rodenticides, nematicides, fungicides and growth regulators.

pH - A numerical measure of acidity of hydrogen ion activity and of alkalinity. The neutral point is pH 7.0. All pH values below 7.0 are acid and all above 7.0 are alkaline.

Phosphorus, Available - Inorganic phosphorus that is readily available for plant growth.

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

Physiographic province - A region, all parts of which are similar in geologic structure and climate, which consequently has a unified geomorphic history.

Planned unit development (PUD) - A special classification authorized in some zoning ordinances, where a unit of land under control of a single developer may be used for a variety of uses and densities, subject to review and approval by the local governing body. The locations of the zones are usually decided on a case-by-case basis.

Plasticity index - The numerical difference between the liquid limit and the plastic limit of soil; the range of moisture content within which the soil remains plastic.

Plastic limit - The moisture content at which a soil changes from a semisolid to a plastic state.

Plunge pool - A device used to dissipate the energy of flowing water that may be constructed or made by the action of flowing. These facilities may be protected by various lining materials.

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

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

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

Porosity - The volume of pore space in a rock.

Porous pavement - A pavement through which water can flow at significant rates.

Principal spillway - A dam spillway generally constructed of permanent material and designed to regulate the normal water level, provide flood protection and/or reduce the frequency of operation of the emergency spillway.

Rainfall intensity - The rate a which rain is falling at any given instant, usually expressed in inches per hour.

Rational method - A means of computing storm drainage flow rates (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area.

Reach - The smallest subdivision of the drainage system consisting of a uniform length of open channel or underground conduit. Also, a discrete portion of river, stream or creek. For modeling purposes, a reach is somewhat homogeneous in its physical characteristics.

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

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

Recharge basin - A basin provided to increase infiltration for the purpose of replenishing groundwater supply.

Retention - The storage of stormwater to prevent it from entering the sewer system; may be temporary or permanent. VESCR: the process by which an impoundment structure stores the total runoff of a given storm and then releases the flow at a controlled rate over an extended period.

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

Rhizome - A modified plant stem that grows horizontally underground.

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

Rill - A small intermittent watercourse with steep sides, usually only a few inches deep.

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

Riprap - Broken rock, cobbles or boulders placed on earth surfaces, such as the face of a dam of a stream, for protection against the action of water (waves). Also applied to brush or pole mattresses, brush and stone, or other similar materials used for soil erosion control.

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

River basin - A major water resource region. The U.S. has been divided into 20 major water resource regions (river basins). See Drainage Basin.

Rock-fill-dam - A dam composed of loose rock usually dumped in place, often with the upstream part constructed of hand-placed or derrick-placed rock and faced with rolled earth or with an impervious surface of concrete, timber or steel.

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

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

Saturation point - In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.

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

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

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

Sediment delivery ratio - The fraction of the soil eroded from upland sources that actually reaches a continuous stream channel or storage reservoir.

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

Sediment grade - Measurements of sediment and soil particles that can be separated by screening. A committee on sedimentation of the National Research Council has established a classification of textural grade sizes for standard use.

Sediment pool - The reservoir space allotted to the accumulation of submerged sediment during the life of the structure.

Seedbed - The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seedling - A young plant grown from seed.

Septic tank - An underground tank used for the deposition of domestic wastes. Bacteria in the wastes decompose the organic matter, and the sludge settles to the bottom. The effluent flows through drains into the ground. Sludge is pumped out at regular intervals.

Settlings basin - An enlargement in the channel of a stream to permit the settling of debris carried in suspension.

Shoot - The above-ground portion of a plant.

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

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

Silty clay - A soil textural class containing a relatively large amount of silt and clay and a small amount of sand. See Soil Texture.

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

Slope - Degree of deviation of a surface from the horizontal; measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plan with a 90° slope being vertical (maximum) and 45° being a 1:1 or 100 percent slope.

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

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

Soil horizon - A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming factors.

Soil profile - A vertical section of the soil from the surface through all horizons, including C horizons.

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

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

Spillway - A passage such as a paved apron or channel for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

Storm frequency - The time interval between major storms of predetermined intensity and volumes of runoff which storm and combined sewers and such appurtenant structures as swirl concentrator chambers are designed and constructed to handle hydraulically without surcharging and backflooding, e.g., a 5-year, 10-year or 20-year storm.

Storm sewer - A sewer that carries stormwater and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. Also called a storm drain.

Stormwater infiltration - The entrance of stormwater into a sanitary sewer.

Stormwater management - (1) The control, regulation, or treatment of stormwater runoff, especially relating to the effects of land development on the natural hydrology. (2) A program which deals with quantity and quality of stormwater runoff.

Stormwater runoff - See <u>Runoff</u>.

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

Stream gaging - The quantitative determination of stream flow using gages, current meters, weirs or other measuring instruments at selected locations. See <u>Gaging station</u>.

Sub-basin - A physical division of a larger basin, associated with one reach of the storm drainage system.

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

Subdrain - A pervious backfilled trench containing stone or a pipe for intercepting groundwater or seepage.

Subsoil - The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil), in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as the "subsoil".

Subwatershed - A watershed subdivision of unspecified size that forms a convenient natural unit.

Surcharge - The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.

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

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

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

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

Tailwater depth - The depth of flow immediately downstream from a discharge structure.

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

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

Terrace outlet channel - Channel, usually having a vegetative cover, into which the flow from one or more terraces is discharged and conveyed from the terrace system.

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

Thermophilic - Of, or relating to, an organism growing at high temperatures.

Tile, Drain - Pipe made of burned clay, concrete, or similar material, in short lengths, usually laid with open joints to collect and carry excess water from the soil.

Tile drainage - Land drainage by means of a series of tile lines laid at a specified depth and grade.

Toe drain - A drainage system constructed in the downstream portion of an earth dam or levee to prevent excessive hydrostatic pressure.

Topography - General term to include characteristics of the ground surface such as plains, hills, mountains, degree of relief, steepness of slopes and other physiographic features.

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

Transpiration - The process by which water vapor escapes from living plants and enters the atmosphere.

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

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

Unified soil classification system (engineering) - A classification system based on the identification of soils according to their particle size, gradation, plasticity index and liquid limit.

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

Urban runoff - Surface runoff from an urban drainage area that reaches a stream or other body of water or a sewer.

Urbanized area - Central city, or cities, and surrounding closely settled territory.

Vegetative protection - Stabilization of erosion or sediment-producing areas by covering the soil with:

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

Warm season grasses - In Virginia, a grass which experiences most of its growth during the warm summer months (June, July and August) of the year. The onset of freezing temperatures turns warm season grasses brown and they remain dormant until late spring. Significantly more heat and drought tolerant than cool season grasses.

Watercourse - A definite channel with bed and banks within which concentrated water flows, either continuously or intermittently.

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

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

Watershed - The region drained by or contributing water to a stream, lake or other body of water. See Drainage Basin.

Watershed area - All land and water within the confines of a drainage divide or a water problem area consisting in whole or in part of land needing drainage or irrigation.

Watershed lag - Time from center of mass of effective rainfall to peak of hydrograph.

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

Watershed planning - Formulation of a plan to use and treat water and land resources.

Water table - The upper surface of the free groundwater in a zone of saturation; locus of points in subsurface water at which hydraulic pressure is equal to atmospheric pressure.

Weir - Device of measuring or regulating the flow of water.

Weir notch - The opening in a weir for the passage of water.

Wet storage - Volume within a basin (e.g., sediment basin) which is allotted for pooling or ponding of stormwater runoff.

Wet weather flow - A combination of dry weather flows and infiltration, inflow and/or runoff, which occurs as a result of rainstorms.

Zoning ordinance - An ordinance based on the police power of government to protect the public health, safety and general welfare. It may regulate the type of use and intensity of development of land and structures to the extent necessary for a public purpose. Requirements may vary among various geographically defined areas called zones. Regulations generally cover such items as height and bulk of buildings, density of dwelling units, off-street parking, control of signs and use of land for residential, commercial, industrial or agricultural purposes. A zoning ordinance is one of the major methods of implementation of a comprehensive plan.