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ABSTRACT

This program training text was designed to provide uniform instruction to the engineer, architect, planner, and others who will be helping to implement an erosion and sediment control program. Although tailored for use in Virginia, the basic principles covered are universal, and the material is adaptable to meet the needs in any State. The 11 units are grouped into four parts. Part 1 introduces Virginia's erosion problems, specific damages, costs, and the Erosion and Sediment Control Program. Part 2 covers the erosion and sedimentation process, soil loss prediction, channel erosion, and storm water management. Erosion control practices and principles and implementation of a control plan are presented in parts 3 and 4. A list of references is given for each part. Each unit in the program begins with a statement of the purpose and significance of the unit. The objectives for the unit are stated, followed by the subject matter content which may include outside references, background questions, or problems. Criterion questions enable the student to test himself. A summary answers the questions and briefly lists pertinent points. Photographs, charts, and drawings illustrate the text. Material to supplement the text is appended. Also cited is "The Virginia Erosion and Sediment Control Handbook," required as part of the subject content of the program. (Author/RG)

COMPREHENSIVE EROSION AND SEDIMENT

CONTROL TRAINING PROGRAM

FOR

ENGINEERS, ARCHITECTS AND PLANNERS

Prepared By:

Harry L. Porter, Jr.
Under contract with the
Virginia Soil and Water Conservation Commission
March, 1976

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COMMONWEALTH of VIRGINIA

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March 10, 1976

To the Users of this Training Program

Ladies and Gentlemen

On behalf of the Virginia Soil and Water Conservation Commission, I am pleased to present the "Comprehensive Erosion and Sediment Control Training Program for Engineers, Architects and Planners" Since the passage of the Virginia Erosion and Sediment Control Law in 1973, there has been a rapidly increasing need for some type of uniform Statewide training in the field of erosion and sediment control The Soil and Water Conservation Commission recognized this need and entered into a contract with Mr Harry L Porter, Jr. to develop such a training program for Virginia.

The Commission requested Mr Porter to develop a program that would not only give information pertaining specifically to the Virginia Erosion and Sediment Control Program, but would also provide an overall background and knowledge of the erosion and sedimentation process, thereby preparing a foundation on which to build good soil conservation principles I believe that anyone who examines this material will find that this requirement has been fulfilled This is probably one of the few texts in this Country that addresses erosion and sedimentation from its origin to its control and relates the two to provide a firm understanding of the principles behind specific conservation practices

We are very pleased that the National Association of Conservation Districts (NACD), after reviewing this text, has agreed to publish it as part of the National Sediment Control and Manpower Program funded by a grant from the U S Environmental Protection Agency Although this particular program has been tailor-made for use in Virginia, the basic principles and objectives contained herein are universal in scope and adaptable to any state program

The Commission expresses its sincere appreciation to Mr Porter for the fine job he has done in preparing this text and to all those agencies and individuals who have contributed to its content Also, special thanks is due NACD for making national publication and distribution possible

Sincerely,

Joseph B Willson, Jr

Joseph B Willson, Jr
Director

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(NOTE: All photographs courtesty of USDA, Soil Conservation Service)

Preface

This program is designed to provide instruction to the engineer, architect, planner, and others who will be helping to implement the Virginia Erosion and Sediment Control Program. It is intended to add to the student's capabilities so that he will be able to demonstrate measurable performance of the necessary new skills.

Behavioral objectives are basic to this training program. They are statements telling what the student should be able to do as a result of the training. A comprehensive list of objectives was prepared. These were sequenced so that each ability mastered would be the building block for the next objective. These objectives then became the basis for the sequence, design, and content of the entire training program.

The content was carefully selected. It is the material which the student needs to know in order to carry out the stated objective.

Objectives are spelled out in the program. When possible the objectives indicate the acceptable level of performance. The student will know what he is to learn and what is considered acceptable. This provides both student and teacher a means of measuring how well they are doing.

Each unit in the program begins with a statement of the purpose and significance of the unit. Next, the objectives for the unit are stated. Objectives are followed by the subject matter content which will include outside references in some units. The "contents" may also include some background questions or example problems. Criterion questions are included following the content so that the student can test himself. A summary answers the questions and briefly lists pertinent points, with very little discussion.

The "content" section of some units will refer to and assign pages in the Appendix. It is essential that these pages be read as a part of the subject matter content for that unit. Some of the criterion questions will be drawn from the Appendix assignments and the summary will cover both the "content" and Appendix material. For instance, Unit 1 in Part I includes references to Appendix A, pages V-35 to V-42.

In Parts III and IV, Appendix A, Virginia Erosion and Sediment Control Handbook and Appendix C, the USDA-SCS Technical Release No. 55. Urban Hydrology For Small Watersheds, are to be used as part of the subject matter content. In all cases, the content section of this program presents whatever material is necessary to supplement the Handbook and the Technical Release and assigns specific pages in these references as part of the program content. Instructors may also choose to develop visuals and other teaching aides in teaching Parts III and IV.

How To Use This Program

First, read the program preface to get an understanding of the purpose and organization of the whole program. The program is designed to be used in sequence from beginning to end.

Each subject matter unit will have a short statement of the purpose and significance. This will prepare you for the subject and help you to understand the applications to be made of the skills you are to learn. The next to appear are specific objectives. Read these carefully, they will tell you not only what you should be able to do upon completion of the unit, but also what is considered an acceptable level of performance

Read the subject matter content including the Appendix references which are indicated. When you feel that you have mastered the subject and can perform as stated in the objective, move on to the questions and check yourself. Read the summary to see how well you did. If performance was satisfactory, move on the next unit; if not, check the content and references again until you feel sure you have mastered the unit.

PART I INTRODUCTION

Unit 1 The Virginia Erosion and Sediment Control Program

Purpose and Significance:

This unit introduces the Virginia law and the Virginia Erosion and Sediment Control Handbook. It presents and discusses the basic purpose of the program. Basic responsibilities for various aspects of the program are given. The Handbook is essential for program implementation. A knowledge of the items discussed in this unit are basic to understanding the total erosion and sediment control program. The information will reinforce you in your continuing study and will help you in discussing the program with employers, associates, and the public

Objectives:

When you have completed this unit, you will be able to do the following things:

1. Name the two documents which are the legal bases for the Virginia Erosion and Sediment Control Program.

2. State the purpose of the program as given in the Virginia Erosion and Sediment Control Law.

3. State where the basic responsibilities for the program are placed.

Content:

Read Appendix A, pages V-35 to V-42, Virginia Erosion and Sediment Control Handbook, The Virginia Erosion and Sediment Control Law.

The law was passed March 20, 1973. It states the purpose of the program p. (V-35, 21-89-2) and indicates that it is to be implemented through the Virginia Soil and Water Conservation Commission * and the

* The Virginia Soil and Water Conservation Commission is an agency of the state created by § 21-6 of the Code of Virginia. In addition to the powers granted under the Erosion and Sediment Control Law, the commission has responsibility for the Small Watershed Program (Public Law 566), coordination of all shore erosion programs of state agencies, administrative leadership in the program for accelerating the Virginia portion of the National Cooperative Soil Survey, coordination and assistance with the programs of Soil and Water Conservation Districts, and administration of the Conservation, Small Watershed Flood Control and Area Development Fund.

soil and water conservation districts * in cooperation with counties, cities, towns, and other subdivisions of this state. In 21-89-4, of the law the guidelines referred to in (b) are in the Virginia Handbook, which was adopted by the Commission in April 1974. This Handbook is the basis for the state program, and provides guidelines and standards for the local programs. Most districts, counties, cities, and towns have adopted ordinances and have developed programs. These programs are consistent with the state program and were reviewed and approved by the Commission. You will also find a summary of the purpose and responsibilities for the program in Appendix A, the first four paragraphs on page I-3.

Questions:

When you have read the above material and pages V-35 to V-42 of Appendix A, test yourself by:

1. Writing the names of the two documents which are the legal bases for the Virginia Erosion and Sediment Control Program.

2. Stating the purpose of the Virginia program.

3 Naming the state and local entities that were assigned responsibility for establishing and implementing the program.

Summary:

The two basic documents are (1) the Virginia Erosion and Sediment Control Law and (2) the Virginia Erosion and Sediment Control Handbook. The purpose of the program is "... to protect the land, water, air, and other natural resources of the Commonwealth." The basic responsibility for the program is assigned to the Virginia Soil and Water Conservation Commission and Soil and Water Conservation Districts working through counties, cities, and towns.

* Soil and Water Conservation Districts are subdivisions of state government responsible under state law for conservation work within their boundaries. Districts are responsible for developing programs to deal with land and water resource problems and to coordinate help from public and private sources to accomplish their soil and water conservation goals.

Unit 2. Background and Extent of the Problem

Purpose and Significnace:

This unit gives a very brief history of the erosion and sediment problem and discusses efforts that have been made to solve it. It defines erosion and distinguishes between geologic erosion and accelerated erosion. The gross extent of the problem as well as the amounts attributed to various activities of man are presented. The events and pressures which led to the present law and program are discussed and analyzed.

The law is motivation enough for some. Others will want a deeper understanding of the problem. Broad-based support will depend on a well informed public. Knowledge of the background and the nature and extent of the problem should strengthen the resolve to help solve it. Understanding of past efforts and of trends affecting the problem will help you to understand the approach taken in the Virginia Program.

Objectives:

1. Define erosion and distinguish between geologic and accelerated erosion.

2. State the total tonnage of sediment pollution in the U. S. and the percentages attributed to various activities of man.

3. List three major activities of man that cause accelerated erosion.

4. Name and describe the federal-state program started in the 1930's to deal with the erosion problem.

5. Name the conditions that have brought renewed attention to erosion and sediment problems in the last few years.

6. Name the recent federal legislation which supported and provided stimulus for the state effort to control non-point source pollution.

7. Explain why the construction industry has received current attention in many states' laws, including Virginia's.

Content:

In the previous unit you learned the purpose of the Virginia program. The problem which it seeks to correct is extensive Sediment is the greatest single pollutant, by volume, of our lakes, rivers, and streams. It is the end result of the equally destructive process of erosion.

Content (Cont.)

Soil erosion is usually defined as the wearing away of the land surface by water, wind, ice, and gravity. In Virginia, we are primarily concerned with erosion by water. For our purposes, we can define soil erosion as a process of detachment and transportation of soil materials by erosive agents.

Erosion is not a recent phenomenon. It has been going on since the beginning of time. Whole mountains have eroded away. Sediment deposits several miles thick have been formed. Features as spectacular as the Grand Canyon have resulted from erosion. This natural process is called geologic erosion. In the well vegetated meadows, pastures, and forests of Virginia the erosion process continues at a slow rate. It seldom is discernable to us. It usually continues as a slow natural process unless it is disturbed by the activities of man. Geologic erosion produces about 30% of the total sediment in the U. S.

The erosion which we are more concerned with results from man's use of the land. This type is called accelerated erosion since the geologic rate is speeded up by the intervention of man. In this country, accelerated erosion began when the first settlers from Europe cleared sloping land and planted soil exposing crops. Accelerated erosion produces about 70% of all the sediment produced in the U. S.

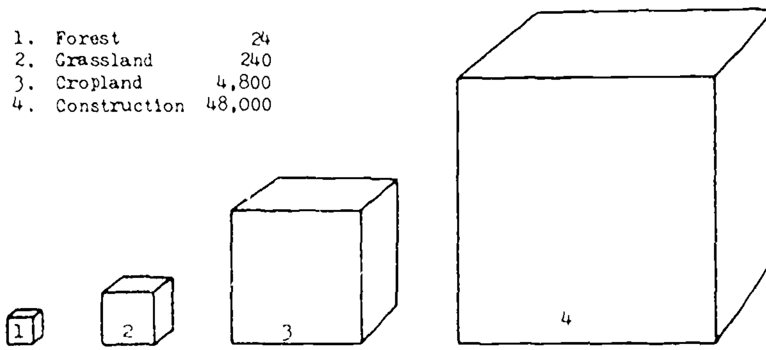
Total sediment production in this country is estimated to be four billion tons each year. (Ref. 1) This tremendous volume of material exceeds the sewage load by some 500 to 700 times. (Ref. 2) An estimated 1-1/3 billion tons of sediment is deposited in reservoirs and causes a loss in storage capacity of the nation's reservoirs, estimated at 1 million acre feet per year.

Agriculture, construction, and surface mining are the major activities causing accelerated erosion. (Ref. 3) About 70% of the total sediment is from accelerated erosion. About 50% of this sediment comes from agricultural land. Cropland is the chief source of this sediment. Construction activities, surface mining, forestry, and stream channel erosion account for the remaining 20%. Indirect effects of construction may be resulting in much higher sediment production than the direct activities. Stormwater runoff from impervious surfaces in urban areas is causing many streams that were relatively stable to suffer severe channel erosion. (Ref. 4)

It is obvious from the above figures that the total sediment produced by construction activities is small. However, the rates of erosion per acre on construction sites may be 10 to 20 times that from cropland. Figure 1 indicates sediment production per square mile from various uses.

Figure 1. Sediment Volume: Tons/Square Mile/Year
(Data from EPA 430/9-73-014)

1. Forest 24
2. Grassland 240
3. Cropland 4,800
4. Construction 48,000



This high rate of sediment production is one of the reasons why construction activities have received attention in the law. In addition, construction is usually concentrated in relatively small areas. The sediment problem is a "people" problem. (Ref. 5) It is highly visible to people. It is usually in areas of heavier population and higher land values. Sediment from these areas can completely fill small ponds and literally destroy small streams.

The first major effort to deal with erosion problems began in the 1930's with the passage of Public Law 46, 74th Congress, and the establishment of the Soil Conservation Service. Shortly after passage of PL-46 the President of the U. S. wrote to the governor of each state recommending legislation to establish soil and water conservation districts. The President's letter expressed this concern: "The nation that destroys its soil destroys itself." The concern which led to these acts was for the loss of valuable soil resources to erosion. The emphasis was on the control of erosion on agricultural lands. Soil Conservation Districts Laws were passed in all states. The Virginia Soil Conservation Law was passed in 1938. The law established Soil Conservation Districts which were to provide local leadership for a soil conservation program. The Soil Conservation Service and other federal and state agencies provided technical assistance to farmers through districts. This voluntary federal-state program made substantial progress in controlling farmland erosion.

Today we are dealing with much the same problem but with more emphasis on sediment control. This is in keeping with most of the environmental concerns of today. The effect of the sediment on the people downstream, on the user and consumer of the water resource is a major consideration.

The erosion control program carried out under PL-46 and through local Soil and Water Conservation Districts was eventually extended to assist urban and urbanizing areas. In the 1960's it became apparent that voluntary programs were not enough to get the job done. Local jurisdictions began to enact ordinances to control erosion and sedimentation. On October 26, 1966, Fairfax County became the first county in Virginia to adopt an erosion and sediment control ordinance. In 1970, Maryland became the first state to enact legislation for sediment control. The Federal Water Pollution Control Act of 1965 and the Amendments of 1972, PL-92-500, have given impetus to the states to enact legislation to control non-point source pollution. This law established goals that will require increasing attention to erosion and sediment control efforts. These goals are: (1) to attain an interim goal of water quality by July 1, 1983, which will provide for protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water and (2) the elimination of discharge of pollutants into navigable waters by 1985.

The conditions which brought about the recent attention to the erosion and sediment problem are many and varied. The limits of our land resources are being felt by more and more people. Land per person has dropped from about 17 acres in the 1940's to about 10 today. The rapid growth of highways, suburban housing, and shopping centers following World War II has magnified the problem. The tremendous increase in powerful machinery made massive alteration of the landscape possible. Increasing numbers of people with greater mobility, more money, and more leisure have made the problem much more visible to the public. Basically, people simply are annoyed by the loss of the streams, lakes, and natural areas that brought them to the suburbs in the first place. The cost to the public has become more apparent. They are no longer willing to accept it.

Questions:

1. Write a definition of erosion. Distinguish betwen geologic and accelerated erosion.

2. Give the total annual tonnage of sediment production in the U. S.

3. List activities of man that cause accelerated erosion. Give the percentage of the total which is attributed to each activity.

4. Discuss the federal-state program which was started in the 1930's to deal with the erosion problem.

5. Name the conditions that have brought renewed attention to erosion and sediment problems.

6. Name the recent federal legislation that has stimulated erosion and sediment control efforts.

7. Explain why the construction industry has been singled out in several of the recent state laws.

Summary:

Erosion is a process of detachment and transportation of soil materials by erosive agents. As a natural phenomenon it has shaped much of our land as we know it today. This natural process is geologic erosion. In areas of forest or grassland, it is a very slow process. When man intervenes and destroys the protective vegetation, the process is accelerated. The erosion caused by man's activities is called accelerated erosion. Geologic and accelerated erosion results in a total sediment production of 4 billion tons in the U. S. Geologic erosion accounts for about 30% of this total. Agriculture, construction, and surface mining are the major activities which cause accelerated erosion. Agriculture produces [illegible]% of the total sediment. Construction, mining, and stream channel erosion produce about 20%.

Public Law 46, 74th Congress, plus state soil and water conservation district laws established a cooperative federal-state program for soil erosion control in the 1930's. This was a voluntary program. The building boom following World War II and the population-growth put new pressures on land resources. The concentration of activities around most major cities brought renewed attention to the erosion and sediment problems The Federal Water Quality Act of 1965 and the Amendments of 1972, PL 92-500, have stimulated efforts for control.

The extremely high rates of erosion from construction sites plus their visibility, and their nearness to valuable land and water resources and densely populated areas, has meant that they are among the first to receive attention.

Unit 3. Specific Damages and Costs

Purpose and Significance:

This unit gives you information about specific damages and the known costs of correcting them. Costs and benefits of control are discussed. This unit relates closely to the previous unit and includes a discussion of characteristics of the problem that is pertinent to both units.

A knowledge of specific damages and costs is essential in evaluating alternative solutions to the problems. It is equally essential if we are to develop the moral imperatives to support the technology and to comply with the law. This basic understanding is necessary to help adjust our attitudes, improve our abilities, and stimulate us to carry out a program for erosion and sediment control. To quote Aldo Leopold, "No important change in human conduct is ever accomplished without an internal change in our intellectual emphasis, our loyalties, our affection, and our convictions." (Ref. 6)

Objectives:

When you have completed this unit, you will be able to:

1. List at least six specific types of damages caused by erosion and sediment.

2. Cite specific dollar costs of sediment pollution and list social and non-quantified costs.

3. Discuss costs and benefits of erosion and sediment control.

4. Explain why the problem is unlikely to diminish in importance or receive less attention.

Content:

One of the most frequently mentioned damages due to sediment is the reduction of reservoir capacity.

Figure 2. This Recreation Lake in Fairfax County Has Been Severely Damaged by Sediment

It is estimated that one and a third billion cubic yards of sediment is deposited in reservoirs each year. (Ref. 7) This represents a loss in water storage capacity of 270 billion gallons or an amount sufficient for a city of 5-1/2 million people. One source reports costs ranging from $.90 to $2.40 per cubic yard for removal of sediment. (Ref. 8) At a conservative estimate of $1.00 per cubic yard, the annual cost of removal if it were possible would be 1-1/3 billion dollars. Reservoir sites are a scarce resource. Sediment must be controlled to preserve existing water storage capacity

Sediment clogs stream channels. Reduction in channel capacity contributes to flooding, interferes with navigation, and may cause excessive channel movement. It is estimated that the volume of material excavated annually from streams, estuaries, and harbors exceeds one half billion yards. (Ref. 9) The Rappahannock River which drains 616 square miles averages 142 tons sediment/square mile or 87,472 tons per year. (Ref. 5) The same author, reporting Army Corps of Engineers costs, indicates a 10-year average cost for removal ranging from $0.15 to $1.00 per cubic yard. Their average cost for all work in 1962 was $0.29 per cubic yard. Applying this figure to the estimated total volume of material excavated (500 million tons) gives a total cost of $145 million dollars per year. If dredged material must be transported long distances for disposal, the cost can be multiplied several times.

In addition to the value of lost water supply capacity, there are other costs associated with sediment in water supply reservoirs. Except for water supplies used for cooling only, most industrial water supplies must be silt free. In domestic water supplies, people will not use water with readily observable sediment. Removing sediment is one of the major purposes of water treatment. In 1960 Washington, D.C. treated about 165 million gallons per day. (Ref. 10) If there had been no need to treat this water to remove sediment, the estimated annual savings would have been $20,100. This amounts to a cost of $0.33/million gallons.

Deposits of sediment in streets, culverts, storm drains, waterways, and flooded properties represent another substantial cost.

Figure 3. Sediment From An Unprotected Shopping Center Development

EPA reports street removal costs of $8.00 per cubic yard for a case study in California and $6.60 in Virginia. (Ref. 8) Basement removal costs were $77.00 per cubic yard in California and $65.00 in Virginia. Storm sewer cleanout by hydro-flush method was $68.00 per cubic yard in California and $62.00 in Virginia.

Sediment causes both direct and indirect damages to aquatic life. It may physically damage or kill the organism or damage the habitat by affecting food supply, spawning areas, and so forth. Fish can tolerate fairly high turbidity though the physiological stress may make them more susceptible to disease. Damage to the habitat can be much more serious. Ritchie reports several types of damages. (Ref. 11) Reduction of light limits photosynthesis and hence food supply. Organic matter, frequently deposited with sediment, uses oxygen in decomposing, thus reducing the supply. Sediment reduces survival rate of eggs. It has destroyed fish and oyster spawning areas in the Upper Chesapeake. Reductions of insects and plants due to sediment have reduced food supplies. The costs associated with these damages are not well quantified.

Figure 4. Sediment Above A Recreation Area

Damages to the soil resource from erosion have received considerable attention in agricultural areas. It is also a significant damage in urbanizing areas. Some of the costs of these damages are passed on to the buyer in much higher landscaping and ground maintenance costs or in dissatisfaction with landscaping results on badly damaged soils. Some are direct costs of construction such as regrading, removal of mud, and higher landscaping costs.

Figure 5. Single Storm Sediment Damage
From An Industrial Site Development

Other damages include sealing of soil surface and hence greater runoff, soil deposits on land, loss of esthetic values, and loss of recreational values of ponds, lakes, and rivers.

Figure 6. Loss of Esthetic Values

The costs of erosion control measures are not well documented. However, there is some information available for use in planning control systems. Brandt, et al (Ref. 12) reports that for an investment of $7,000 in sediment control, one developer was allowed a higher density zoning. He gained 75 lots which brought in $500,000 additional revenue. One developer reported an increase of costs of $25.00 to $50.00 per lot. (Ref. 7) Costs in the Washington, D.C.-Northern Virginia area may range from $25.00 to $200.00 per single family detached dwelling. Costs of individual practices have been reported by EPA. (Ref. 8) These will be discussed later in the program as individual measures are discussed but some of their conclusions are pertinent here. First, one of the most effective erosion control methods, hydro-mulching, is also one of the most economical. Costs in the EPA study were $400 per acre for areas of 15 acres and over, and $900 per acre for areas of less than one acre. Most important, the costs of preventing soil erosion and sediment runoff per unit of sediment retained are less, in a great many instances, than the cost of later removing the silt. When one realizes that the removal only cures part of the problem, then erosion and sediment control appears in a favorable light from an economic standpoint.

The cost benefit analysis of erosion and sediment in relation to urban development may be of two sorts. First, an analysis of costs for erosion control may influence decisions on land use. If costs of control with an intensive development plan are too high it may be desirable to go to a less intensive development. This analysis should help to keep intensity of land development in line with the suitability of the land. Because by law in Virginia an acceptable level of erosion and sediment control must be achieved, it is not relevant to make a cost-benefit analysis to decide whether to control or not to control erosion. The second consideration requiring analysis is the costs of alternative measures or combinations of measures which would give the acceptable level of control. Fortunately, the cost data available seems to favor heavier emphasis on controlling erosion at the source rather than trapping sediment at site boundaries.

One further point relating to this unit and the preceding one should be discussed. The characteristics of the erosion and sedimentation problem are similar to those of other environmental concerns. They clearly indicate that the concerns that generated the control program will see that it is continued.

Erosion and resulting sediment pollution is very visible, and tends to threaten many people. The blame, not necessarily the cause, can be placed on a small group. We do have technical solutions to the problem which are economically feasible. The costs of control can be passed on to the public through higher prices, which are less noticeable and more acceptable than the higher taxes, which are caused by the public damages of improper development. Some of the apparent ambiguities associated with this as with other environmental issues are a strength, since everyone wants to improve the quality of the environment. An "industry" has devloped and is profiting from control of sediment and other pollutants. Also, lawyers and some other professions have found it to be a lucrative field. A lobby for control has thus been formed. Lastly, the present law adds pressure to control sediment, this and all of the above points seem to indicate that the program will be strengthened rather than forgotten.

Questions:

Test yourself on the material in this unit.

1 List six or more types of damage caused by erosion and/or sediment.

2. Cite specific dollar costs of correcting sediment damages for at least three types of damages.

3. Discuss cost-benefit analysis of erosion and sediment control. What two types of analyses would you make?

4. List at least four characteristics of the erosion and sediment problem that will tend to keep the issue alive.

Summary:

The specific sediment damages include siltation of lakes and reservoirs; sediment deposits in streams, rivers, and harbors; and clogging of culverts, storm sewers, and open waterways. The sediment kills or greatly reduces the amount of aquatic life. It reduces the usefulness of water resources for recreation. Water treatment costs are increased. Erosion damages may cause considerable extra costs to the developer and may permanently damage the land, making it less satisfactory to the ultimate user.

The cost of removing sediment from reservoirs ranges from \$0.90 to \$2.40 per cubic yard. The cost to the Corps of Engineers for removing sediment from streams, estuaries, and harbors averaged \$0.29 per cubic yard in 1962. This does not include transporting dredged material to suitable disposal sites. Water treatment costs for Washington, D.C., to remove sediment, were \$0.33 per million gallon, or \$20,100 per year. Cleaning sediment from streets cost \$6.60 per cubic yard in one Virginia study. Removing it from basements cost \$65.00 per cubic yard and removing it from storm sewers cost \$62.00

In developing erosion and sediment control plans, cost benefit analysis should be used in two ways. First, to determine the best land use for the area under consideration and second to compare alternative erosion control measures and combinations of measures.

The erosion and sediment control problem will continue to receive emphasis because it is a very visible problem. It affects most people in some way or another. The blame may be placed on a small group. Technical solutions exist which are economically feasible. Costs can be passed on to the consumer. Also, "everyone" wants to improve the environment. An "industry" has developed around erosion and sediment control and some professions have found it to be a good field. The program seems much more apt to be strengthened rather than forgotten.

PART I References:

1. Control of Agriculture-Related Pollution. A report to the President by the Secretary of Agriculture and the Director of the Office of Science and Technology, Washington, D.C., January, 1969.

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PART II THE EROSION AND SEDIMENTATION PROCESS

Unit 1. The Erosion Process

Purpose and Significance:

This unit discusses and defines the five types of soil erosion with which we are concerned. It names the causative agent or agents for each type. It covers in detail the factors which influence erosion from the land surface so that you will understand the specific effects of each factor in the erosion process. Channel erosion is included in the definitions here, but the discussion of the specific factors effecting it will be in the third unit of this Part.

An understanding of the types of erosion, of the forces causing erosion and of other influencing factors is basic to understanding how to develop a control program. Erosion is a process. Knowledge of how it functions will help you to understand at what stage in the process intervention with control practices will be most effective. An understanding of the forces and factors will help you to know what practices will be most effective for each situation.

Objectives:

1. Define five types of erosion and name the erosive agents responsible for each type.

2. List the major factors influencing erosion.

3. Indicate the characteristics of each of the above factors which determine their effect on erosion.

4. Name the factors which determine the volume of runoff from a site.

5. Name the factors which determine the velocity of runoff in overland flow.

6. Describe the process which results in rills and gullies and indicate the factors responsible.

Content:

In Part I, we defined erosion as a process of detachment and transportation of soil materials by erosive agents. This emphasizes the process nature of erosion. First, soil particles are torn loose from the soil mass. This makes them available for transport. Second, the detached materials are transported. Sedimentation, the last step in the total process, is discussed in the last unit in this Part.

We also mentioned in Part I that we are primarily interested in erosion caused by water. It will help us to understand the erosion process by water if we think . the detaching capacity of the erosive agents and their transporting capacity as separate variables. Soil materials also vary in detachability and transportability. Each of the factors discussed will have a bearing on detachment and/or transport of soil materials.

It will be 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 of the land surface. The force of falling rain is applied vertically. The force of flowing water is applied horizontally. They both perform work in detaching and moving soil particles, but their actions are different. The 1955 Yearbook of Agriculture gives an excellent description of water erosion. (Ref. 1)

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

Sheet erosion is the erosion caused by shallow sheets of water as it runs off of 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 conformation of the surface. As the flow changes from the shallow sheet flow to deeper flow in these low areas, the velocity of flow 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 tiny channels of its own. Rills are small but well defined channels which are at the most only a few inches deep. They are easily obliterated by harrowing or other surface treatments, and have no more than 1 square foot cross section.

Gully erosion occurs as the flow in rills comes together in larger and larger channels. The major difference between this and rill erosion is a matter of size. 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.

There are four major factors which have a direct influence on the detachment and transportation of soil materials. These are climate,


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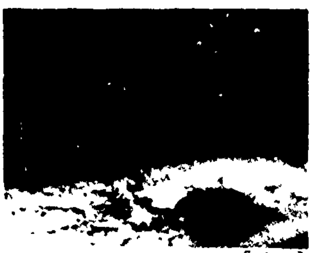
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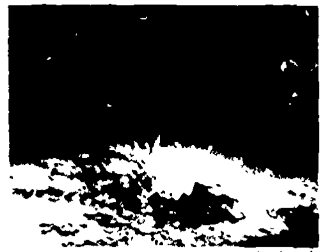
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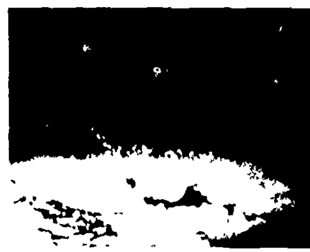
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soils, topography, and vegetation (or surface cover).

We will first discuss climate since it is the source of the major erosive agent in the erosion process. When we talk about climate we are primarily concerned with rainfall, although temperature and snow cover are also important.

The discussion of rainfall can be divided into the effect of raindrops and the effects of runoff.

Raindrop erosion is the first step in the erosion process. The action of falling rain is responsible for 90% or more of the total soil erosion. It produces two damaging effects -- the detachment and transportation of surface soil, and the puddling or sealing of the soil surface. Neutralizing these two effects is the first and most important part of erosion control.

Figure 7. Raindrop Splash Series

This sequence of photographs shows the action of a raindrop striking wet soil. The drop of water is a sphere, about 1/8 inch in diameter. It travels at the rate of about 30 feet per second when it strikes the soil. The force pushes the wet earth outward in all directions and throws particles of soil and water to distances of 2 to 5 feet. The resulting crater is about 4 times as large as the raindrop. (USDA-SCS photo by Naval Research, Bureau Yards & Docks, November 1949)

How can rainfall be responsible for so much damage? Observation of a hard rain on bare soil would confirm its destructive power. The drops hit the surface like tiny bombs. They shatter soil granules and splash the detached material back and forth. Splashed particles may be moved more than two feet high and five feet horizontally. On level land, this is self-canceling. On sloping land, the net movement is downhill. On a 10% slope, 75% of the soil movement is downslope. More than 100 tons of soil per acre may be detached in a single rain.

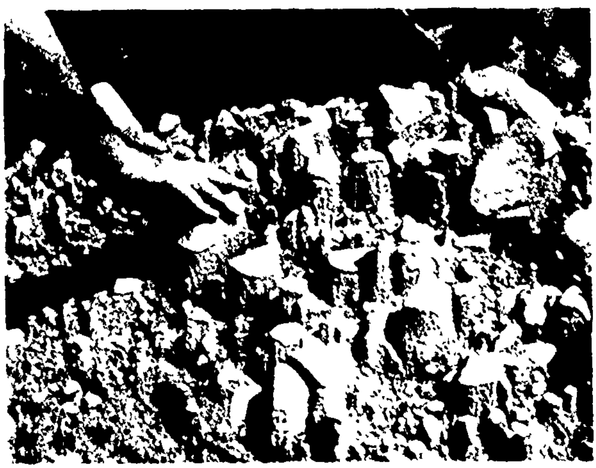
The erosive capacity of rainfall comes from the energy of its motion or kinetic energy. It is dependent on the amount and intensity of rainfall, raindrop diameter, and raindrop velocity.

Drop size varies from the finest mist to drops which are 1/3 inch or nearly 8 millimeters in diameter. Any rain will contain drops of various sizes. A hard rain has a much higher proportion of large drops.

Raindrop velocity is tied very closely to drop size. Fine mist with droplets about 1/100 inch in diameter fall at about 1 inch per second. The largest drops attain a velocity of 30 feet per second. It is obvious from this that an inch of rain falling as large drops in a hard thunderstorm has many times more erosive capacity than an inch falling as fine drizzle over a longer period of time. The actual force (kinetic energy) of raindrop impact in a hard summer storm may be 2 or 3 hundred times the force of the surface runoff, even on steep slopes.

The effects of splash erosion are easy to see in nature. Splashed soil particles can be seen clinging to the foundation of buildings which are adjacent to bare soil. Particles can be seen on stems and leaves of plants which are growing in a partially vegetated field. Pedestals of soil capped with protective stones can be seen where raindrops splash carried away unprotected soil material. Figure 8 shows an extreme case of pedestal formation.

Figure 8. Pedestals Under Protection of Small Stones Are Formed By Splash Erosion



Another important aspect of rainfall is its distribution. The most erosive rains are not scattered evenly throughout the year. In Virginia, they are concentrated in the months of June through September. Unfortunately, these periods of most erosive rains coincide with the most active part of the construction season.

Table 1 indicates some significant differences between storms occurring during the spring and summer and those occurring in the fall and winter.

Table 1. Precipitation Characteristics by Seasons

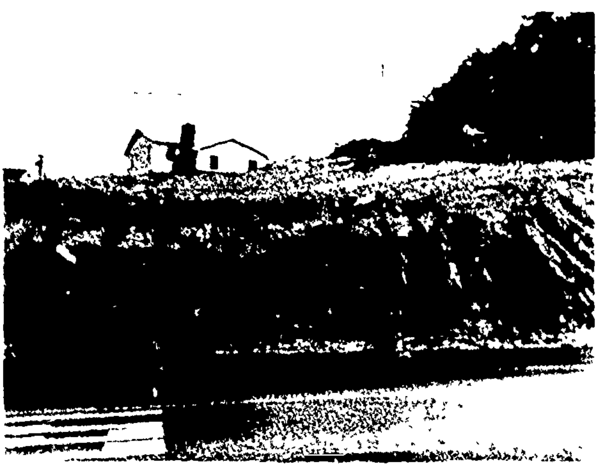
Characteristic	Sept. Through April	May Through August
Form	Rain and snow	Rain
Intensity	Low	High
Drop Size	Small	Large
Duration of Storm	Long	Short
Area of Storm	Large	Small

So far we have concentrated on the force of falling rain and its capacity to detach and move soil material. The second damaging effect is the compacting, puddling, and sealing of the soil surface. As mentioned before, large drops strike with tremendous impact, compacting the soil under the point of impact. Repeated strikes churn the surface into a slurry. As this semi-fluid mass attempts to infiltrate into the soil it does a very effective job of sealing the pore spaces against further entry of water. As drops continue to beat against the surface they sort and compact the material until an almost complete seal is formed. Even on coarse sands this action reduces the intake of water.

This brings us to the second damaging aspect of rainfall -- runoff. Runoff is the second erosive agent. It begins when the rate of rainfall exceeds the intake capacity of the soil. When a hard rainfall is unimpeded as it strikes the soil, runoff begins a few minutes after the start of the rain. In the early stages, its major potential for damage is as a transporting agent for soil dislodged by raindrop splash. As water begins to collect on the surface it has no kinetic energy. It derives energy from its movement as it beings to run downslope. The amount of runoff depends on two things, the amount and intensity of the rainfall, and the nature of the soil or intervening surface that it falls on. Runoff at first takes the form of a layer of water flowing more or less uniformly over the ground. Depth of this flow is usually very shallow. Runoff from bare plots 116.7 feet long on 20% slope at the rate of 1.25 to 3.68 inches per hour produced depths of flow ranging from 0.06 to 0.15 inches. Flows of this sort have practically no capacity to detach soil but they do have capacity to transport particles which are detached and kept in suspension by raindrop impact. The result of this combination of the detaching capacity of raindrops and the transporting capacity of sheet-flow runoff is sheet erosion. The effects of this type of erosion occur on all the land surface except in rills and gullies. Because it removes soil in thin layers from 95% or more of the land surface, it is difficult to observe even though the total soil losses may be tremendous.

Under normal field conditions, runoff occurs both as sheet flow and channelized flow. As water moves downslope, it tends to follow the path of least resistance. The flow begins to concentrate in the depressions and irregularities of the land surface. This is the beginning of channelized flow. As the amount of water in these channels increases, the velocity and turbulence also increases. As the runoff concentrates first in tiny channels then combining into larger and larger ones, it gains the force to both detach and transport soil material. The erosive capacity of flowing water derives from its velocity, turbulence, and the amount and type of abrasive material that it carries. The velocity varies with the depth or volume of flow, the roughness of the channel, and the slope gradient. As the length of slope increases, the depth and hence the velocity also increases.

Figure 9. Rill and Gully Erosion



Detachment by flowing water is confined primarily to the areas of concentrated flow (rills and gullies). The detachment of soil particles is by rolling, lifting, and abrasive actions. The force is horizontal, in the direction of flow. The forces of flow detach some soil particles by rolling or draging them out of position. As velocity and turbulence increase, vertical currents and eddies occur. This upward movement of water lifts soil particles from their place and sets them in motion. As the particles of soil already being transported by the flow strike or drag over other soil particles, they detach them and set them in motion. This is the detachment by abrasive action. The amount and abrasiveness of the particles in the flow will influence the amount of soil detached by abrasion.

The same factors that determine detaching capaci'y act to determine the transporting capacity. As mentioned before, sheet flow has very little detaching capacity. It is effective in transporting soil materials because raindrop impact keeps the material in suspension. It has been observed that muddy water flowing across a parking lot left a deposit of mud under each car while the surrounding pavement was washed clean. (Ref. 2) In this case, the velocity and turbulence of flow alone were not enough to keep the material in suspension. The material detached by raindrops and transported by sheet flow is the finer textured soil material.

The flow in rills and gullies transports material by "surface creep," "saltation," and by suspension. In surface creep, the particles roll or slide along the bottom of the rill or gully. The particles move by saltation when the eneven forces of turbulent flow lift and move them by jumps. Particles travel in suspension when the upward velocities of turbulent flow exceed the settling velocities of the soil material. In general, the larger particles are moved by surface creep and saltation while smaller particles are moved by suspension. Unless limited by the amount that can be detached, the total amount of material moved depends on the transporting capacity of the runoff and the transportability of the soil material.

One other aspect of climate can cause severe erosion. Rainfall on partially frozen soil can cause excessive runoff and erosion. In such a case, infiltration may be practically zero, resulting in nearly 100% runoff.

In the second unit in Part II, we will discuss soil loss prediction using the Universal Soil Loss Equation. The effects of rainfall are represented in this equation by the factor R. This factor reflects the combined potential of raindrop impact and turbulence of runoff to transport dislodged particles from the field. (Ref. 3)

The second factor influencing erosion is the soil. When all other factors are held constant, different kinds of soil will erode at different rates. Soil differences may cause more than a tenfold difference in erosion rates. The difference in erosion rate which is due to the properties of the soil itself is called the soil erodibility. (Ref. 3)

The soil properties which influence erodibility by water are (1) those that affect the rate at which water enters the soil (infiltration rate), (2) those that affect the rate at which water will move through the soil (permeability), (3) the total water capacity, (4) factors affecting detachment by raindrop impact and detachment by rolling, lifting and abrasion of flowing water, and (5) those that resist the transporting forces of rainfall and runoff.

Soil erodibility has been investigated intensively in development of the Universal Soil Loss Equation. The important properties are: (1) particle size and gradation; (2) percent of organic matter; (3) soil structure; and (4) soil permeability. There are several additional properties which influence soil erodibility, but the above account for the about 85% of the variance in observed soil loss.

Wischmeier and others have shown a very good correlation between erodibility and an index derived from five soil parameters. (Ref. 4) Two of these reflect particle size and gradation while the other three are % organic matter, soil structure, and soil permeability.

Soil particle size distribution plays a major part in determining erodibility. (See Figure 10 for texture sizes in various soil classification systems.) Erodibility tends to increase with greater silt (.002 to .05 m.m.) and very fine sand (.05 to 0.1 m.m.) content and to decrease with greater sand (0.1 to 2.0 m.m.), clay ($<$ .002 m.m.), and organic matter content. Soils with a high clay content are generally more resistant to detachment, although once detached, the clay particles are easily transported. Clay soils also usually have poor infiltration, thus increasing runoff. An increase in organic matter reduces erodibility by improving structure and the stability of structure. Organic matter also improves permeability.

Size and type are the important structure properties. Wischmeier uses four structure codes to obtain an erodibility index. Code 1, very fine granular structure, is the least erodible; followed by code 2, fine granular; then code 3, medium or coarse granular; to the most erodible, code 4, blocky, platy, or massive structure.

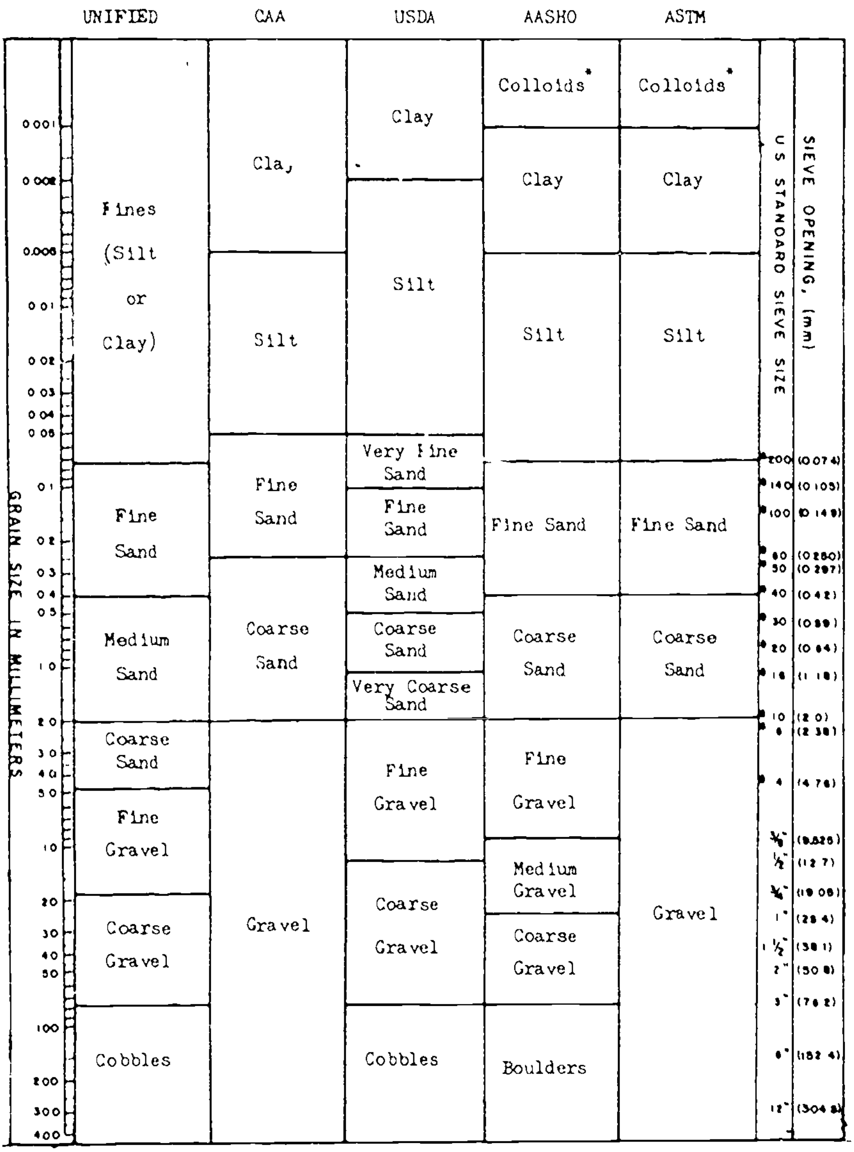
Permeability must reflect the permeability of the whole soil profile. In undisturbed soils, the limiting layer is usually below the surface. In fragipan soils (soils with a natural subsurface horizon which is very dense and very slowly permeable to water), the position of the layer in the profile is important. If the fragipan is near or moderately near the surface, it will increase erodibility. If it is below a thick loam surface, it may have little effect on erodibility except in very large storms.

The soil properties will be discussed further in the unit on soil loss prediction. The K factor of the Universal Soil Loss Equation is the index of erodibility.

In the two factors discussed thus far, we have covered the causes of erosion by water. We have been concerned with the power of the rain to erode and the resistance or susceptibility of the soil to erosion

Figure 10 Soil Classification Systems

Soil-Separate Size Limits



* Included in clay fraction in test reports

The remaining two factors function to modify the effects of the interaction of rain and soil.

The most important effects of topography are the results of length or steepness of slope. Slope shape and slope direction will have some effect.

Slope length is the distance from the point where overland flow begins to the point where it enters a well defined waterway or the point where deposition may occur because of a decrease in slope gradient. The longer the slope, the greater the depth of runoff. There is a build-up in depth of flow and hence in velocity. Research has shown the soil loss per unit area is proportional to some power of slope length ($E \propto L^m$). (Ref. 3) The average value of the exponent m is about 0.5. On slopes steeper than ten percent, the value of m is about 0.6 and on very long flat slopes 0.3 is more appropriate.

Steepness of slope influences erosion in several ways. There is more splash downhill on steep slopes. The velocity of flow increases with slope steepness, and there is more runoff on steep slopes. Wischmeier concluded that soil loss is proportional to: $\frac{0.43+0.30s+0.43s^2}{6.613}$ where s is the gradient expressed as percent slope.

In the Universal Soil Loss Equation, the factors for slope length and slope gradient have been combined into a single topographic factor LS.

The shape of slopes will affect erosion. On convex slopes (slopes which steepen at the lower end) and concave slopes (slopes which flatten at the end), erosion will be either over (on convex) or under (on concave) the amount that would be expected if the effect were calculated on the basis of an average grade.

Direction of slope has an indirect effect simply because of the effect which exposure has on vegetation. South and southwest facing slopes are usually harder to vegetate and maintain, other things being equal.

Vegetation and surface cover is the last of the four factors influencing erosion. It is perhaps the most important factor from the standpoint of control. The use of vegetation, mulches, and other surface covers offers the greatest range of control alternatives.

Hudson (Ref. 5) illustrates the dramatic reduction in soil erosion that can be obtained when the soil is well covered. He had two plots about 5 by 90 feet. Each was kept free of weeds. One plot was covered by fine-mesh wire screen. All of the rain passed through the screen but the raindrops were broken so they reached the soil as small droplets. In a ten-year period, the soil loss from the bare plot was more than 100 times that on the screen covered plot. The loss on the covered plot was only 3.8 tons per acre for the ten-year period.

Vegetation of the right type and density can provide the same protection as the fine wire screen. Erosion takes place on the soil that is exposed to the unimpeded impact of falling rain. The amount of erosion depends on how much of the land surface is left exposed to this force. Hudson illustrated this by experiments with corn grown at two populations:

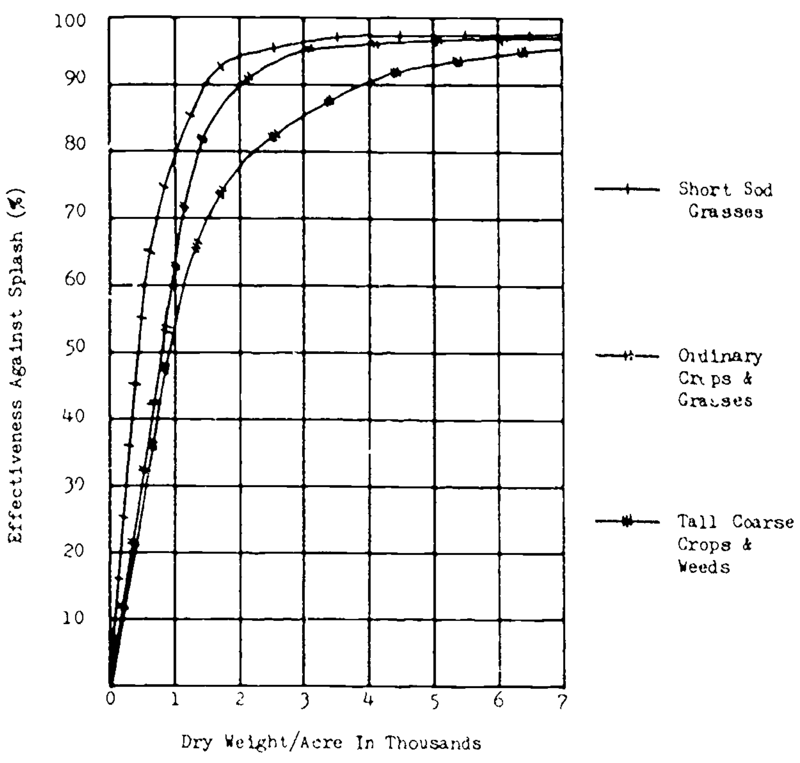
plants/acre	9,000	14,500
% ground exposed	40%	10%

Soil loss over a ten-year period was four times as much on the 9,000 plants per acre plot as on the 14,500 plants/acre plot. In the above study, the amount of soil exposed was measured from photographs taken vertically down on the plots.

Osborn reported that amount of cover far outweighed factors such as plant type or species. (Ref. 6) His studies were measuring the splashed soil or detachability rather than soil loss. Effectiveness against splash was best indicated by the product of total air dry weight of the above ground vegetation and percentage of soil coverage. There were some differences between types of plants that are worth noting. These are presented in Figure 11.

It is obvious from the results of the wire screen covered plots that there are other ways of providing effective cover besides vegetation. In fact, if erosion is to be controlled during the establishment period of new seedings, spriggings, or plantings, some type of surface protection must be provided. The U. S. Soil Conservation Service indicates the effectiveness of several ground covers in preventing erosion. (See Table 2.)

Figure 11. Effectiveness Of Vegetation In Preventing Splash Erosion



(Assumes that vegetation is more or less evenly distributed over area)

Table 2. Effectiveness Of Various Ground Covers In Preventing Soil Loss

Kinds of Ground Cover	Soil Loss Reduction As Related To Bare Soil Surface Percent Reduction
Full, established stands of:	
Permanent grasses	99
Perennial ryegrass	95
Annual ryegrass	90
Small grain	95
Millet or sudan grass	95
Field bromegrass	97
Grass sod (permanent species)	99
Mulches: (Anchored)	
Hay @ 2 tons/acre	98
Small grain straw @ 2 tons/acre	98

Values for woodchips, woodcellulose fiber, fiberglass, asphalt emulsion, and similar materials have not been established. However, these should be at least 90% effective when used at the following rates:

Woodchips @ 6 tons/acre
Wood cellulose fiber @ 1-3/4 tons/acre
Fiberglass @ 1/2 ton/acre
Asphalt emulsion @ 1250 gallons/acre

The discussion thus far has emphasized the tremendous reduction in erosion on well vegetated or mulched areas. Vegetation not only prevents splash erosion, but also prevents puddling and sealing of the soil surface. The effects of a good vegetative cover or mulch on runoff are equally spectacular. Stallings reported on experiments comparing infiltration on vegetated, mulched, and bare plots. (Ref. 7) In these studies on several different soil types, the protected plots maintained a high water intake rate and practically no soil loss even at sustained high rates of rain. Infiltration rates on bare soil plots dropped rapidly and leveled out at very low rates. This effect was significant even on an area of dune sand.

Studies on grassland confirmed the value of vegetation for increasing water intake. (Ref. 8) Water intake results are summarized in Table 3.

Table 3. Rates of Water Intake On Plots With Varying Amounts of Vegetative Cover

	Air Dry Material Vegetation (Pounds/Acre)	Dead Plant Litter (Pounds/Acre)	Rate Of Water Intake 1st 30 min. (Inches/Hour)	Rate Of Water Intake 2nd 30 min. (Inches/Hour)	Total Intake (Inches)
Heavily grazed plot	727	342	1.81	1.16	1.48
Moderately grazed plot	1,574	1,792	2.78	2.15	2.40
Ungrazed plot	2,204	4,151	4.27	4.27	4.27

In this study, multiple regression analysis indicated that total vegetation and dead plant litter accounted for 88% of the difference in water intake.

One further value of vegetation is its effect on runoff velocity. Certain types of vegetation are known to be very effective in reducing erosion by flowing water. Vegetation is frequently used to provide a protective lining in shallow waterways.

In these channels, vegetation provides protection by reducing the velocity near the bed of the channel. Observations through vertical glass walls in experimental channels reveal that the vegetation remains up in the flow, whipping back and forth. The severity of the whipping is a function of velocity, depth of flow, roughness of the bed, and velocity distribution from surface to bed. Vegetation with a dense uniform growth near the soil surface and a strong fibrous root system is most effective in reducing erosion. Good uniform stands of Bermuda grass, Kentucky bluegrass, or tall fescue meet these requirements. All three are sod-forming and have a high percentage of basal leaves (leaves originating near the soil surface). They will provide good surface cover even after mowing and with good management will retain their density indefinitely.

Roots have important influences on both erosion and water intake. Their primary effect is through improvement of soil structure and organic matter content. Roots are not in a position to shield the soil from raindrop impact or to hold soil against the detaching force of runoff unless erosion has already progressed far enough to place them on the surface. They may provide some protection against the mud flows which occur on thawed saturated surface layers above frozen soil.

The C value in the Universal Soil Loss Equation reflects the vegetative or surface cover role in erosion and the managment of the vegetation.

This completes the detailed discussion of the erosion process. An understanding of the material covered in this unit is basic for development of erosion and sediment control systems,

Test yourself by answering the following questions:

1. Define the five types of erosion and name the erosive agent(s) for each type.

2. What are the major factors affecting erosion and what particular characteristics determine their effect? List factors and indicate characteristics for each.

3. What factors determine the volume of runoff from a site?

4. What factors determine the velocity of runoff in overland flow?

5. Describe the process which results in rills and gullies and indicate why they form.

Summary:

<u>Raindrop erosion</u> is the first effect of rain on the soil. The erosive agent is the vertically applied force of falling raindrops.

<u>Sheet erosion</u> is the loss of shallow layers of soil as the particles of soil dislodged by raindrops are carried off by surface runoff. The primary agent is raindrop splash which dislodges and keeps the particles in suspension. Runoff is the secondary agent.

<u>Rill erosion</u> is the erosion which develops as the shallow surface flow gathers in surface irregularities. Tiny channels erode as the flowing water gains enough velocity and turbulence to dislodge and transport soil material.

<u>Gully erosion</u> occurs as rills join to form deeper and faster flows.

<u>Channel erosion</u> is the cutting of banks and/or beds of ditches and streams.

The four major factors in water erosion are climate, soils, topography, and vegetation.

Rainfall is the most important aspect of climate affecting soil erosion. The total kinetic energy of the storm and its intensity determine its erosive effect.

Soils differ in erodibility other factors being equal. The important characteristics are particle size gradation, organic matter content, type of soil structure, and permeability.

Two major characteristics of topography affect erosion. The length of slope determines the amount of water added as the flow proceeds downhill and so influences velocity by increasing depth of flow. The slope gradient increases the velocity of flow. There is more splash downhill on steep slopes and more runoff.

Slope shapes will also affect erosion. On slopes which steepen at the lower end, erosion will be greater than for a comparable length at a uniform grade of the same average percent. On slopes which flatten out at the lower end, it will be less.

Vegetation reduces the effects of raindrop impact by absorbing the force before it can act on the soil. This prevents the detachment of soil particles and the sealing of the soil surface.

The volume of runoff from a site is determined by the amount f rain on it less that which soaks into the ground or is held in surface depressions and on leaves and stems. Soil infiltration and percolation rates and the effect of vegetation on infiltration determine the water intake.

Velocity is a function of slope gradient, depth of flow, and the retardance due to the surface over which it flows. The effect of length of slope is to add to the amount of contributing watershed thus increasing the depth of flow.

Rills and gullies are caused by channelized flow. Runoff begins as a very thin sheet of flow all over the soil surface as the rate of rainfall exceeds the infiltration rate. It remains as sheet flow only to the nearest depression or irregularity that is lower than the surrounding surface. Tiny rills form then join to make larger ones and so on. The pattern of resulting rills and gullies resembles the silhouette of a tree -- the twigs at the outermost part representing the first tiny rills, these join to form branches representing larger rills which join to form larger limbs like gullies until all is converged into the trunk or main channel. The rills result from the scouring action where the flow and velocity are enough to detach and transport soil material.

Unit 2. Predicting Soil Losses

Purpose and Significance:

This unit will discuss the use of the Universal Soil Loss Equation in predicting rainfall erosion losses. Planning for erosion and sediment control requires a knowledge of the factors that cause soil erosion and those that prevent it. We must be able to determine the erosion hazard in quantitative terms before we can decide how to control it. This unit will prepare you to answer such questions as, "Just how erodible will the subsoil at this site be if exposed by grading?" or "How will erodibility differ at different depths of cut?"; "Where are the most hazardous areas?"; "Where are the least hazardous?" Also, "After all possible erosion control measures have been taken, what are the probable soil losses, and what sediment control measures will be required?"

This unit builds on the knowledge of the nature of the process of erosion which you acquired from the previous unit. It will give you rather definite quantitative values for the influence of soil, rainfall, length, and gradient of slope and of vegetation in the erosion process. It will help you to understand the interrelationships between these factors.

Objectives:

When you have completed this unit, you will be able to:

1. Write the Universal Soil Loss Equation.

2. Name and explain each equation factor.

3. Give data for a specific location and site, using the USLE estimate the expected soil loss in tons per acre per year or for a given period under various cover conditions.

Content:

The basic references that you will need for this unit are the content which follows and data in Appendix B which was taken from Predicting Soil Losses in Virginia, U.S. Soil Conservation Service, Richmond, Va., 1975.

The development of equations for estimating soil loss began in the early 1940's. Forerunners of the present equation proved their value as tools in conservation planning. These early equations had some shortcomings, particularly when attempting to use them in parts of the country other than where they were developed. The present equation was developed in the 1950's. Data from erosion control research obtained since the early 1930's was assembled and analyzed at the USDA Soil Loss Data Center at Purdue University. The result is called, "The Universal Soil Loss

Equation." (Ref. 3) This equation is used to predict sheet and rill erosion.

The Soil Loss Equation is: A = RKLSCP, where:

A, is the computed soil loss in tons per acre.

R, the rainfall factor, is the number of erosion-index units in a normal year's rain. The erosion index is a measure of the erosive force of a specific rain. When other factors are constant, storm losses from rainfall are directly proportional to the product of the total kinetic energy of the storm times its maximum 30-minute intensity.

K, the soil erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow on a 9% slope 72.6 feet long. This unit is in tons per acre.

L, the slope length factor, is the ratio of soil loss from the field slope length to that from the 72.6 foot plot.

S, the slope gradient factor, is the ratio of soil loss from the field slope gradient to that from the 9% plot slope.

C, the cropping-management factor, is the ratio of soil loss from a field with specific vegetation or cover and management to that of the standard bare fallow condition. This factor measures the combined effect of all the interrelated cover and management variables plus the growth stage and vegetal cover at the time of rain.

P, the erosion control practice factor is the ratio of soil loss with the practice to that from a field with no practices.

Soil erosion by water is influenced by many variables, as you know from the previous unit. The soil loss equation isolates each variable and expresses its effect as a number. When the numbers for each variable are multiplied together, the product is the amount of soil loss. In using the equation for any given situation, the numerical value of each factor is fixed. That is, there is an area of land with a certain slope gradient and slope length on a specific kind of soil with either a bare surface or some type of vegetation and/or mulch cover on the surface. These numerical values are readily available for the soils, slope, rainfall, and vegetative conditions you will encounter in Virginia. The equation estimates sheet and rill erosion. It does not consider soil losses caused by gully erosion.

R, the rainfall factor was reported by Wischmeier in 1959. (Ref. 9) Values for key locations in Virginia are given in Appendix B, page B-6.

The R value was derived after analyses of over 8,000 plot years of data. It reflects locational differences due to total erosivity and distribution of erosive rains. The analysis of data ruled out the conclusion that significant soil loss is associated with only a few rare storms. The results of more than 30 years of measurements show that annual soil loss is the result of the cumulative effects of many moderate sized storms plus the effects of the occasional severe storms.

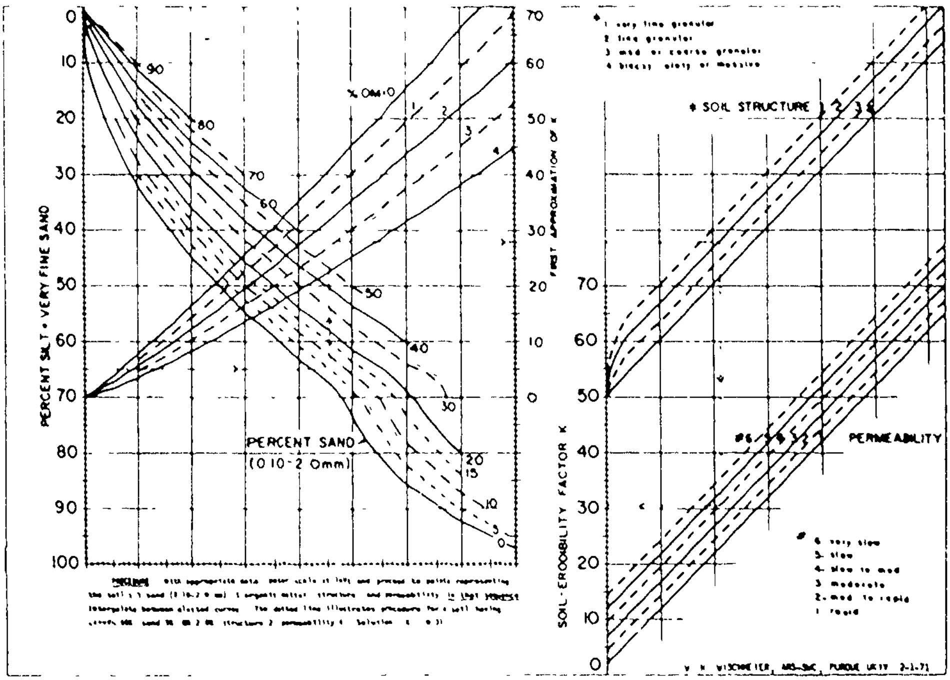
Research data show that when other factors are held constant, the soil losses per storm are directly proportional to the product of the total kinetic energy of the storm times its maximum 30-minute intensity (Erosion Index - EI). This erosion index reflects the combined ability of raindrop impact to dislodge soil particles and of runoff to transport the dislodged particles from the field. The term 30-minute intensity means the intensity of the 30-minute period with the greatest average intensity of a storm. It can easily be obtained from a recording raingage. It is in inches per hour. The energy of a storm can be computed from data on a recording raingage chart and tables of rainfall energy.

The usual R factor is the average annual value of the erosion index. Appendix B, page B-7, indicates R value probabilities for R values that might occur one year in five, and one year in twenty. Although R is the average annual value, data is available so that the erosion index for any part of the year can be determined. Appendix B, page B-7, also gives the percentages of the annual R which occur in each month.

The soil erodibility factor K for a particular soil is the rate of soil loss in tons per acre for one unit of erosion index from standard plot. Standard plots are 72.6 feet long and 6 feet wide. The K value is the only quantitative value in the equation. The first K values were determined for 23 major soils on which plot studies were conducted. K values for most other soils were estimated by comparing their characteristics with those of the 23 soils on which K had been established. In 1971, Wischmeier presented a nomograph for the determination of K. (Ref. 4) This was referred to in the previous unit when describing the soil properties which influence erodibility. The K values for Virginia soils are given in Appendix B, pages B-8 to B-26 for named soils. For determining K on other soil materials the nomograph, Figure 12 is used.

To use the nomograph, you will need the following data: (1) % silt + very fine sand (.002 to 0.1 m.m.); (2) % sand (0.1 to 2.0 m.m.);

Figure 12. Soil Erodibility Nomograph



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(3) % organic matter; (4) type of soil structure * (Code 1-very fine granular, Code 2-fine granular, code 3-medium or coarse granular, and

* Structure is the arrangement of the primary soil particles into lumps, granules, or other aggregates. The structure is often described as weak, moderate, or strong to express the durability of the aggregates, but this characteristic is not represented in the nomograph. The size of the aggregates are described as very fine, fine, medium, coarse, and very coarse. Aggregate shape is described as granular, platy, or blocky. Structure-less soils, in which the particles are coherent, are described as massive.

Code 4-blocky, platy, or massive); and (5) permeability (1-rapid, 2-moderate to rapid, 3-moderate, 4-slow to moderate, 5-slow, 6-very slow). Refer back to Figure 10 for chart of texture sizes in various soil classification systems.

The five parameters used in the nomograph can be obtained from routine laboratory determinations and standard soil profile descriptions. If you are using USDA mechanical analysis data, adjust them by subtracting the percent of very fine sand from the sand fraction and adding it to the silt fraction. All data should be for the upper 6" to 7". This would be the newly exposed layer on graded areas. Enter the nomograph with percent silt plus very fine sand on the vertical scale at the left. Proceed horizontally to intersect the correct percent sand curve (for values falling between the curves make a linear interpolation), then move horizontally to the right. If the structure is fine granular and the permeability moderate, the K can be read from the "first approximation of K scale" on the right-hand margin of the nomograph. If structure is other than above, proceed across to the appropriate structure curve in the second section and vertically downward to the appropriate permeability curve, then horizontally to the left to the K scale. The nomograph has proven to be very accurate when checked against actual field measurements of K.

Slope length is the distance from the point of origin of overland flow to either the point where the slope gradient decrease enough to cause deposition or to a point where the runoff enters a well defined channel. The slope gradient is in feet fall per hundred feet (percent). In the equation, length L and slope S are handled as one factor, LS. It can be obtained from Appendix B, Table 1, page B-1. Measure actual slope length and grade from the area under consideration in the field. It would be satisfactory to pace off the slope length and measure the percent of slope with an Abney level. Obtain the LS factor from the body of the table opposite the percent slope and in the column under the slope length. The LS factor is the expected ratio of soil loss per unit area on the field slope to the corresponding loss from the standard plot on 9% slope 72.6 feet long.

With the factors discussed thus far, an estimate can be made of soil loss on bare construction sites. For example:

For a site location in Rockingham County R = 150 (Appendix B, p. B-6). Soil is Duffield, surface horizon, from Appendix B, p. B-14; K = .32. The slope is 200 feet long and 10% gradient, from Appendix B, Table 1, page B-1, LS = 1.94

For bare soil C and P are unity.

$A = RK(LS)$
$= 150 \times .32 \times 1.94$
$A = 93.12$ tons per acre

Assume that this same area was going to be bare only from June to

August 30.

From Appendix B, page B-7, under "Mountains & Valleys" June has 20% of annual R, July 25%, and August 17%; or 62% for the three months. Sixty-two % of 150 = 93.

A = 93 x .32 x 1.94
= 57.7 tons per acre (Note: This is the most erosive period of the year.)

In the second example above, if mulch at 2 tons straw per acre is to be applied to the area and anchored immediately after the vegetation is removed, the losses would be:

A = R K(LS)C
= 93 x .32 x 1.94 x .05 (C value from Table 2d., page 6a.)
= 1.73 tons per acre

Erosion can be estimated in the same manner as above when surface conditions will change during the time period you are dealing with. If an area is to be bare one month before seeding and mulching, calculate the soil loss using RK (LS) only. The R value must be calculated by taking the percentage of total R which occurs in that month from Appendix B, page B-7. For example, if August is the month, 17% of 150 = 25.5 = R for August. The R for the remaining time period that you are concerned with must be obtained in the same way, and the C factor for mulch is obtained from Appendix B, page B-5, Table 2d.

When conservation practices, such as diversions or interceptor dikes are used, they simply alter the slope length. The C values for mulches, given in Table 2d. of Appendix B, should be used on slopes below 10%. There is evidence which indicates that higher C values should be used on slopes above 10% grade. Also, as slope length increase above a certain maximum level, the C value rises rapidly. Tentative values of C proposed by Wischmeier are given in Table 4.

The equation will have many uses in evaluating the erosion hazards on construction sites. If K values are needed for soil material below the depths given in Appendix V, they can be easily determined by a soils technician from 4-inch diameter soil cores taken at the site. The K can be obtained, using the nomograph. Having this information, it may be possible to adjust planned depths of cuts to terminate either above or below highly erodible layers. The relative advantages of slope shapes may be determined by erodibility of the exposed material. Decisions on whether topsoiling is needed may rest on

Table 4. Tentative Values Of C For Various Mulches And Slope Conditions

Mulch	Ton	Slope	C Value	Maximum Slope Length
	Tons/Ac.	%		Ft.
Type				
1. None	0	All	1	---
2. Straw or Hay 1/, tied down by anchoring or tracking equipment across slope	1.5	3-5	.12	300
		6-10	.12	150
	2.0	3-5	.06	400
		6-10	.06	200
		11-15	.07	150
		16-20	.11	100
		21-25	.14	75
3. Crushed Stone	60	15	.17	---
		20	.17	---
	135	15	.05	200
		20	.05	150
4. Woodchips	7	15	.08	75
		20	.08	60
	12	15	.05	150
		20	.05	100

1/ If straw is not anchored, rilling may occur beneath it. In such a case, C values should be doubled.

2/ As lengths are increased beyond these limits, the C value would rise rapidly and approach a value of 1. This would greatly increase the predicted loss.

erodibility of the exposed layer.

Check your grasp of the Universal Soil Loss Equation by answering the following questions:

1. Write the Universal Soil Loss Equation.

2. Name and explain each factor in the equation.

3. Determine the soil loss for each of the following situations:

   a. A ten-acre construction site in Loudoun County is to be graded March 1, and will be under construction one year. The soil type is Glenelg. The slope is 10% and the slope length is 350 feet. Grading will not exceed 2 feet in depth. What is the estimated total soil loss from sheet and rill erosion if left bare the whole year?

b. If the area was left bare until May 1, then mulched and a temporary seeding made, what would be the soil loss?

c. What would the soil loss be if 1/2 the area were graded 3 feet deep and the whole area remained bare?

Summary:

The Universal Soil Loss Equation is A = R K L S C P.

A is the soil loss in tons per acre from sheet and rill erosion.

R is the rainfall factor. It is the number of erosion index units in a year's rain. The erosion index is a measure of the erosion force of a specific rainfall.

K is the soil erodibility factor. It is the erosion rate in tons per acre for each unit of the erosion index (R) for a specific soil in cultivated continuous fallow on a 9 percent slope 72.6 feet long.

L is the slope length factor. It is the ratio of soil loss from the field slope length to that from a 72.6 feet length on the same soil type and gradient.

S is the slope gradient factor. It is the ratio of soil loss fror field gradient to that from a 9 percent slope.

C, the cropping-management factor, is the ratio of soil loss with specified cropping or vegetation and management to that from continuous fallow.

P is the erosion control practice factor. It is a ratio of soil loss with a specified practice to that from straight-row cultivation up and down slope.

The soil loss from a ten-acre site left bare from March 1 for a full year would be: (C and P are unity)

A = R K (LS) x 10 acres = 150 x .32 x 2.55 x 10 = 1224 tons

If the area was bare from March 1 to May 1 then mulched and seeded:

A = R K (LS) C for March and April

R for March and April is 10 percent of annual or 15

A = 15 x .32 x 2.55 x 10 = 122.4 tons

For May through February:

A - R K (LS) C

where R is for May through February = 135

where C is 05

A = 135 x .32 x 2.55 x .05 x 10 = 55.08 tons

122.4 plus 55.08 = 177.48 tons for year.

If the same area were bare all year and one-half had been graded 3 feet deep, and slope remained 10 percent and 350 feet long:

A = 150 x .32 x 2.55 x 5 plus A = 150 x .43 x 2.55 x 5

= 612 plus 822.37

= 1434 tons.

These problems illustrate the versatility of the equation. In actual practice, in part two of the problem, the C factor for May through February would be slightly lower. The 0.05 would prevail while the 2.0 tons of tied down mulch was the sole protection. Vegetation would begin to improve the cover after the first month so that a C of about 0.02 would be applicable -- probably in about two months.

Unit 3 Channel Erosion and Storm Water Management

Purpose and Significance:

This unit covers some aspects of channel erosion, and some of the effects of urbanization on channels. These effects are described and illustrated.

A knowledge and an appreciation of the factors affecting stream channel erosion and of how urbanization influences runoff is essential in making a reasoned response to the storm water management requirements in the Virginia Erosion and Sediment Control Program. This unit deals with the general changes that occur with urbanization. It discusses the direction of these changes. Methodology for determining the magnitude of these changes will be covered in Part III.

Objectives:

1. List abuses, which often occur with development, which cause channel erosion.

2. List the flow characteristics which cause channel erosion.

3. Refer to the factors which affect volume of runoff (Objectives under Erosion Process) and explain how runoff volume changes might affect channel erosion.

4. List the factors which determine velocity of runoff in channelized flow.

5. List factors which determine turbulence of flow.

6. Explain how urbanization affect volume and velocity of runoff, travel time, time of concentration, and peak discharges.

Content:

This unit is concerned with the erosion and sedimentation which occurs in the well defined permanent watercourses both on the development site and off site.

Some of the most damaging channel erosion is caused by the construction activities. In the relatively stable small streams, the upper portion of the banks become fairly well vegetated. This vegetation protects the banks from flows which are higher than the normal flow. Vegetation along the floodplain also provides protection. It protects by slowing the runoff which comes from the adjacent land and spills over the banks and into the stream. Careless construction activities may destroy the bank and floodplain vegetation and leave the banks vulnerable to erosion. General construction trafffic may cause damage if allowed too near the banks. Careless grading, unprotected stream crossings, and other activities which destroy the vegetation on and near the banks will lead to erosion damages. Also, temporary construction roads or other works may concentrate runoff, bringing it into the stream in such a way as to cause erosion.

The changes which usually occur after urbanization are described by Guy. (Ref. 10) Urban construction is usually followed by a period of rapid channel erosion if no control measures are installed. Channels, which prior to development were relatively stable, have been observed to completely unravel during the first few years after development. It is the tremendous potential for damage, the causes, and possible cures that will be examined.

Channel erosion was defined in the unit on the erosion process. It is essentially the same process that occurs in rills and gullies. Flowing water is both the detaching and transporting agent. The detaching capacity of the flowing water is determined by its velocity, turbulence, and by the amount and type of abrasive material that it carries. If the flow is already carrying sediment up to its total capacity, it will not be able to detach and carry more from the particular reach of channel under consideration. Since urban development is usually followed by a period of rapid stream or channel erosion, some of the above factors presumably are changed by urbanization.

Figure 13. Urbanization Has Typically Provided For Rapid Conveyance Of Storm Drainage

(This structure will handle water safely on this site, but may cause higher and more hazardous peak flows downstream.)

Leopold discusses the relationships between land uses and stream channel characteristics. (Ref. 11) He points out that stream channels form in response to the regimen, or characteristic behavior, of the flow. The two principal factors governing changes in the characteristic behavior of the flow are the percentage of the area made impervious by urbanization and the changes brought about in conveyance of water from the developed area through provisions for storm drainage. Urbanization greatly increases the impervious area, and it usually provides for rapid conveyance of storm runoff to the point of disposal. These changes influence the number of times that the normal flow rises in response to runoff. They influence the peak discharge and discharge duration from these events, and they may change the amount of sediment carried by the rises in flow.

The volume of runoff is related to types of cover, land slope, and infiltration capacity of the soil. Volume is directly related to the percentage of the area covered by impervious material such as streets, parking lots, and roofs. Leopold summarizes some data on the relationship between lot size and percentage of impervious area for residential areas:

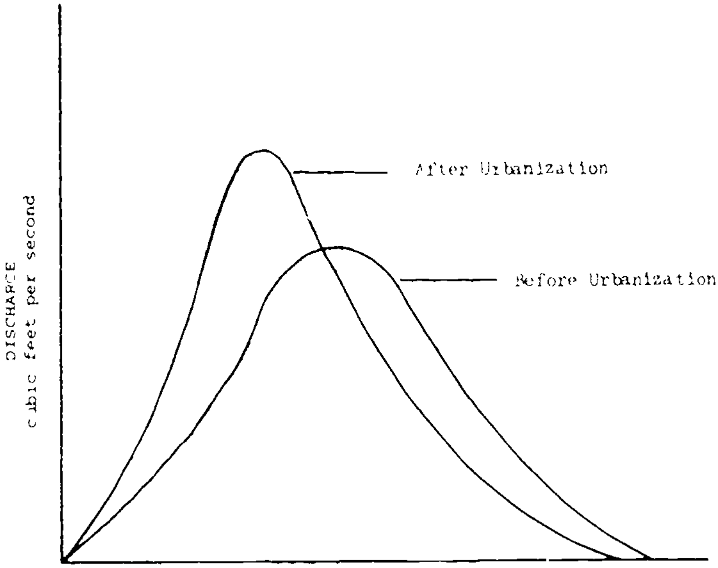
Lot Size (Sq. Ft.)	Impervious Surface Area (%)
6,000	80
6,000-15,000	40
15,000	25

The percentage of impervious area may drop below 8 percent for developments of [illegible]-acre lot size.

The increased volume of runoff which results from various percentages of impervious area obviously causes increases in flood peaks. Typical differences between runoff from an area before and after urbanization is presented graphically in Figure 14.

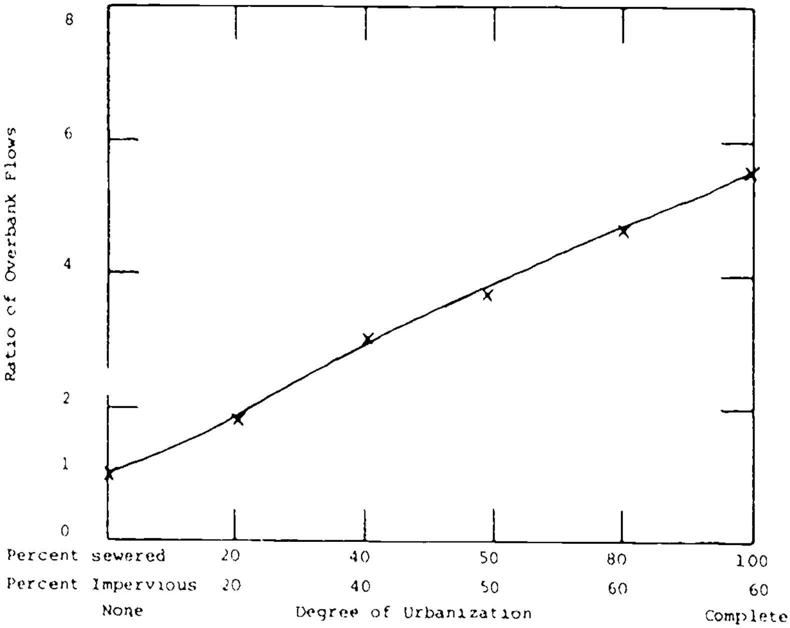
It was mentioned earlier that stream channels change in size in response to the characteristic behavior of the flows. Studies have shown that they cut and maintain channels which carry a discharge slightly smaller than the average annual flood without overflowing the banks. The recurrence interval of this bankfull flow in most rivers is between 1-1/2 to [illegible] years. Since urbanization tends to increase flood potential from the affected area, the recurrence interval of bankfull flows will be more often than 1-1/2 to 2 years. Leopold estimates that [illegible] percent of a one square mile drainage area

Figure 14. Hypothetical Unit Hydrographs, Before And After Urbanization



sewered, and 20 percent impervious cover, bankfull stage would then occur about two times a year. With 50 percent sewered and 50 percent impervious, it would be nearly four times a year. Figure 15 illustrates these changes.

Figure 15. Increase in number of flows per year equal to or exceeding original channel capacity (one square mile drainage area), as ratio to number of overbank flows before urbanization for different degrees of urbanization. (From: U. S. Geologic Survey Circ. 554)



The increased number of bankfull flows and nearly bankfull flows cause the original channel to erode. It will continue to adjust to the changes until a channel that will handle the new average annual flood is formed. Leopold illustrates this using a slightly less than one square mile drainage basin in the Brandywine River Watershed in Pennsylvania. Before urbanization, a channel carrying 55 cfs at bankfull stage would handle the average annual flow. Urbanization could cause this flow to increase 2.7 times or 150 cfs. The channel would adjust in keeping with the new flow characteristics.

	Before	After
Size of Channel	2 ft. deep, 11 ft. wide	3 ft. deep, 2 ft. wide
Velocity	2.5 ft./sec.	2.5 ft./sec.
Capacity	55 cfs	150 cfs

If such an adjustment takes place in one mile of channel, the erosion would produce 10,000 tons of sediment.

The adjustment in channels takes place because of the increase in the number and size of high flows. Velocity is higher for these flows than for pre-urbanization flows, and since turbulence increases with increased velocity, it is also higher. The channel adjusts in size until the number of these erosive events is about the same as before urbanization.

In addition to the devastating erosion and sediment problem, there are other damaging aspects to this channel enlargement. The increase in direct runoff and decrease in infiltration mean less ground-water recharge to sustain low flows between the rainfall periods. This maladjustment causes a very unsightly channel during low flows. Erosion has denuded the banks, and the bed is apt to be muddy and full of debris. The effect on aquatic life is to decrease numbers and variety.

All of these damages point to the need for measures which will counteract the effects of urbanization. The measures should increase infiltration to the extent possible and provide flood storage and controlled release to maintain the pre-urbanization flow characteristics as much as possible.

Practices which increase infiltration are: the use of swales along streets for water disposal instead of paved gutters and curbs; the use of cluster development, planned unit development, and other arrangements which provide the planned number of housing units with a minimum of rooftops and paved areas; and the use of pervious paving materials. Both underground and surface storage facilities of various types can be used to store excess runoff. Release facilities could control the flow to keep it to the level which prevailed before development.

Read pages 1-1 to 1-4 of Appendix C, USDA, Soil Conservation Service Technical Release No. 55. Then test your grasp of this unit with the questions below.

Questions:

1. Briefly describe some construction practices which are often damaging to stream channels during construction.

2. Name the flow characteristics which cause channel erosion.

3. Explain how changes in the volume of runoff might affect channel erosion.

4. Name the factors which affect velocity of runoff in channelized flow.

5. List the factors which determine turbulence of flow.

6. Explain how urbanization affects volume and velocity of flow in channels.

Summary:

Construction activities which destroy streambank and adjacent vegetation or bring in concentrated flows at unprotected points will cause stream channel erosion. Uncontrolled traffic, careless grading, the use of unprotected crossings, and other activities which destroy vegetation are examples of these destructive construction practices.

The flow characteristics which cause erosion are velocity and turbulence of the flow plus the amount and type of abrasive material in the flow. The increase in volume of runoff from urbanized areas causes higher peak flows in the channels and hence higher velocity. Since turbulence also increases with velocity, it adds to the erosiveness of the flow. The number of high flows per year also increases so the channel is not only subjected to higher velocities, but also more often during the year.

Depth of flow, gradient, and roughness of the channel bed and banks determine velocity of the flow. The depth of flow is the main factor which is increased by development in the watershed. If the channel is realigned or smoothed during development then the grade and roughness may be affected. Straightening the channel would increase the grade and hence the velocity and smoothing would reduce the roughness or retardance and thereby increase the velocity.

Turbulence increases with velocity and with increased roughness in the channel.

Urbanization increases the volume of runoff by covering part of the watershed with impervious streets, roofs, and parking areas. Gutters and storm sewers hurry the runoff to the channel. The chief reason for increased volume is the impervious cover. Velocity is higher in the flows of increased depth, and it will also increase if the runoff is flowing over smoother surfaces than it did prior to development.

Unit 4. The Sedimentation Process

Purpose and Significance:

This unit discusses sources of sediment, transport, yield, and deposition of sediment. Transporting capacity will be related to characteristics of the material transported and characteristics of the transporting flow. The factors governing the deposition will be discussed and related to types of sediment material.

A knowledge of all of these items is essential to the development of a complete erosion and sediment control plan. It is particularly important in planning and designing the second line of defense in the system, the sediment control practices.

Objectives:

1. Indicate the sources of sediment, and discuss the relationship between source and size of material.

2. List the factors which determine the sediment load.

3. Describe the behavior of the various sizes of soil materials in a flow.

4. Explain how sediment is deposited.

Content:

Sedimentation includes erosion, transportation, and deposition of sediment. The first unit in this part discussed the erosion part of the process. In this unit, our main concern with erosion is as the source of sediment.

Sediment is transported as suspended material in the flow, as material bounced along the bed and as material which slides and rolls along the bed. As one would suspect, the suspended load is made up of the very fine materials. Clay and colloids are generally evenly distributed throughout the flow. Silts are more or less evenly distributed in turbulent flow, but have a tendency to be more concentrated near the bottom. Sands and larger material bounce, roll, and slide along the bed. These are referred to as the bed load.

The nature of the sediment is primarily determined by the source. Splash erosion and associated sheet erosion remove fine materials. These materials are carried as suspended load. This material, particularly the clay, stays in suspension for long periods of time. The amount of the very fine material moving in a flow is related to the rate of supply of the material. It is seldom present in amounts equal to the carrying capacity of the flow The amount of these materials supplied depends on the soil material make-up, the resistance to detachment, and the detaching capacity of the erosive agent

The amount and type of bed load are related directly to the flow. The movement of bed load tends to be in balance with flow conditions. This has an important bearing on channel stability. If the flow becomes loaded beyond its transporting capacity deposition occurs. However, if the load is less than the transporting capacity, the flowing water attacks the channel in an effort to achieve the balance between load and capacity. Any change in sediment load or in flow characteristics will have an effect on channel stability. Velocity, turbulence, and the size and type of materials available are the primary factors determining the sediment load.

Deposition of sediment is the inverse of erosion. It occurs when the carrying capacity of the flow is reduced until it is less than the sediment load. When flow is diminished, the coarser fragments are deposited first. As it continues to diminish, smaller and smaller particles are deposited. Deposition, like erosion, is a selective process which results in a gradation in the size of material in sediment deposits.

Sediment deposits may occur on land or in various forms in bodies of water.

Deposits can occur on land when the runoff from slopes reaches more gently sloping land. The runoff loses velocity and hence the capacity to carry the sediment load. Runoff flowing from bare to vegetated areas will also lose carrying capacity and deposit some of its load.

Deposits occur in water as a faster flowing stream flows into a slow moving one or into a pond, lake, reservoir, or ocean. A stream reaching a lower gradient channel will also lose carrying capacity and form deposits if the load it is carrying exceeds the new carrying capacity

To develop adequate sediment control we need to know the source, amount, and nature of the sediment. If the sediment is mainly from splash and associated sheet erosion, then land treatment is the most appropriate control Sediment traps and basins are much less efficient in trapping the very fine material from this type of erosion. If the material is mainly coarse material from gullies and channels, there are two ways to control the erosion. One is to alter the flow characteristics by reducing grades, widening cross sections, and reducing turbulence, or by reducing the flow with the use of reservoirs. The other is to provide some protective cover to the channel banks and, perhaps, to the bed.

When erosion cannot be controlled at its source then sediment may be removed from the flow before going off-site by the use of sediment traps or sediment basins.

Questions:

1. What is the primary source of the clay and silt materials in the sediment load? Of the sands and coarser materials?

2. What factors determine the sediment load?

3. Describe the behavior of the various sizes of material in a flow.

4 Explain why, how, and where sediment is deposited.

Summary:

The primary source of clays and silts is from splash erosion This erosion process is very selective Coarser materials usually come from gullies and from channel banks and beds.

The amount of sediment, or sediment load, depends upon the energy of the moving water. Energy increases with increased velocity. Velocity increases as gradient increases, as depth of flow increases, and as channel roughness decreases.

Colloidal materials, such as clay, remain suspended in the flow and move along as a part of it. Silts may be suspended throughout the entire depth of turbulent flow, but tend to be more concentrated near the bottom. Sands and coarser materials usually bounce, roll, and slide along the channel bed.

Sediment is deposited as the flow loses its energy. This happens when a flow spreads out into a more shallow flow at the same grade, when the grade is reduced, and when the flow enters a pond, lake, or other still body of water.

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PART III CONTROL

Unit 1. Principles of Erosion and Sediment Control

Purpose and Significance:

The principles which are basic to the planning and carrying out of effective erosion and sediment control are presented and discussed. Principles are in two major categories. First are the principles which guide the sequence and breadth of the program for any given site. Second are the specific "how to do it" principles of erosion control and sediment control.

The principles relate directly to the things which you have already learned about the erosion and sedimentation process. They are based on the need to neutralize the force of erosive agents and of transporting agents.

An understanding of these principles and of the fundamentals of the erosion process will give you the basic knowledge you will need in developing an erosion and sediment control plan.

Objectives:

1. Name and be able to describe the three over-riding principles which guide the development of an erosion and sediment control plan.

2. Name five principles for the control of erosion.

Content:

There are three over-riding principles of erosion and sediment control which provide the basis for all of your plan and design work. These should become so ingrained as to provide a basic approach on each development project.

The three principles are:

1. Erosion control is fundamental to the whole program and must be the first line of defense.

2. Sediment control is a backup for the erosion control measures and the second line of defense.

3. Coordination of erosion control, sediment control, and control or management of the flow of water leaving the site to get a complete well-integrated program.

That erosion control is the first line of defense logically follows what we have learned about the erosion process. If there is no erosion there can be no sediment. Control at the source of material prevents both erosion damages and sediment damages. In some instances it may be the only way to have an acceptable level of control of the very fine sediments. In many instances, in field situations, it will be impossible or impractical to impound water laden with this fine material for long enough periods for it to settle out.

Sediment control is the second line of defense. It provides a backup when all possible erosion control measures have been utilized. Sediment should be filtered out of the runoff water or allowed to settle out before the runoff leaves the site. Care must be taken so that runoff released from the site will not cause channel erosion and sediment damage downstream.

These lines of defense must be coordinated to achieve the most effective level of protection. This calls for coordination of erosion and sediment control items and coordination of these with the overall plan for the development. Erosion control will seldom if ever be completely effective during construction. It must be backed up by adequate provisions for trapping sediment before it leaves the site. To insure against downstream damages an evaluation must be made to determine what is needed to counteract the higher runoff which will occur after development. Facilities should be provided to reduce the damages which could occur. Erosion and sediment control must be planned along with the total plan for the site. If this is not done during or along with the planning for the total development, you will be left with limited, costly, and unsatisfactory options for erosion and sediment control.

There are several "how to" principles of erosion control The first is to fit the specific land uses, including that used for water management, to the natural features of the site, such as soils, topography, vegetative cover, and the natural drainage system. Avoid exposing steep erodible soils to rainfall and runoff. Protect drainageways, streams, and other vulnerable areas during construction. Keep disturbance of critical areas to a minimum.

Second, protect bare soil from raindrop impact. Keep both the area of soil exposed and the length of time that it is exposed to an absolute minimum. Temporary mulches and seedings should follow grading wherever possible. Jobs should be done in stages so that both time of exposure and area exposed are kept to a minimum. Jobs can also be staged to avoid the periods of most erosive rains.

Third, maintain the infiltration function of the land to the extent possible. Choose layout and designs to minimize the amount of impervious areas. Retain areas of unique natural vegetation whenever possible. Keep compaction due to traffic and construction machinery to a minimum except where compaction is specified for some structures as a means of improving their stability. Don't confuse firming an area to improve it as a seedbed with compaction. The latter would be excessive for seedbed purposes and would greatly increase runoff.

Fourth, keep runoff velocities low. Use mechanical measures to shorten slopes. Avoid unnecessary creation of steep gradients.

Fifth, protect disturbed or bare areas from runoff which is generally off-site or on-site areas above the disturbed areas.

Sixth, control sediment at the development site perimeter by retarding runoff and filtering or trapping sediment. Vegetative and mechanical measures combine to slow runoff in level spreaders and grassed waterways. Mechanical measures such as gravel outlet structures, sediment basins, and sediment traps slow or hold runoff and allow sediment to settle out.

Seventh, control the release of excess stormwater runoff which is generated by the development to prevent channel erosion both on the site and downstream from it.

Questions:

1. Name each of the three guiding principles for developing an erosion and sediment control plan. Explain each.

2. Name five principles for the control of erosion and sediment.

Summary:

Erosion control is the first line of defense in an erosion and sediment control system. Controlling erosion means taking the energy out of erosive forces before they can dislodge and transport soil. If the measures taken here are effective enough, sediment control may not be needed.

Sediment control is the second line of defense. It provides a backup for the erosion control practices. Runoff water should be retarded for long enough periods to allow the sediment to settle out.

Coordinating erosion control, sediment control, and stormwater management with each other and with the specific land use and development plans is the third guiding principle.

The "how to" principles of erosion control include:

1. Fit the development to the natural features of the site, avoiding disturbance of very erodible soils.

2. Protect bare soil from raindrop impact by limiting size and duration of exposure.

3. Maintain the natural infiltration function of the land by minimizing extent of impervious areas and by using measures which prevent sealing of the soil surface.

4. Keep runoff velocities low by mechanically shortening slopes or by keeping gradients low.

5. Protect disturbed or bare areas from runoff which is generally off-site.

6. Control sediment at the development site perimeter by retarding runoff and trapping sediment.

7. To prevent channel erosion downstream, control the release of excessive stormwater runoff which is generated by the development.

Unit 2. Control Measures

Purpose and Significance:

This unit presents a discussion of all of the erosion and sediment control practices which are used in the Virginia Erosion and Sediment Control Program. It includes detailed study of the Standards and Specifications for practices in Appendix A, the Virginia Handbook. Practices are related to the particular principles that they help to satisfy.

In addition to the approved practices, planning techniques which help to satisfy the principles are also discussed.

The name, purpose, and applicability of each practice must be understood in order to use them properly in an erosion and sediment control plan. This means knowing the limitations of each practice as well as you do their strength. This unit on practices and specific planning techniques should be mastered before we are ready to discuss the planning process and the development of an erosion and sediment control plan.

Objectives:

1. Name each practice in Appendix A, the Virginia Handbook; which provides protection by protecting bare or disturbed areas from raindrop impact. Give the stated purpose and conditions where applicable for each.

2. Name each practice which helps control erosion by keeping runoff velocities low. For those not included in Objective 1, give the stated purpose and condition where applicable.

3. Name the practices which help to maintain the infiltration capacity of the soil. For those not named under 1 and 2, be able to give the purpose and conditions where applicable.

4. Name the practices which help to reduce or control the release of runoff from the site and give the purpose and conditions where applicable for each.

5. Name the practices used to filter and trap sediment before it leaves the site and give the conditions where applicable for each.

6. Describe planning techniques or procedures which would:

(a) Limit area and duration of bare soil exposure.

(b) Maintain infiltration capacity.

7. Using Appendix C, USDA-SCS TR 55, and given appropriate data:

   (a) Use method in Appendix C, Chapter 2, and compute runoff volume.

   (b) Name the parameters used to determine peak rates of run-off.

   (c) Given appropriate data, use the method in Appendix C, Chapter 3, to compute travel time, lag, and time of concentration.

   (d) Given appropriate data, use the methods in Appendix C, Chapters 4 and 5, to compute peak discharges.

Content:

There are several practices in the Virginia Handbook which owe their effectiveness to their ability to protect the soil from raindrop impact. The lowest cost practices are in this category and fortunately they are the most effective in controlling erosion. The practices are listed below and the page number in the Handbook is cited. Read the Standard and Specification in the Handbook carefully and be sure to learn the purpose and conditions where applicable for each practice.

Practices which protect soil from raindrop impact (pages cited are in Appendix A):

1. Disturbed area stabilization (with mulching only) page III-114.
2. Disturbed area stabilization (with temporary seeding) III-116.
3. Disturbed area stabilization (with permanent seeding) III-120.
4. Disturbed area stabilization (with sod) III-131.
5. Disturbed area stabilization (with Bermuda grass) III-135.
6. Disturbed area stabilization (with ground covers) III-139.
7. Tidal bank stabilization (vegetative) III-141.

Also read Appendix A, pages III-3 and III-4 down to Mechanical Practices.

Figure 16. Straw Mulch At Two Tons Per Acre

In addition to the practices listed above, there are several planning techniques and development procedures which minimize the size of area of bare soil exposed to raindrop erosion and limit the duration of exposure.

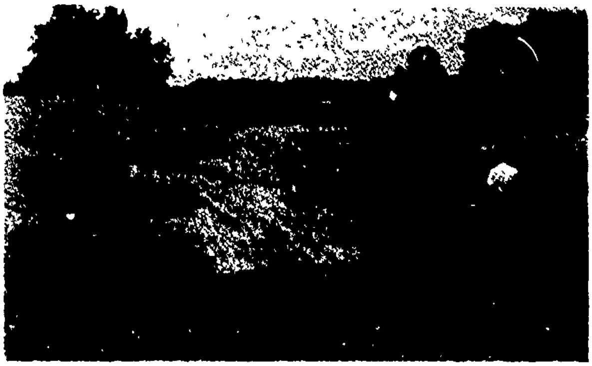
1. Make erosion and sediment control planning a part of the total planning job and choose a layout which will meet the development objectives with the least disturbance of the site. Layouts such as clusters and planned unit developments will provide density equal to conventional development with a much lower percentage of disturbed area.

2. Stage the grading and construction activities to limit the area disturbed at any one time.

3. To the extent possible, schedule operations so that hazardous areas are not exposed during the months with highly erosive rains.

4. Schedule temporary practices such as mulching and temporary seedings to immediately follow rough grading. See Figure 17. Seed is often applied through blower along with mulch.

Figure 1''. Mulch Applied By Machine



5. Provide designated and protected areas to handle construction traffic and equipment. Avoid traffic up and down slopes, along drainageways and streams, and over unprotected stream crossings.

The above practices should receive first consideration in developing an erosion and sediment control plan. They may be all that is needed on many sites. They definitely fall into the category of first line defense.

The second group of practices which should be considered are those which function to keep runoff velocities low. Read Appendix A, pages III-4 to III-8 and the cited Standards and Specifications.

Figure 18. Mulch Should Be Anchored

All of the mulching and vegetative practices listed above help keep runoff volume and velocity low by favoring infiltration and by retarding runoff. Mulch must be anchored to be effective in slowing runoff.

1. Land grading - Appendix A, page III-53.

This practice should be used only after careful study of the site, and care should be taken not to expose highly erodible materials. Grading should usually be held to a minimum both in area and depth. Long grades should be done in stages so that the entire slope is not exposed at one time. It functions to eliminate areas of excessive concentration of flow or even by removal of smaller irregular areas where potential for gullying exists.

2. Temporary Diversion Dike - Appendix A, page III-11.

This must be used in conjunction with a stablized area which will provide a safe outlet.

3. Temporary Interceptor Dike - Appendix A, page III-14.

Must be used in conjunction with a safe outlet. Both the temporary diversion and the interceptor function by shortening the slope. You can check the effect by using the USLE to estimate soil loss with and without.

4. Temporary Straw Bale Barrier - Appendix A, page III-20.

Note that this practice is used only when there is a very small contributing area, and there is no concentrated flow.

5. Temporary Level Spreader - Appendix A, page III-25.

This practice must be used only where the area which receives the flow is well vegetated and has a configuration such that water will not reconcentrate.

6. Waterway or Outlet - Appendix A, page III-28.

The dense vegetation of a waterway provides protection by reducing the velocity of flow near the soil surface.

7. Diversion - Appendix A, page III-33.

Figure 19. Diversions Shorten Slopes

This is a more permanent structure than the diversion dike described on page III-11. It influences erosion by reducing the length of slope, and carrying runoff at a safe grade to a stabilized outlet.

A third group of practices reduces erosion and sedimentation by helping to maintain the infiltration capacity of the soil. These practices can materially reduce the amount of surface runoff and erosion.

1. All of the mulching and vegetative practices described in the first group. These are the most effective practices to prevent sealing of the soil surface.

2. Temporary Level Spreader - page III-25.

3. Topsoiling Disturbed Area - page III-120.

This will serve to increase infiltration when the topsoil material has a higher infiltration rate than the material in the area to be covered. It will also aid establishment and maintenance of vegetation, which will in turn maintain infiltration.

There are several planning techniques and innovations which will help to maintain infiltration in a development.

1. Choose a layout for the development which will minimize the size of the areas to be disturbed by grading and other construction activities. This will also serve to keep the percentage of land covered by roads and driveways to a minimum.

2. Outlet road drainage and other drainage on well vegetated swales where the velocities of flow can be kept within safe limits.

Figure 20. This well vegetated grassed waterway provided protection during construction, and remained as an attractive and functional feature of the development.

3. Use erosion resistant pervious paving materials for parking areas and driveways.

4. Control or restrict traffic and construction equipment to reduce the amount of land which is compacted.

5. Identify the natural recharge areas of a site and design the development to maintain their recharge function.

6. Read Appendix C, Chapter 7, USDA-SCS-TR-55.

The fourth category of practices includes those which manage both runoff on the site and the discharge of runoff from the site. Practices and techniques which maintain infiltration help to reduce the volume of runoff which must be handled.

1. Waterway or Outlet - Appendix A, page III-28. (Also helps keep runoff velocities low.)

(Stone center waterways must use the Standards and Specifications for Riprap to match size of stone to velocity.)

2. Grade Stabilization Structure - Appendix A, page III-38.

3. Temporary Downdrainage Structure (flexible) - Appendix A, page III-68.

4. Riprap - Appendix A. page III-57.

5. Water Storage and Release Facilities.

These practices are not included in the Virginia Erosion and Sediment Control Program. However, the Virginia program does require that an analysis be made of peak runoff with the present use and with the use after development. It is suggested that Appendix C, USDA-SCS-TR-55 be used to estimate the peak after development. Storage and release facilities may be required by local ordinances. Where analysis indicates that the new runoff peaks will cause excessive channel erosion, control facilities should be provided. Study Appendix C, Chapter 2 through 6

Protect vegetation in drainageways and stream channels and along both sides of the channel. Where crossings are necessary, provide culverts or otherwise protect the crossing.

The fifth category of practices are those used to remove sediment from runoff water.

1. Temporary Gravel Outlet Structure - Appendix A, page III-22.

This is always used in conjunction with and as a part of a diversion dike, interceptor dike, or perimeter dike. It must outlet onto a protected area or into a stable watercourse.

2. Sediment Basin - Appendix A, page III-41.

3. Sediment Trap - Appendix A, page III-49

Figure 21. A Well Constructed Sediment Basin (However, the banks and adjacent area should be mulched and seeded.)

Special purpose practices are discussed in Appendix A, on pages III-7 and 8 of the Handbook. (See Miscellaneous Practices.)

There are several other practices in the Handbook which were not included in the above categories. They have special applicability, but will be valuable additions to the control program. These practices and the Handbook references follow:

1. Construction Entrance - Appendix A, page III-10

2. Guide for Protection of Trees on Disturbed Areas - Appendix A, page III-153.

3. Guide for Tree Planting on Disturbed Areas - Appendix A, page III-157.

4. Dune Stabilization - Appendix A, page III-148.

5. Subsurface Drain - Appendix A, page III-59.

6. Dust Control on Disturbed Areas - Appendix A, page III-151.

Questions:

1. Name at least six practices which are effective in preventing splash erosion and associated sheet erosion and indicate the conditions where each is applicable.

2. Name six practices (excluding those named in response to Question No. 1) which provide protection by keeping runoff velocities low, and indicate the conditions where applicable for each practice.

3. Name eight measures which help to maintain the infiltration capacity of the land. For those not named in response to Questions 1 and 2, give the conditions where applicable.

4. Name five practices which are used to safely handle runoff on the site and to provide safe discharge from the site. Give the conditions where applicable and the stated purpose for each practice.

5. Name three practices used to remove sediment from runoff water. Give the conditions where applicable for each.

6. Describe the planning techniques or procedures which:

(a) Limit the area and duration of exposure of bare soil.

(b) Help to maintain infiltration.

7. Compute the volume of runoff to be expected from the following watershed:

350 acres, all soils in Group B

40 percent cultivated

30 percent meadow, good condition

30 percent pasture, good condition

4.7 inches of rainfall.

If the above 350 acres was developed with the following uses, what would the runoff be from the same rainfall?

60 percent residential with 1/2 acre lots

20 percent commercial 85 percent impervious

10 percent parks with good grass cover

10 percent paved streets and roads.

8. Solve for Lag and Time of Concentration for present conditions and future urbanized conditions given below: (Use modified curve number method, Appendix C, pages 3-5 to 3-10.)

Drainage area = 500 acres

Hydraulic length of watershed = 7,000 feet

Average watershed land slope = 4%

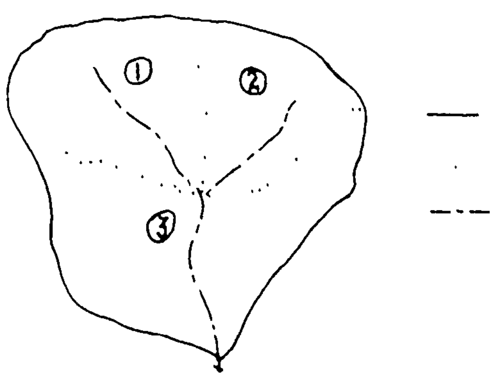
Percent impervious area under future conditions = 30%

Runoff curve number under present conditions = 80, future = 85

Percent of hydraulic length of watershed modified under future conditions = 50%

9. Use the same watershed and conditions as in problem number 3. Compute the peak discharge for the present condition and anticipated future condition for a 100-year 24-hour storm with 6 inches of rain. Use method in Appendix C, Chapter 4.

10. A developer plans to develop sub area 2 in the watershed sketched below. A county ordinance requires that the effect of this development on 100-year peak discharge (P=6") at the downstream end of sub area 3 be included with erosion and sediment control plan.



Sub Area	Drainage Area $Mi.^2$	Time Of Concentration Hours Pres.	Fut.	Runoff CN Pres.	Fut.	Runoff Inches Pres.	Fut.	Travel Time Hours Pres.	Fut.
1	0.35	1.00	1.00	70	70				
2	0.30	1.25	0.75	75	85				
3	0.40	1.50	1.50	75	75			0.75	0.75

Develop discharge summary tables for present and future conditions using Appendix C, Table 5-3. Indicate the peak discharge for present and future conditions.

10a. Use the graphic method and determine the effect on peak discharge of a planned unit development in the upper part of a watershed with the basic data given below:

Drainage area = 192 acres

CN present = 75

CN future = 85

Tc present = 1.25 hr.

Tc future = 0.75 hr

P24 = 6.0 inches (24 hours, 100-year frequency).

Summary:

Practices to reduce splash erosion:

Practice	Condition Where Applicable
1. Disturbed Area Stabilization (with mulching only)	On areas to be bare less than 6 months or where seedings cannot be made.
2. Disturbed Area Stabilization (temporary seeding)	Areas which would remain bare for one year or less before permanent grading and seeding.
3. Disturbed Area Stabilization (permanent seeding)	On bare areas where permanent vegetation is needed.

Practice	Condition Where Applicable
4. Disturbed Area Stabilization (with sod)	On bare areas where quick cover is needed to prevent damage.
5. Disturbed Area Stabilization (with Bermdua grass)	On hot, dry, bare areas and where warm season grass is desired.
6. Disturbed Area Stabilization (with ground covers)	On bare areas where vegetation other than grass is desired.
7. Tidal Bank Stabilization (with vegetation)	On tidal banks where vegetation alone will provide protection, or in conjunction with stuctures.

Practices which help keep runoff velocities low:

Practice	Conditions Where Applicable
1. Land Grading	Where grading will help control erosion.
2. Temporary Diversion Dike	At top or toe of slopes.
3. Temporary Interceptor Dike	Across disturbed right of way and similar areas until they can be permanently stabilized.
4. Temporary Straw Bale Barrier	On very small bare areas - not for concentrated flow. For sheet flow only.
5. Temporary Level Spreader	Where diverted or otherwise concentrated runoff is to be released onto already stabilized areas.
6. Waterway or Outlet	Where concentrated runoff must be carried at controlled velocities to prevent erosion.
7. Diversion	Where length of slope needs to be reduced to prevent damage from runoff from higher areas. To intercept shallow subsurface flow.

Practices which help maintain infiltration capacity of the land are:

Practice	Condition Where Applicable
(The six practices above which reduce splash erosion)	
1. Temporary Level Spreader	(See Above)
2. Topsoiling	Where deeper soil is needed. Where better soil material is needed.

Practices which are used to safely handle runoff on the site and its discharge from the site include:

Practice	Purpose and Condition Where Applicable
1. Waterway or Outlet	To dispose of runoff without causing erosion or flooding. Where channel capacity at controlled velocity is needed to carry concentrated runoff.
2. Grade Stabilization Structure	To convey runoff safely down slopes. Where concentrated flow must be carried over (short) slopes.
3. Downdrainage Structure	To safely conduct storm runoff from one elevation to another. See Above.
4. Riprap	To protect soil surface from erosive force of water. Applicable to waterways and channels.
5. Water Storage and Release Facilities	Where excessive runoff is generated by urbanization and release at or near pre-development rates is essential.

Practices which remove sediment from runoff water are:

Practice	Condition Where Applicable
1. Temporary Gravel Outlet	In conjunction with diversion, interceptor, or perimeter dikes and where there is a need to dispose of sediment laden runoff at a protected outlet.
2. Sediment Basin	Where it is impossible to install erosion control practices to reduce sediment.
3. Sediment Trap	For small sediment producing areas (less than one acre) where it was impossible to keep sediment production to acceptable levels with erosion control practices.

Planning techniques and development procedure which help to maintain infiltration are planned unit development, planned residential development, cluster development, and similar layouts which give the desired density with a minimum amount of impervious cover on the area. Outleting road and parking lot drainage on well vegetated areas where it can soak in is also helpful. The use of erosion resistant pervious paving material will help maintain infiltration. The use of grassed waterways and strips provides some infiltration and slow runoff. Devices such as french drains, perforated pipes, or other porous pipes, and dry well are also helpful. High roughness (coarse) grasses are more effective in promoting infiltration. Note the reference assigned earlier in Appendix C, TR-55.

The Lag for the present condition on the 500-acre drainage area is L = 0.75 and the Time of Concentration is Tc = 1.25 hours, Equation 3-2:

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1900\,Y^{0.5}} = \frac{2000^{0.8}(2.5+1)^{0.7}}{1900\,(4)^{0.5}} = \frac{1191.5\,(2.404)}{3800} = 0.75 \text{ hrs.}$$

$$Tc = \frac{L}{0.6} = 1.67\,(0.75) = 1.25 \text{ hrs.}$$

Lag and Time of Concentration For Future Conditions are:

L = 0.41 and Tc = 0.68 hours

$$\text{Basic } L = \frac{2000^{0.8}(1.26+1)^{0.7}}{1900\,(4)^{0.5}} = \frac{1191.5\,(2.04)}{3800} = 0.64 \text{ hrs.}$$

Adjusting L for impervious = 0.85 (See Figure 3-5.)

Adjusting L for modifications of hydraulic length = 0.75 (See Figure 3-4.)

L = 0.64(0.85)(0.75) = 0.41 hours

Tc = 1.67(0.41) = 0.68 hours

Using the method in Appendix C, Chapter 4, gives the effect of the 100-year rain as 718 cfs for present conditions and 1309 cfs for future conditions.

1. From Table 2-1, "Present Q = 3.78" "Future Q = 4.31"

2. From Appendix C (Appendix D, Sheet 2 of 3), q_p = 190(3.78)=718 cfs

3. From Appendix C (Appendix D, Sheet 2 of 3), q future basic = 215(4.31) = 927 cfs

4. Adjusting for 30% impervious area:

   From Figure 4-1 for CN 85, peak factor = 1.13

5. Adjusting for length of hydraulic modification:

   From Figure 4-2 for CN 85, peak factor = 1.25

6. q_{future} = 927(1.13)(1.25) = 1309 cfs

Here is the completed basic data for Question 10:

Sub Area	Drainage Area $Mi.^2$	Time of Concentration Hours Pres.	Fut.	Runoff CN Pres.	Fut.	Runoff Inches Pres.	Fut.	Travel Time Hours Pres.	Fut.
1	.35	1.00	1.00	70	70	2.80	2.80	--	--
2	.30	1.25	0.75	75	85	3.28	4.31	--	--
3	.40	1.50	1.50	75	75	3.28	3.28	0.75	0.75

Discharge Summaries For Question 10

Present Conditions

Sub Area	T_c Hr.	T_t Hr.	Drainage Area Mi2	Rainfall Inches	CN	Runoff Inches	HOUR 12.7 cfs	12.8 cfs	12.9 cfs	13.0 cfs	13.2 cfs	13.5 cfs	14.0 cfs
1	1.00	0.75	0.35	6	70	2.80	161	197	228	251	268	231	137
2	1.25	0.75	0.30	6	75	3.28	118	146	174	199	231	238	162
3	1.50	0.00	0.40	6	75	3.28	308	309	309	295	264	201	130
Total (Composite hydrograph at end of sub area 3)							587	652	711	745	763	670	420

Future Conditions

Sub Area	T_c Hr.	T_t Hr.	Drainage Area Mi2	Rainfall Inches	CN	Runoff Inches	HOUR 12.7 cfs	12.8 cfs	12.9 cfs	13.0 cfs	13.2 cfs	13.5 cfs	14.0 cfs
1	1.00	0.75	0.35	6	70	2.80	161	197	228	251	268	231	137
2	0.75	0.75	0.30	6	85	4.31	309	359	392	402	370	269	138
3	1.50	0.00	0.40	6	75	3.28	308	309	309	295	264	201	130
Total (Composite hydrograph at end of sub area 3)							778	865	929	948	902	701	405

The effect of development of sub area 2 is to increase the 100-year peak discharge from 763 cfs to 948 cfs.

The graphical solution for peak discharge on the 192-acre watershed with a present condition CN of 75 and future CN 85, a present time of concentration (T_c) of 1.25 hours, and a future time of concentration of 0.75 hours is as follows:

Present Condition:

From Figure 5-2 for T_c = 1.25 hours, peak discharge = 270 csm/inch of runoff.

From Table 2-1 for P24 = 6.0 inches and CN = 75, Q = 3.28 peak discharge (q) = 3.28(0.3)(270) = 266 cfs.

Future Condition:

From Figure 5-2, T_c = 0.75 hours, peak discharge = 390 csm/inch of runoff.

From Table 2-1 for P24 = 6.0 inches and CN = 85, Q= 4.31 peak discharge (q) = 4.31(0.3)(390) = 504 cfs.

The development will increase the 100-year peak discharge from 266 cfs to 504 cfs.

Unit 3. The Planning Process and the Erosion and Sediment Control Plan

Purpose and Significance:

This unit discusses the planning process including setting of development and erosion control objectives, useful inventory data and analyses, consideration for coordinating erosion control with the complete planning job, the selection and design of practices, and the requirements for plans under the Virginia Erosion and Sediment Control Program. The value of planning erosion control along with the other plans for the area is discussed. The data required in an Erosion and Sediment Control Plan have many other uses. These uses are presented for soils and hydrologic data.

An understanding of the above should help you to bring together all of the knowledge you have acquired about erosion and sedimentation and to use this knowledge to develop an effective plan for erosion and sediment control.

Objectives:

1. List three reasons why planning for erosion and sediment control should be part of the overall planning for the development.

2. Describe how erosion and sediment control planning and the planning of the development can be coordinated.

3. List the kinds of information you would need to identify areas of potential erosion hazards. List data required by the Virginia Handbook that is not included above.

4. Given appropriate data for a specific site, delineate potential erosion areas.

5. Given appropriate data for a development, select, locate and design erosion and sediment control practices according to the Standards and Specifications in Appendix A, the Virginia Handbook.

6. Given all the necessary data for a development site, develop an erosion and sediment control plan which meets the requirements in the Virginia Erosion and Sediment Control Handbook. See Appendix A, pages II-7 to II-11.

Content:

It is essential to plan for erosion and sediment control as an integral part of the planning of the development. Decisions which are made in regard to intensity of uses and location of specific uses and facilities will have a substantial effect on erosion and sediment.

One of the strongest arguments for making the erosion control planning an integral part of planning of the development is that you do not destroy your options for placement of the planned improvements or placement of practices and facilities for erosion control. It will not only be difficult but also costly to superimpose erosion control measures after all other improvements have been located. The coordination of all planning retains full flexibility in developing the possible alternative plans.

The second argument is based on the concept that for any development area there is an arrangement of uses that will maximize the net productivity use of the land. Some of the net productivity will be in terms of benefits to the public. Some will be of long time benefit to the property owner. The developer, too, can expect to be reimbursed for a quality development. Degradation of soil resources or water resources which are brought about by a development will result in reduction of values to all those concerned. To maximize these values the possible impacts of various layouts of buildings, roads, water management facilities, and other improvements should be studied.

The third argument for coordination is economic. Careful study of all elements of the development can help avoid costly mistakes. The flexibility of choice mentioned in connection with the first argument is advantageous for economic reasons as well as the technical reasons. The study of soil conditions for erosion and sediment control may also reveal other stability problems that could prove costly if not discovered. Benefits to costs of over 100:1 have been realized by the use of soils information. (Ref. 1) Layouts which favor erosion and sediment control may often reduce the costs of development while still meeting the original objectives for density and use. Cluster development and planned units or planned residential development can mean substantial reduction in sewerage mains and laterals, roads, driveways, and in percentage of the area to be graded and restabilized.

Planning a development, no matter what its size or intended uses, requires that a certain series of steps be followed in order to arrive at the most satisfactory plan for the area. The usual steps in the process are:

Setting objectives

Gathering facts

Interpreting and analyzing the facts

Developing alternative plans

Choosing the most suitable plan

To incorporate erosion and sediment control planning into the planning for the whole development, one must include erosion and sediment control as one of the development objectives.

Objectives or goals for the type and quality of development have undoubtedly been made when the site is acquired. Some goals on the density, variety, size, and quality of residential units or size and diversity of commercial area are probably also tentatively decided at this stage These should be flexible and subject to change in keeping with the potential of the site. Goals which should be considered from an erosion control standpoint, and in fact from a total quality of the environment standpoint are:

1. To accommodate the desired specific uses; i.e., houses, streets, play areas, and so forth with the least possible degradation of the resources.

2. To have safe water management during and after development and thereby protect land resources and water resources.

3. To control erosion and sediment during development and leave the area completely stabilized on completion of work

4. To utilize unique natural features of the site in such a way that they can continue to provide benefits indefinitely.

In gathering the facts which you will need for planning, include all the data needed to evaluate its full potential. This would include facts pertinent to erosion and sediment control as well as those needed in evaluating the site potential for the intended uses. These are overlapping areas of concern. Information needed would include:

1. Information about the soils and geology.

2. Topographic information including contours that will adequately describe the area.

3. Information about the drainage patterns on the site and on surrounding influencing areas. Channel flow and conditions, ponds, lakes, and streams should be included

4. Vegetative cover and condition should be mapped and unique vegetation areas delineated.

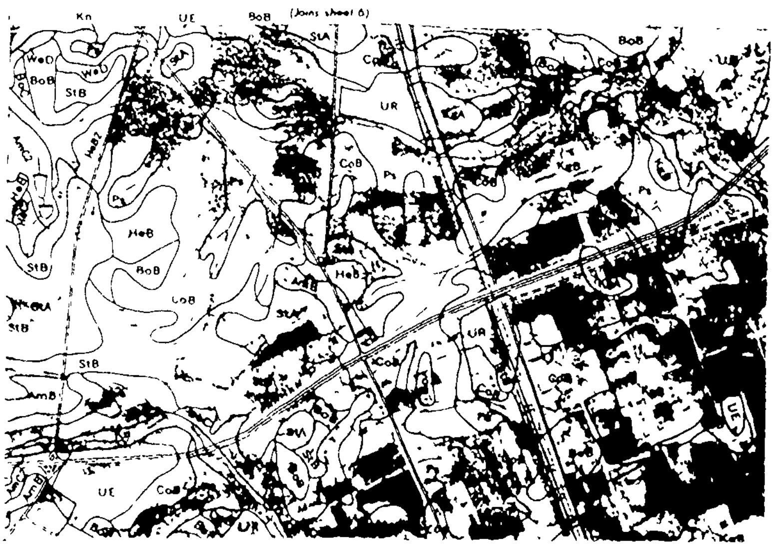
5. Location map of the site relative to streams, highways, and other features.

Compare this list with the data required in an Erosion and Sediment Control Plan as given in Appendix A, on pages II-7 to 11. The above types of information will provide all that is usually needed to complete the items in the plan. The data required is not only important in developing the erosion control plan, but will have broad usefulness in overall planning of the site.

Most of the physical data for planning can be collected and recorded on maps of a suitable scale for planning. This is particularly true for soils, topography, drainage, and vegetation information.

Soil survey maps and detailed information on soils are available in the Soil Survey Reports developed by the U. S Department of Agriculture and the Virginia Polytech Institute for many counties in the state. The same soil will obviously have potential for many uses. It may have limitations which must first be overcome before realizing this potential, but if the practices needed for overcoming the limitations are identified, determining their cost can be part of the evaluation process. The soil survey will provide the facts needed to make these determinations. Let's examine a typical soil survey.

Figure 22. Soil Survey Soil Map



The boundari of each kind of soil are outlined on an aerial photograph by solid lines. There is a symbol for the kind of soil within each delineation if there is enough room; if the delineation is too small, the symbole is outside with a pointer to the area. All areas marked with the same symbol will be the same kind of soil wherever they appear on the map. A guide to these map symbols is included immediately ahead of the map sheets. The symbol itself conveys specific information once the system is understood. For example, the symbol StB appears in the left center of the above map. St designates State fine sandy loam, clayey substratum. The first capital letter in all symbols is the initial letter of the soil name. The second capital letter designates the slope. The B of StB indicates that the slope in the delineated area is within the range of 2 to 6% slope. If the second capital letter is omitted, it means that the delineation is essentially a level area. When a number 2 or 3 follows the second capital letter, it shows how much erosion has taken place; 2-moderate, 3-severe. The maps show, by standard symbols, many other features such as roads, railroads, bridges, buildings, mines, quarries, power lines, pipelines, cemeteries, dams, streams, lakes, ponds, marshes, and other features.

The body of the report gives detailed information about each kind of soil. The narrative portion gives a soil series description which gives the texture, structure, pH, and other characteristics of each horizon in the profile. (A horizon is a layer of soil approximately parellel to the soil surface, with distinct characteristics produced by the soil forming processes. Horizons are identified by letters of the alphabet with A being the horizon at the surface. A profile is a verticle section extending from the surface through all horizons from the surface to the parent material.) The series description also indicates certain hazards common to the soil such as flooding, high erodibility, wetness, or other problems. Tables of soil properties give further details on texture, organic matter content, permeability, and engineering properties. Interpretive tables give the degree of limitation of each soil for various uses in terms of slight, moderate, and severe limitations.

K or erodibility for soils may be in the more recent reports, but it is in Appendix B, pages B-8 to B-26.

Hydrologic information on soils is given in Appendix C, TR-55 in terms of four hydrologic soil groupings. These are designated A, B, C, and D, with A being the low runoff potential group and D the high runoff potential. It should be noted that compaction of the soil by heavy equipment, or barren conditions may significantly influence the rate of runoff and cause a soil to be classed in the next lower hydrologic group.

Topographic features of the area are among the items which must be depicted on a map for the erosion and sediment control plan. A good topographic map with contour intervals small enough to indicate topography in sufficient detail is an excellent planning tool. For most developments, this would mean a large scale map with contour intervals of 1 or 2 feet verticle distance. A skilled person can visualize the shape of the land from a well prepared contour map as accurately as if he were on the site. It is possible to identify convex and concave slopes and to calculate land slopes. When combined by means of overlays or perhaps on the same map with soils information and drainage information, it is invaluable in determining water management and erosion and sediment control needs.

The drainage pattern, including sizes and shapes of each contributing area, should be mapped out on a good base map. An adequate topo map would be ideal. It should be delineated from field checking. Drainage and contributing areas off-site should be included in the information collected. Data on conveyance systems; i.e., culverts, pipes, and channels should include sizes, length of each reach, and conditions. Note all points where concentrated overland flow enters channels and indicate the present stability condition.

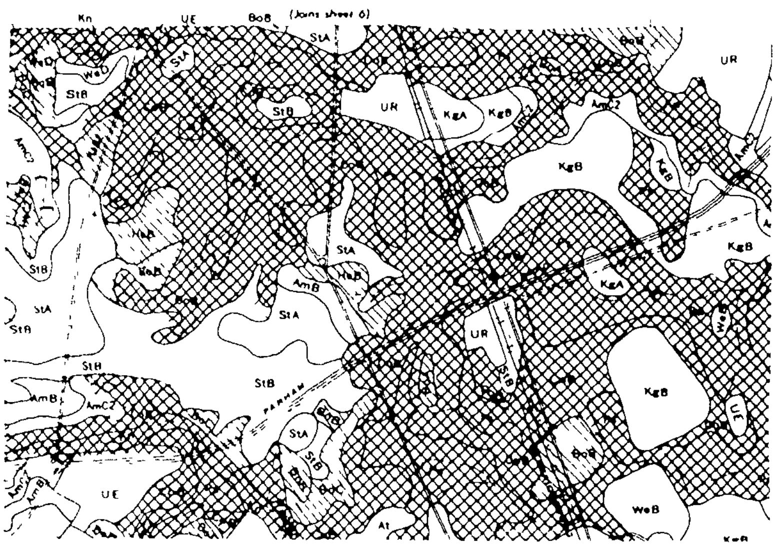
The vegetative cover should include type and condition of cover. Types will include wetlands, grasslands, cultivated lands, idle weed-covered land, forest land, and others. Condition should reflect the percent of bare area and the quality of existing cover.

Once the data on soils, topography, drainage, vegetation, and other physical features has been collected, it should be interpreted and analyzed in order to reveal the potentials and problems of the site. There is no set way that governs this step, in fact several approaches may be useful on the same site. It is helpful if all the above data is put on large scale maps or on one map with overlays. As mentioned earlier, a good quality topographic map makes an excellent base map for planning.

Soil maps can be interpreted in several ways. Some planners find that a soil condition map is very useful. Figure 23 illustrates a soil condition map for the same area as the soil survey map in Figure 22.

This particular example shows areas of poorly drained soils and areas of seasonal high water table. Another approach is to delineate all of the areas which should not be disturbed or built upon because of specific hazards. This definitely should include flood plains and other areas adjacent to streams; it would also include steep erodible areas, wetlands, and unique areas which should be preserved.

Figure 23 Soil Condition Map



Seasonal High Water Table

Poorly Drained Soils and Seasonal High Water Table

A third approach, which has been widely used by planners, is to prepare overlay maps showing the relative soil suitability for various uses. Information for this can be taken directly from the tables of the soil survey report which shows slight, moderate, and severe limitations for various uses.

Erosion hazard areas can be identified from the soil survey information including the erodibility factor K, and the slope class as indicated on the soil survey map. However, when a map overlay, showing soils information, is used with the topographic map these areas can be very easily delineated.

Evaluate the topography by delineating areas of various slopes. Areas which are over 15% slope will have more severe erosion, water management, and construction problems. It will be helpful to draw in ridge tops, indicate direct of slope, and length of slope in each sub-drainage area.

Existing drainage patterns should also be shown on the topographic base map. From this pattern and your notes on sizes and condition of culverts, ditches and other channels, you can pinpoint potential problem areas. It may be necessary to delineate the watershed of each drainage area and then calculate runoff amounts and velocities in order to identify all of the water management problems and needs.

When all of the data has been interpreted, analyzed, and the results put on the base map, the results should suggest the most favorable layouts to you. The delineations of floodplains and adjacent stream belt areas as places where no building should take place will be one of the first things to help set the development pattern. The limitation ratings for the various uses may help in taking the next step. These ratings should indicate the best areas for accommodating the development objectives

Using the above approach or other methods which the data may suggest to you, select the areas for houses, streets, and other buildings on the basis of highest potential for the purpose and least risk of degradation of the environment. It will be necessary to make compromises. For each possible layout think out the needs for water management, erosion control practices, and sediment control practices. Economic evaluations should be made for the various possible layouts. Keep in mind that the highest quality development is usually one with the least disruption of the natural features of the site. Excessive grading is not only expensive; in many cases, it creates more problems that it solves.

Once the layout of buildings, roads, and other facilities has been decided, delineate the areas to be cleared and graded, identifying cut and fill areas, and identify and estimate the erosion hazard on these areas and existing bare areas on the site. Design the storm water management system based on runoff expected after development. Use all possible means to keep peak discharges low. Identify where runoff from adjacent properties are likely to cause erosion problems. A temporary interceptor or diversion dike should be used at these locations. These should outlet only on protected stable areas. Where there is a risk of erosion from graded and other bare areas to adjacent property, a temporary perimeter dike should be constructed. These should outlet into a gravel outlet structure, sediment trap, or sediment basin. See Standards and Specifications for each of these practices. Study the design requirements for a sediment basin, Appendix A, pages III-41 to 48 and Appendix B-9, and be prepared to design such a pra tice.

All diversions, interceptors, and earthen structures should be mulched and seeded, sodded, or stabilized by other acceptable means immediately upon completion. Where a choice of grades is possible, keep gradients low. Remember that diversions and interceptors convert sheet flow to concentrated flows.

The stormwater management facilities may include diversions and waterways or outlets. Study the Standards and Specifications for these practices in Appendix A, pages III-28 to 40, and be prepared to design a waterway or outlet which would meet these requirements. See, also, Appendix A, pages III-75 to 89. Use Appendix C, TR-55 to compute peak discharge as required.

For all bare areas that can be graded to desired finished grades during a satisfactory season for establishment, select permanent vegetative practices that are in keeping with the intended use of the area, that will fit the soil conditions, and that will provide the needed protection. Study the appropriate Standards and Specifications and Appendix A, pages III-165 to 183. Be prepared to use this material to choose permanent vegetative measures, including species for actual field conditions.

For all other bare areas, including those completed to finish grade which cannot be seeded because of time of year, use tied down mulch Where seeding can be done on rough graded areas, use mulch and temporary seedings. Omit from seeding only those immediate areas where construction of facilities will begin in two or three weeks.

Evaluate the need for practices such as level spreaders, gravel outlet structures, sediment traps, storm drain outlet protection and riprap, and be prepared to properly locate and design them for a hypothetical case.

If the area is large and will be developed over a period of several months, develop a plan for staging the grading so that the first area can be stabilized before the second is opened up. To the extent possible, plan major grading outside the months with the highly erosive rains.

Unforeseen delays can upset a well planned erosion control scheme. For this reason, flexibility must be retained so that the job superintendent can make appropriate changes in specifications to fit seasonal and other requirements.

Read Appendix A, pages II-7-11, which define an Erosion and Sediment Control Plan and describes what needs to be included in it.

Data and assistance on soils information, hydrology, and related fields is available through the local Soil and Water Conservation District and the U.S.D.A., Soil Conservation Service personnel assigned to assist the district.

Questions:

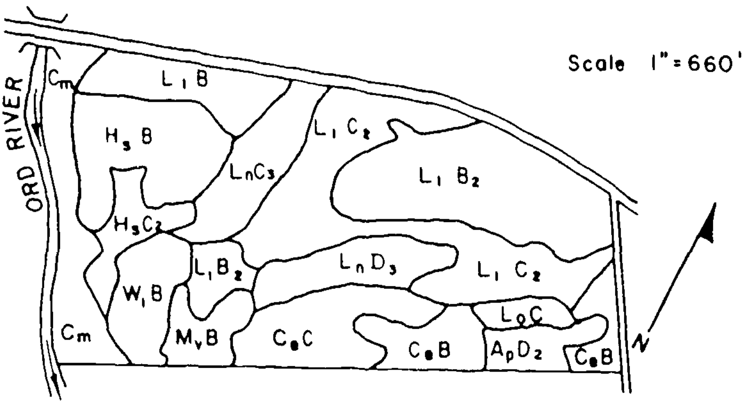
1. Give three reasons why planning for erosion and sediment control should be a part of overall planning of the development.

2. How can planning for erosion and sediment control and the planning of the development be coordinated?

3. What kinds of data would you need in order to identify areas with high potential for erosion? List the data required in the Erosion and Sediment Control Plan (as indicated in the Handbook) that is not included above.

4. Using the soil and topographic information below, delineate the areas which are potentially critical erosion areas:

Soil survey of 90-acre site:

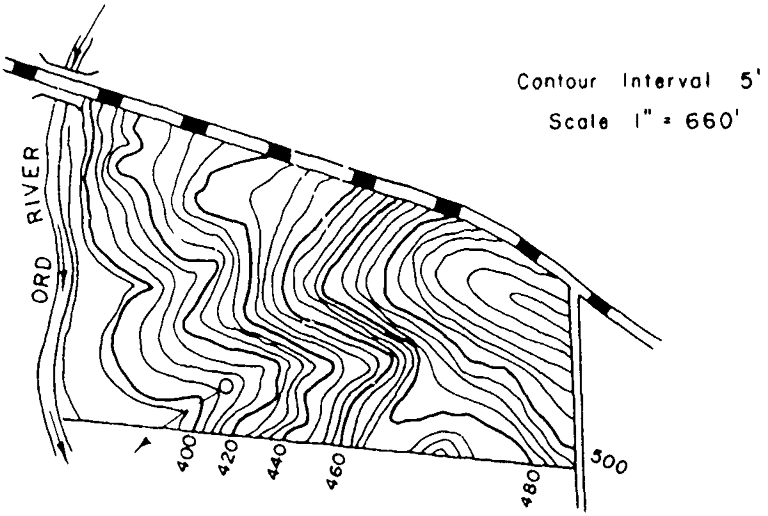


Map Symbol	Soil Name	Slope	Position on Landscape
ApD2	Appling fine sandy loam	7-20%	Upland
CeB	Cecil fine sandy loam	2-7%	Upland
CeC	Cecil fine sandy loam	7-15%	Upland
Cm	Chewacla silt loam	--	Floodplain
HsB	Hiwassee loam	2-7%	High River Terraces
HsC2	Hiwassee loam	7-15%	High River Terraces
LlB2 *	Lloyd loam	2-7%	Upland

* K for Lloyd is .43 (It is omitted from Appendix B.)

Map Symbol	Soil Name	Slope	Position on Landscape
LlC2	Lloyd loam	7-15%	Upland
LnC3	Lloyd clay loam	7-15%	Upland
LnD3	Lloyd clay loam	15-25%	Upland
LoC	Louisburg sandy loam	5-15%	Upland
MvB	Meadowville loam	2-7%	Coluvium
SrC	Starr silt loam	2-10%	Plateau
WhB	Wickham	2-7%	River Terrace

Topographic Map



(This topographic map is inadequate for determining actual grades. In practice, the topographic maps should be of larger scale and smaller contour interval for this purpose and as a base map for planning. However, it will help reinforce the judgments made on the basis of the soils information.)

No runoff enters the site from adjacent land; highway runoff is carried in a stable grassed channel parallel to the major road and outleting in the river.

5. Using the information which follows, develop a plan showing placement of the building, walks, driveway, and all required features of an erosion and sediment control plan.

(a) The project is a 20,000 square-foot elementary school building with exercise areas. The site is approximately 6 acres in size.

(b) The work is scheduled to start May 1, and is to be completely stabilized by October 1.

(c) Access to the site is by Custard Lane.

(d) The present vegetation consists of mixed hardwood forest roughly south of the 392-foot contour interval. Trees are mixed age and size from small understory up to 15 inches. There are mixed tree species along the southern half of the east boundary and a small wooded area on both sides of Custard Lane, northeast of the 390-foot contour. There are a few widely spaced large trees along the west boundary extending from Custard Lane south about 150 feet. The remainder of the area is old pasture with some briers and small saplings. All areas have adequate cover for protection from erosion.

(e) The soil is Cecil silt loam eroded rolling phase.

(f) Topographic information is on Page 88.

Summary:

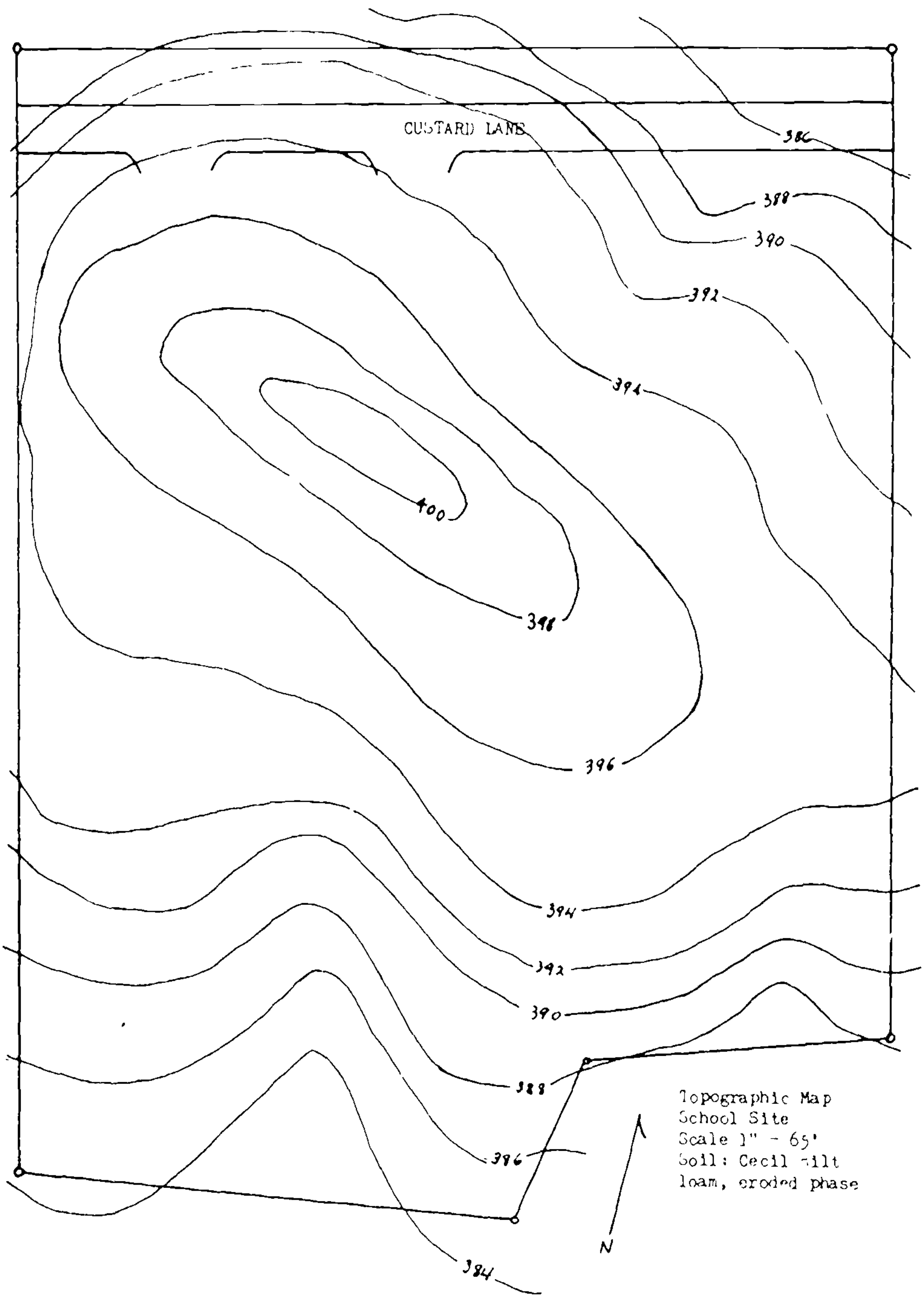
Coordination of erosion control planning and the development planning will keep the options flexible for each plan. It will allow compromises and adjustments which give the best use of the land and water resources at the least cost. This is the maximum "net productivity" concept. Coordination of all planning can help avoid costly mistakes. The flexibility of choices mentioned above has both technical and economic advantages.

To coordinate the erosion control planning and development planning, the erosion control goals must be part of the overall goals for the development. These goals must occupy an important place in making all the planning decisions.

The data needed in order to identify erosion prone areas would be soils, topographic, and hydrologic data. We should know the soil K value and the lengths and grades of slope. Hydrologic data would include rainfall, runoff coming onto the site and that generated on the site, drainage patterns including channel sizes and condition, watershed slopes, and the effects of development on runoff.

The Handbook requires that pertinent data in the above categories be included in the erosion and sediment control plan. See Appendix A, pages II-7 to 11.

On the 90-acre site, the area with the most severe erosion potential is the Lloyd clay loam, 15-25% slope. The Lloyd clay loam and Lloyd loam, 7-15% and the Cecil loam, 7-15% slope, have severe erosion hazard potential once the cover is removed. The smaller area of Hiwassee loam


CUSTARD LANE
386
388
390
392
394
396
398
400
394
392
390
388
386
384
N
Topographic Map
School Site
Scale 1" - 65'
Soil: Cecil silt
loam, eroded phase

on 7-15% also has a high erosion potential. Erosion hazard even on the B slopes could be severe if the soils remain bare during the period of most erosive rains.

The following plan was developed for the site described in Question 5.

EROSION-SEDIMENTATION CONTROL PLAN-SAMPLE NARRATIVE

ELEMENTARY SCHOOL

DESCRIPTION: The project is a 20,000 square-foot school building with exercise fields on a 6-acre site.

DATES OF CONSTRUCTION: Project is scheduled to start on May 1, 1975, to be completely stabilized by October 1, 1975.

SOIL DATA: The entire site is Cecil silt loam eroded rolling phase

TREE PROTECTION: Trees along the perimeter will be protected from equipment damage by appropriate signs and barriers

EROSION CONTROL PROGRAM: Not more than one-half the site is to be cleared at one time. Anchored mulch and temporary seeding will be done immediately after grading to all graded areas except building site and 30 feet border and parking area. Parking lot to be covered with gravel after grading.

SEDIMENT CONTROL PROGRAM: Control will be achieved through installation of one temporary sediment basin of 0.5 acre-foot capacity and one temporary sediment trap of 0.15 acre-foot capacity. Fifteen hundred feet of earth diversions to direct storm runoff to the basins.

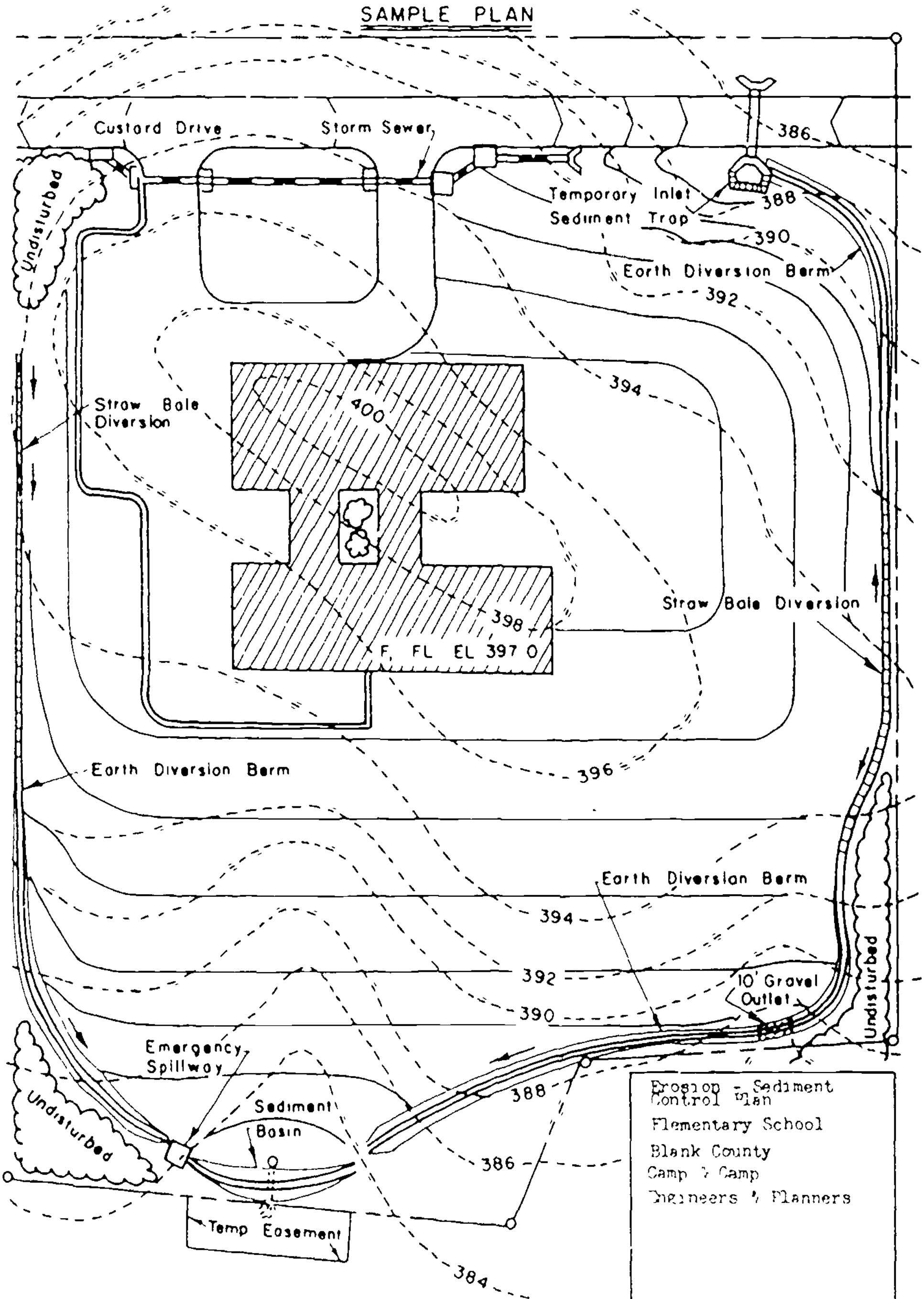
SAFETY PROTECTION: The sediment basins will be posted and the larger one fenced to exclude children.

PLAN OF OPERATION: All mechanical controls are to be placed, mulched, and seeded prior to or as the first step in clearing and grading. Following their completion, the school site and area east of the school building are to be stripped and the topsoil stockpiled at the southeast corner of the site. This area will then be brought to grade as nearly as possible without disturbance to other areas. All areas brought to grade will then be mulched and seeded with temporary vegetation. Mulch will be anchored with mulch anchoring tool. As soon as mulch is anchored, the remainder of the site except for the area at the south sediment basin will be graded and a stockpile of soil material established near the topsoil stockpile for filling the sediment basin as the last step in grading.

STORM WATER MANAGEMENT: The peak runoff for a 10-year frequency rainfall after development shall not exceed the 10-year fequency peak before development. This will be accomplished by use of roof top and parking lot storage (See attached calculations) All calculations are based on the methods set forth in the Soil Conservation Service publication "Urban Hydrology For Small Watersheds," Technical Release No. 55, SCS, USDA, January 1975.

MAINTENANCE PROGRAM: All measures are to be inspected daily by the site superintendent and inspector. Any damaged structural measures will be repaired by the close of the day. Sediment basins are to be cleaned out in accordance with the specifications and the material disposed of by spreading on the site. Mechanical controls will be removed after areas above them have been stabilized with vegetation. The sediment basin at the south end will be left until all other mechanical measures have been removed and the areas permenently stabilized

SAMPLE PLAN



Custard Drive
Storm Sewer
386
Temporary Inlet
Sediment Trap
388
390
Earth Diversion Berm
392
Undisturbed
394
Straw Bale
Diversion
400
398
F. FL EL 397.0
Straw Bale Diversion
Earth Diversion Berm
396
Earth Diversion Berm
394
392
10' Gravel
Outlet
390
Undisturbed
Emergency
Spillway
Sediment
Basin
388
Undisturbed
386
Temp Easement
384
Erosion - Sediment
Control Plan
Elementary School
Blank County
Camp & Camp
Engineers & Planners

EROSION AND SEDIMENT CONTROL PLAN NOTES:

ELEMENTARY SCHOOL

1. No disturbed area will be exposed for more than 30 calendar days without seeding, mulching, or other protective measures.

2. All mechanical erosion and sediment control measures are to be placed prior to or as the first step in clearing and grading

3 All storm and sanitary sewer lines not in streets are to be mulched and seeded within 15 days after backfill No more than 500 feet are to be open at any one time.

4. Electric power, telephone, and gas supply trenches are to be compacted, seeded, and mulched within 15 days after backfill

5 All temporary earth berms diversions and sediment control dams are to be mulched and seeded within 10 days after grading Straw, hay, or comparable mulch is required.

6. Trees along the perimeter will be protected from equipment damage by appropriate signs and barriers.

7 Any disturbed area not paved, sodded, or built upon by November 1 is to be seeded on that date with temporary vegetation and mulched

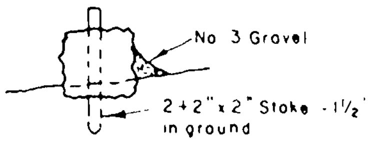
8. All land, on or off site, which is disturbed by construction and which is not built upon or surfaced, shall be adequately stabilized to control erosion and sedimentation

9. All erosion and sediment controls, including seeding and mulching, shall be in accordance with standards and specifications contained in the local erosion and sediment control handbook.

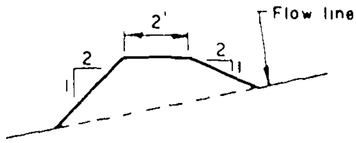
DETAILS OF MECHANICAL CONTROLS

SAMPLE

SAMPLE

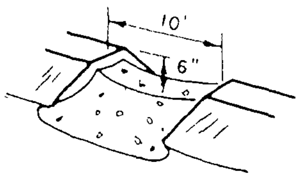


STRAW BALE DIVERSION

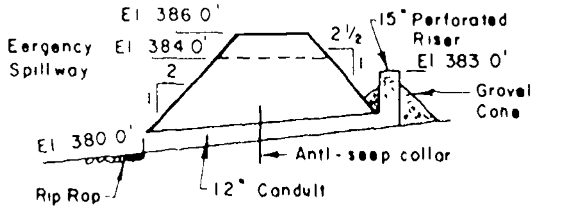


EARTH DIVERSION BERM

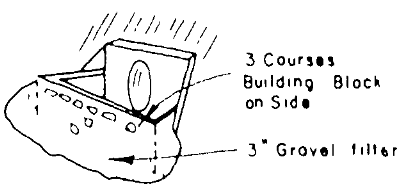
(Height Varies)



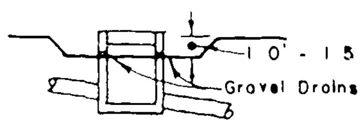
GRAVEL OUTLET



SEDIMENT BASIN - Clean Out at El 382 0'



TEMPORARY SEDIMENT TRAP
AT CULVERT HEADWALL



TEMPORARY SEDIMENT TRAP
AT ALL INLETS

The above plan is only one of several ways that the school site could have been laid out and protected from erosion and sediment damage. Even if the basic layout was retained, there could have been much less grading. The wooded area, or at least part of it, could have been retained. The depth of grading may have been excessive. Straw bale barriers were used to the limit of their applicability or, perhaps, more than the limit. It would have been safer to lengthen the earth diversions along the east and west boundaries. The plan calls for spreading the sediment cleaned from the basin on the site. It should also have specified when and how erosion of this material would be controlled. The plan is also silent on how permanent stabilization will be accomplished.

PART III References:

1. Klingebiel, A.A., "Costs and Returns of Soil Surveys," Soil Conservation, August, 1966.

PART IV IMPLEMENTING THE VIRGINIA EROSION AND SEDIMENT CONTROL PLAN

Purpose and Significance:

Part IV consists of just one unit. The unit discusses the responsibilities for the program. It covers requirements for plan submission; the contents of the application or accompanying letter; approval and disapproval of plans, issuance of permits, performance bonds, erosion and sediment control agreements; steps required if plan is disapproved; appeals; inspection; inspector responsibilities, notice to comply; complaints; and how to handle ineffective measures which comply with Handbook requirements. The Handbook is the sole reference for this unit.

A knowledge of the above is essential to the smooth and efficient handling of the administrative details of the program whether you are the applicant or the plan approving authority. The responsibilities, authorities, and procedures will vary somewhat by local areas so that the local program requirements should be checked.

Objectives:

1. Indicate who is responsible for submission of the erosion and sediment control plan, plan approval, issuance of permits, inspection, and legal action in your local area.

2. List the information which an application or letter of submission must provide when submitting an erosion and sediment control plan.

3. Name the contents of a preliminary plan, if such is required.

4. Indicate the procedure which must be followed if a plan is disapproved.

5. Describe the requirements for modification of a plan.

6. State the provisions for inspection, handling non-compliance, and [illegible] measures when measures are in accordance [illegible]

7. Describe the major points most apt to be considered by an inspector.

Content:

Read Handbook, pages V-9 through V-11

You will note that the responsibilities may vary by local areas. Study the chart in the state handbook on page V-17. District is referred to mean Soil and Water Conservation District. You [illegible] out which of these alternatives was adopted in the area(s) in which you work.

Note also that according to the Handbook on page V-15, item 2, the plan approving authority shall be guided by requirements in the local handbook. By law these requirements must be at least as stringent as the state handbook, but they may be more so. You should use the local erosion and sediment control handbook for these requirements.

The inspector will check on all measures which are part of the erosion and sediment control plan. He will also evaluate the effectiveness of the plan by checking for evidence of erosion and evidence of deposition of sediment.

He will check the timing and sequence of installation of practices related to the grading and other land disturbing activities. This will include checking on staging of major grading activities.

Structural erosion and sediment control practices will be checked for placement, adherence to design dimensions, and adequacy of mulching, seeding, sodding, or other surface treatment. He will also check on the quality of installation, which includes compaction, smoothness of grading, proper slope and drainage of inlets, and safety of outlets.

Vegetative practices will be checked for such items as timing, amount and kinds of mulch, fertilization, species, and effectiveness of results.

Questions:

1. Who is responsible in your area for:

    (a) Submission of the erosion and sediment control plan

    (b) Plan approval

    (c) Issuance of permit

    (d) Inspection

    (e) Legal action.

2. What information must be included in an application or letter of submission?

3. What are the contents of a preliminary erosion and sediment control plan?

4. What procedure is followed if plan is disapproved?

5. Describe the requirements for modification of an approved plan.

6. State the provisions for handling non-compliance appeals and reporting ineffective measures when such measures are in accordance with an approved plan.

Summary:

The preparation and submission of the erosion and sediment control plan is the responsibility of the owner, lessee, or duly authorized agent of the owner or lessee. The plan approving authority will vary by locality. It may rest with the county, city, incorporated town, or district. A department or position within one of these jurisdictions will be named as the plan approving agency or person. Each local program will indicate this responsibility. Issuance of permits for grading, building, and other actions are not changed except that the permit issuing authority shall not issue permits until the soil erosion and sediment control plan has been approved and so certified. A certificate of performance from the person responsible for carrying out the plan must be provided

The local control program will designate the department or person responsible for inspection. This department or person will be responsible for a systematic program for on-site inspection, recording the dates and results of such inspection. Note Appendix A, Handbook items K.4.a. to K.6., pages 19-20, for non-compliance and the provisions in your local program.

Requirements for an application are given in Appendix A, on pages V-13-14, items B.1.a. to B.1.f. The local requirements should be checked.

Each local control program makes provisions for letting the applicant know, for a plan that is disapproved, the modifications, terms, and conditions which must be met to allow plan approval

Modifications of approved plans must be agreed upon by the plan approving authority and the person responsible for carrying out the plan.

Appendix A, pages V-19 and 20, items K.3. through K.6. discuss alternative ways for handling non-compliance. Check the local program for the specific requirements. If investigation reveals that approved control practices are being followed but are ineffective, the plan approving authority is notified and appropriate changes are agreed upon by the authority and the person responsible for carrying out the plan

APPENDIX B

Selected material from "Predicting Soil Losses in Virginia," U.S.D.A., Soil Conservation Service, Richmond, Virginia.

Table 1

Slope Effect - Topographic Factor, LS

% Slope	Slope Length In Feet 10	20	40	60	80	100	110	120	130	140	150	160	180	200
0.2	0.04	0.05	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10
0.3	0.04	0.05	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11
0.4	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11
0.5	0.05	0.06	0.08	0.08	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12
1.0	0.06	0.08	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.16
2.0	0.10	0.12	0.15	0.17	0.19	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.25
3.0	0.14	0.18	0.22	0.25	0.27	0.29	0.30	0.30	0.31	0.32	0.32	0.33	0.34	0.35
4.0	0.16	0.21	0.28	0.33	0.37	0.40	0.42	0.43	0.44	0.46	0.47	0.48	0.51	0.53
5.0	0.17	0.24	0.34	0.41	0.48	0.54	0.56	0.59	0.61	0.63	0.66	0.68	0.72	0.76
6.0	0.21	0.30	0.43	0.52	0.60	0.67	0.71	0.74	0.77	0.80	0.82	0.85	0.90	0.95
8.0	0.31	0.44	0.63	0.77	0.89	0.99	1.04	1.09	1.13	1.17	1. 1	1.25	1.33	1.40
10.0	0.43	0.61	0.87	1.06	1.23	1.37	1.44	1.50	1.56	1.62	1.68	1.73	1.84	1.94
12.0	0.57	0.81	1.14	1.40	1.61	1.80	1.89	1.98	2.06	2.14	2.21	2.28	2.42	2.55
14.0	0.73	1.03	1.45	1.78	2.05	2.29	2.41	2.51	2.62	2.72	2.81	2.90	3.08	3.25
16.0	0.90	1.27	1.80	2.20	2.54	2.84	2.98	3.11	3.24	3.36	3.48	3.59	3.81	4.01
18.0	1.09	1.54	2.17	2.66	3.07	3.43	3.60	3.76	3.92	4.06	4.21	4.34	4.61	4.86
20.0	1.29	1.82	2.58	3.16	3.65	4.08	4.28	4.47	4.65	4.83	5.00	5.16	5.47	5.77
25.0	1.86	2.63	3.73	4.56	5.27	5.89	6.18	6.45	6.72	6.97	7.22	7.45	7.90	8.33
30.0	2.52	3.56	5.03	6.16	7.11	7.95	8.34	8.71	9.07	9.41	9.74	10.06	10.67	11.25
40.0	4.00	5.66	8.00	9.80	11.32	12.65	13.27	13.86	14.43	14.97	15.50	16.01	16.98	17.30
50.0	5.64	7.97	11.27	13.81	15.94	17.82	18.69	19.53	20.32	21.09	21.83	22.55	23.91	25.21
60.0	7.32	10.35	14.64	17.93	20.71	23.15	24.28	25.36	26.40	27.39	28.36	29.29	31.06	32.74

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Table 1 (Cont.)

Slope Length In Feet

% Slope	300	400	500	600	700	800	900	1000	1100	1200	1300	1500	1700	2000
0.2	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.16	0.17	0.17	0.18	0.19	0.19	0.20
0.3	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.18	0.18	0.18	0.19	0.20	0.21	0.22
0.4	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.19	0.20	0.20	0.21	0.22	0.23
0.5	0.14	0.15	0.16	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24
1.0	0.18	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.27	0.28	0.29	0.30	0.32
2.0	0.28	0.31	0.33	0.34	0.36	0.38	0.39	0.40	0.41	0.42	0.43	0.45	0.47	0.49
3.0	0.40	0.44	0.47	0.49	0.52	0.54	0.56	0.57	0.59	0.61	0.62	0.65	0.67	0.71
4.0	0.62	0.70	0.76	0.82	0.87	0.92	0.96	1.01	1.04	1.08	1.12	1.18	1.24	1.33
5.0	0.93	1.07	1.20	1.31	1.42	1.52	1.61	1.69	1.78	1.86	1.93	2.07	2.21	2.40
6.0	1.17	1.35	1.50	1.65	1.78	1.90	2.02	2.13	2.23	2.33	2.43	2.61	2.77	3.01
8.0	1.72	1.98	2.22	2.43	2.62	2.81	2.98	3.14	3.29	3.44	3.58	3.84	4.09	4.44
10.0	2.37	2.74	3.06	3.36	3.62	3.87	4.11	4.33	4.54	4.74	4.94	5.30	5.65	6.13
12.0	3.13	3.61	4.04	4.42	4.77	5.10	5.41	5.71	5.99	6.25	6.51	6.99	7.44	8.07
14.0	3.98	4.59	5.13	5.62	6.07	6.49	6.88	7.26	7.61	7.95	8.27	8.89	9.46	10.26
16.0	4.92	5.68	6.35	6.95	7.51	8.03	8.52	8.98	9.42	9.83	10.24	11.00	11.71	12.70
18.0	5.95	6.87	7.68	8.41	9.09	9.71	10.30	10.86	11.39	11.90	12.38	13.30	14.16	15.36
20.0	7.07	8.16	9.12	9.99	10.79	11.54	12.24	12.90	13.53	14.13	14.71	15.80	16.82	18.24
25.0	10.20	11.78	13.17	14.43	15.59	16.66	17.67	18.63	19.54	20.41	21.24	22.82	24.29	26.35
30.0	13.78	15.91	17.79	19.48	21.04	22.50	23.86	25.15	26.38	27.55	28.68	30.81	32.80	
40.0	21.92	25.31	28.30	31.00	32.48									
50.0	30.87													
60.0														

Table 2b - "C" Factors For Permanent Pasture, Rangeland, and Idle Land 1/

Vegetal Canopy			Cover That Contacts The Surface					
Type and Height of Raised Canopy 2/	Canopy Cover 3/ %	Type 4/	Percent Ground Cover					
			0	20	40	60	80	95-100
Column No:	2	3	4	5	6	7	8	9
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.041	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

1/ All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

2/ Average fall height of waterdrops from canopy to soil surface: m = meters.

3/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

4/ G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface, and/or undecayed residue.

Table 2c - "C" Factors For Woodland

Stand Condition	Tree Canopy % of Area 1/	Forest Litter % of Area 2/	Undergrowth 3/	"C" Factor
Well Stocked	100-75	100-90	Managed4/	.001
			Unmanaged4/	.003-.011
Medium Stocked	70-40	85-75	Managed	.002-.004
			Unmanaged	.01 -.04
Poorly Stocked	35-20	70-40	Managed	.003-.009
			Unmanaged	.02 -.09 5/

1/ When tree canopy is less than 20%, the area will be considered as grassland or cropland for estimating soil loss See Table 2b.

2/ Forest litter is assumed to be at least two inches deep over the percent ground surface area covered.

3/ Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

4/ Managed -- grazing and fires are controlled.
Unmanaged -- stands that are overgrazed or subjected to repeated burning.

5/ For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table 2b. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

Table 2d - "C" Factors For Different Kinds of Ground Cover (Mulch) That May Be Used In Computing Soil Losses Are:

		T/Ac	C
a.	Straw or hay, tied down by anchoring or tracking equipment used across slope	1.0	20
		1.5	10
		2.0	.05
		4.0	.02
b.	Woodchips	7 0	.08
		12 0	.05
		25 0	.02
c	Wood cellulose fiber	2.0	.10
d.	Fiberglass (1,000 lbs /ac.)		.05
e	Asphalt emulsion (1,250 gallons/ac)		.02
f.	Crushed stone	60.0	.17
		135.0	.05
		240.0	.02
g.	Bare areas	--	1.0
h	Annual cover	--	0 15

Rainfall Factors For Counties And Cities In Virginia

Rainfall Factor (R) = 125

Highland

Rainfall Factor (R) = 150

Alleghany
Amherst
Augusta
Bath
Bedford
Bland
Botetourt
Buchanan
Carroll
Clarke
Craig
Dickenson
Floyd
Franklin
Frederick
Giles
Grayson
Greene
Lee
Loudoun
Montgomery
Page
Patrick
Pulaski
Roanoke
Rockbridge
Rockingham
Russell
Scott
Shenandoah
Smyth
Tazewell
Warren
Washington
Wise
Wythe

Rainfall Factor (R) = 175

Albemarle
Appomattox
Buckingham
Campbell
Culpeper
Cumberland
Faquier
Fluvanna
Goochland
Henry
Louisa
Madison
Nelson
Orange
Pittsylvania
Prince Edward
Prince William
Rappahannock
Spotsylvania
Stafford

Rainfall Factor (R) = 200

Amelia
Caroline
Charlotte
Fairfax
Hanover
King George
Lunenburg
Nottoway
Powhatan

Rainfall Factor (R) = 225

Chesterfield
Henrico
Mecklenburg
New Kent
Richmond (City)

Rainfall Factors For Counties And Cities In Virginia (Cont.)

Rainfall Factor (R) = 250

Accomack
Brunswick
Charles City
Dinwiddie
Essex
Gloucester
Greensville
Isle of Wight
King and Queen
Lancaster
Mathews
Middlesex
Northampton
Northumberland
Prince George
Richmond (Co.)
Southampton
Surry
Westmoreland
York

Rainfall Factor (R) = 300

Chesapeake
Hampton
James City
Newport News
Suffolk
Virginia Beach

Erosion Index Values For Annual Rainfall And Expected Magnitudes Of Single-Storm EI Values At Key Locations In Virginia

Location	Average Annual (R)	Probability One Year In 5	Probability One Year In 20	Single Storm Normally Exceeded Once In 5 Yrs.	10 Yrs.	20 Yrs.
Richmond	225	275	361	86	102	125
Roanoke	150	176	237	48	61	73
Lynchburg	175	232	324	66	83	103
Washington	200	250	336	86	108	136

Annual Distribution Of Rainfall-Erosion Index Factors In Percent By Physiographic Areas

	Coastal Plain		Piedmont		Mountains & Valleys	
	Accumulative	By Month	Accumulative	By Month	Accumulative	By Month
1/1	0		0		0	
2/1	2	2	4	4	2	2
3/1	3	1	7	3	3	1
4/1	6	3	12	5	6	3
5/1	10	4	17	5	10	4
6/1	20	10	25	8	20	10
7/1	35	15	35	10	40	20
8/1	55	20	55	20	65	25
9/1	75	20	78	23	82	17
10/1	85	10	87	9	91	9
11/1	92	7	92	5	95	4
12/1	97	5	97	5	96	1
1/1	100	3	100	3	100	4

K AND T VALUES FOR SOILS IN VIRGINIA

The K values listed are based on field experience and limited test data. On-site analysis and test data might result in K values different from those listed. These values are subject to change as more information becomes available. The soils indicated with an asterisk are either flat flood plains and/or wet, and are not subject to erosion.

Soil	Depth	"K"	"T"
Abell	0 - 8 8 - 40 40 - 60	.28 .28 .43	4
Alamance	0 - 46	.43	4
Albano*			
Albemarle	0 - 45	.37	4
Aldino	0 - 14 14 - 36 36 - 60	.43 .37 37	3
Algiers*			
Alleghany	0 - 65	.28	4
Altavista 1/	0 - 12 12 - 60	.28 - .32 .24	4
Angie	0 - 60	.32	4
Appling 1/	0 - 10 10 - 54	.28 - .32 .28	4
Ashe 1/	0 - 30	.24	2
Ashlar	0 - 18 18 - 34	.24 .43	2

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Athol 1/	0 - 8 8 - 41 41 - 62	.32 - .37 .17 28	4
Atkins*			
Atlee	0 - 9 9 - 26 26 - 52	.37 .37 .37	3
Augusta	0 - 9 10 - 60	.43 .37	2
Aura (see State)			
Aycock	0 - 12 12 - 80	.37 .43	4
Baile			
Bayboro*			
Bedington	0 - 8 8 - 46 46 - 62	.32 .28 .17	4
Beltsville	0 - 8 8 - 25 25 - 60	.43 .37 .32	3
Belvoir	0 - 8 8 - 20 20 - 40	.32 .32 .32	3
Benevola	0 - 6 6 - 42	.32 .28	3
Berks 1/	0 - 10 10 - 26 26 - 33	.28 .17 .17	3

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Bermudian*			
Bertie	0 - 9	.32	3
	9 - 38	.32	
	38 - 60	.17	
Bibb*			
Birdsboro	0 - 10	.28	4
	10 - 46	.28	
	46 - 70	.17	
Bladen*			
Bland 1/	0 - 3	.43	2
	3 - 30	.43	
	30 - 36	.43	
Bolton	0 - 11	.28	4
	11 - 42	.28	
Bourne	0 - 12	.43	3
	12 - 28	.43	
	28 - 52	.43	
Bowmansville*			
Braddock	0 - 8	.32	4
	8 - 48	.28	
	48 - 85	.32	
Brandywine 1/	0 - 25	.24	3
	25 - 40	.37	
Brays*			
Brecknock 1/	0 - 46	.32	3
Bremo	0 - 9	.32	2
	9 - 17	.28	
	17 - 25	.17	

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Brockroad	0 - 8	.32	4
	8 - 59	.32	
	59 - 70	.28	
Bucks 1/	0 - 21	.32	4
	21 - 40	.43	
	40 - 52	.28	
Buncombe	0 - 60	.17	5
Burketown	0 - 60	.43	3
Burton	0 - 21	.15	2
	21 - 28	.24	
Cahaba	0 - 9	.24	4
	9 - 53	.20	
	[illegible] - 80	.24	
Calverton	0 - 11	.32	3
	11 - 40	.32	
	40 - 60	.37	
Calvin 1/	0 - 8	.24	3-2
	8 - 27	.28	
	27 - 34	.28	
Cape Fear*			
Captina 1/	0 - 14	.37	3
	14 - 24	.32	
	24 - 60	.32	
Carbo 1/	0 - 6	.49	2
	6 - 32	.49	
Cardiff 1/	0 - 45	.28	3
Caroline	0 - 8	.43	3
	8 - 80	.43	

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Cartecay*			
Catharpin	0 - 8 8 - 44 44 - 76	32 32 32	4
Catlett 1/	0 - 7 7 - 13 13 - 19	.24 .24 .17	2
Catoctin	0 - 9 9 - 22 22 - 28	.32 .28 .28	3
Cecil 1/	0 - 7 7 - 50	.24 - .32 .28	4
Chagrin*			
Chandler	0 - 4 4 - 23	.15 .15	2
Chastian*			
Chavies* 1/			
Chester 1/	0 - 15 15 - 36 36 - 6[illegible]	.32 .32 .43	4-3
Chewacla*			
Chilhowie 1/	0 - 4 4 - 25	.28 .28	2
Clarksburg 1/	0 - 12 1[illegible] - 60	.37 - .43 .28	3-2
Clarksville	0 - 80	.24	2
Clifton	0 - 7 7 - 34	.37 .32	4

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value

Soil	Depth	"K"	"T"
Clymer	0 - 50	.28	3
Colorus	0 - 18	.49	4
	18 - 54	.37	
	54 - 60	.24	
Colfax	0 - 11	.37	4
	11 - 30	.37	
	30 - 60	.43	
Comus*			
Congaree*			
Corydon	0 - 15	.43	2
Coxville*			
Craigsville	0 - 4	.17	3
	4 - 27	17	
	27 - 60	17	
Craven	0 - 11	.32	3
	11 - 21	.32	
	21 - 65	.28	
Creedmoor	0 - 8	.37	3
	8 - 19	.37	
	19 - 56	.32	
Cullen	0 - 9	37	4-3
	9 - 50	.37	
	50 - 72	.37	
Culpeper	0 - 7	.37	4
	7 - 32	28	
	32 - 60	.17	
Dandridge 1/	0 - 16	.17	2
Davidson	0 - 7	.28	5
	7 - 12	.32	
	12 - 53	.24	
	53 - 73	28	

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Decatur	0 - 7	.32	5
	7 - 20	.32	
	20 - 72	.32	
Dekalb	0 - 40	.24	3
Delanco	0 - 11	.28	4
	11 - 32	.28	
	32 - 50	.37	
Dogue	0 - 9	.28	4
	9 - 47	.28	
	47 - 60	.17	
Dragston*			
Drall	0 - 9	.17	3
	9 - 31	.17	
	31 - 58	.17	
Duffield 1/	0 - 10	.32	4
	10 - 53	.28	
	53 - 58	.28	
Dunbar	0 - 8	.28	4
	8 - 80	.24	
Dunmore	0 - 11	.37	4
	11 - 60	.32	
Dunning*			
Duplin	0 - 8	.32	3
	8 - 80	.28	
Durham	0 - 16	.17	4
	16 - 48	.20	
	48 - 56	.32	
Dyke	0 - 7	.32	4
	7 - 60	.28	

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Edneyville	0 - 10	.28	3
	10 - 30	.28	
	30 - 40	.24	
Edom	0 - 8	.28	3
	8 - 36	.28	
	36 - 46	.17	
Elbert*			
Elioak 1/	0 - 10	.32	4
	10 - 33	.32	
	33 - 60	.43	
Elk 1/	0 - 14	.37	4
	14 - 60	.32	
Elkton*			
Elliber 1/	0 - 60	.24	4
Elsinboro 1/	0 - 60	.28	3
Enon	0 - 7	.37	4
	7 - 34	.43	
Ernest 1/	0 - 8	.32	3
	8 - 60	.28	
Eubanks	0 - 60	.32	4
Faceville	0 - 5	.28	5
	5 - 60	.37	
Fairfax 1/	0 - 8	.43	3
	8 - 40	.43	
	40 - 92	.28	
Fallsington (see Lumber)			
Fannin	0 - 7	.37	3
	7 - 25	.43	
	25 - 32	.43	

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value

Soil	Depth	"K"	"T"
Fauquier 1/	0 - 5	.28 - .32	4
	5 - 60	.43	
Fletcher	0 - 18	.43	4
	18 - 32	.43	
Fluvanna	0 - 8	.32 - .37	3
	8 - 46	.43	
	46 - 60	.28	
Forestdale*			
Fork	0 - 8	.43	2
	8 - 60	.43	
Frankstown 1/	0 - 8	.32	3
	8 - 25	.28	
	25 - 60	.28	
Frederick 1/	0 - 6	.24- .32	4
	6 - 60	.28	
Fuquay	0 - 34	.[illegible]0	5
	34 - 80	.20	
Galestown	0 - 50	.17	5
Genessee*			
Georgeville	0 - 7	.37 - .43	3
	7 - 34	.43	
	34 - 45	.43	
Gilpin 1/	0 - 40	.28	3
Glenelg 1/	0 - 24	.32	3
	24 - 60	.43	
Glenville 1/	0 - 24	.32	3
	24 - 60	.37	
Goldsboro	0 - 15	.20	5
	15 - 76	.24	
Goldston	0 - 25	.20	2

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Soil	Depth	"K"	"T"
Goldvein	0 - 18	.43	3
	18 - 43	.37	
	43 - 53	.32	
	53 - 80	.28	
Granville	0 - 16	17	4
	16 - 45	.20	
Greendale	0 - 50	.32	5
Groseclose	0 - 9	.32	3
	9 - 60	.32	
Grover	0 - 9	.28	3
	9 - 38	32	
Guernsey	0 - 20	43	3
	20 - 50	32	
Gwinnett	0 - 7	.28	4
	7 - 35	.28	
Hagerstown 1/	0 - 8	.32	4
	8 - 60	.32	
Hartboro*			
Hayesville	0 - 5	.32	4
	5 - 60	.28	
Hayter	0 - 9	.20 - .28	4
	9 - 50	.28	
	50 - 60	.17	
Hazel 1/	0 - 30	.28	2
Helena	0 - 12	.37	3
	12 - 19	.37	
	19 - 46	.32	
Herndon	0 - 9	.37	3
	9 - 48	.37	
	48 - 68	.43	
Hiwassee	0 - 6	.32	4-5
	6 - 70	.28	

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Soil	Depth	"K"	"T"
Huntington*			
Iredell	0 - 7	.43	3
	7 - 24	.20	
	24 - 32	.28	
Jefferson 1/	0 - 8	.28	4
	8 - 38	28	
	38 - 62	.28	
Johns	0 - 15	20	3
	15 - 32	.24	
	32 - 60	.10	
Kalmia 1/	0 - 14	.24	4
	14 - 32	.24	
	32 - 60	.10	
Kelly	0 - 6	.43	2
	6 - 36	.37	
	36 - 45	.28	
Kempsville	0 - 11	.28	4
	11 - 53	.43	
	53 - 90	.17	
Kenansville	0 - 22	.15	5
	22 - 40	.15	
	40 - 80	.10	
Keyport (see Craven)			
Kinkora*			
Kingston*			
Klej	0 - 50	.17	5
Klinesville	0 - 5	.20	2
	5 - 15	.28	
	15 - 19	.28	
Laidig 1/	0 - 8	.28	4
	8 - 37	.28	
	37 - 80	.17	

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Soil	Depth	"K"	"T"
Lakeland	0 - 90	.17	5
Landisburg 1/	0 - 20 20 - 60	.43 .32	3
Leetonia	0 - 19 20 - 45	.17 .17	3
Legore 1/	0 - 10 10 - 24 24 - 60	.24 .32 .24	3
Lehew	0 - 6 6 - 32	.17- .24 .17	3
Lenoir	0 - 8 8 - 75	.37 .37	3
Leon*			
Lewisberry	0 - 12 12 - 46 46 - 62	.20 .17 .17	3
Lignum	0 - 5 5 - 38 38 - 72	.43 43 43	2
Lindside*			
Litz 1/	0 - 11 11 - 35	.32 .32	3
Lobdell*			
Lodi	0 - 8 8 - 24 24 - 60	.24 - .32 .28 .28	4
Louisa	0 - 4 4 - 15	.24 .24	2
Louisburg	0 - 7 7 - 24	.20 .24	2

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Lumbee*			
Lunt	0 - 9 9 - 38 38 - 60	.37 .43 28	3
Lynchburg	0 - 9 9 - 72	.20 .20	4
Madison 1/	0 - 7 7 - 44	32 .32	4
Manassas	0 - 15 15 - 60	.32 .32	4
Manor	0 - 15 15 - 60	.43 .49	3
Mantachie*			
Manteo 1/	0 - 5 5 - 15	28 - 32 .28	4
Marlboro	0 - 9 9 - 72	.20 .20	4
Marr	0 - 12 12 - 50	32 32	3
Masada 1/	0 - 9 9 - 55 55 - 72	.28 - .32 28 .28	4
Matapeake	0 - 55	32	3
Mattapex	0 - 50	.37	3
Mayodan	0 - 12 12 - 47 47 - 60	.20 - .24 .24 .24	3
Meadowville 1/	0 - 13 13 - 52	.37 .28	3

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Soil	Depth	"K"	"T"
Mecklenburg	0 - 6	.32	4
	6 - 60	.32	
Melvin*			
Molena	0 - 7	.17	5
	7 - 51	.17	
	51 - 60	.15	
Monongahela	0 - 60	.43	3
Montalto 1/	0 - 45	.32	4
	45 - 60	.37	
Mt. Airy	8 - 33	28	3
Murrill	0 - 15	.24 - .28	4
	15 - 60	.17	
	60 - 80	.28	
Muskingum	0 - 40	.28	3
Myatt*			
Myersville	0 - 6	32	4
	6 - 60	.32	
Nason	0 - 8	.32	4
	8 - 38	.28	
	38 - 50	.43	
Needmore	0 - 7	37	3
	7 - 40	.24	
Norfolk 1/	0 - 17	.28	5
	17 - 80	.24	
Opequon 1/	0 - 20	.43	2
Orange	0 - 10	.49	2
	10 - 38	.28	
	38 - 58	.43	

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Soil	Depth	"K"	"T"
Orangeburg	0 - 7	.24	5
	7 - 60	.24	
Othello*			
Pacolet	0 - 6	.20 - .24	3
	6 - 27	.28	
	27 - 42	.28	
Pactolus*			
Pamunkey	0 - 60	.28	4
Pedlar	0 - 10	.32	2
	10 - 20	.32	
Penn	0 - 8	.28- .32	3
	8 - 23	.28	
	23 - 32	.28	
Philo*			
Pinkston	0 - 8	.32	2
	8 - 19	.32	
	19 - 30	.24	
Pisgah	0 - 8	.28	3
	8 - 50	.28	
	50 - 60	.37	
Plummer*			
Pocomoke*			
Poindexter	0 - 40	.37	2
Pope*			
Porters	0 - 7	.24	2
	7 - 28	.24	
	28 - 42	.32	
Portsmouth*			
Pouncey*			

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Soil	Depth	"K"	"T"
Purdy	0 - 50	.43	3
Rabun	0 - 11 11 - 47	.32 .32	4
Rains*			
Ramsey	0 - 20	17	1
Rapidan	0 - 48	32	4
Raritan	0 - 8 8 - 50	43 .28	3
Readington	0 - 9 9 - 29 29 - 50	.43 43 .28	3
Riverview*			
Roanoke*			
Rohrersville	0 - 15 15 - 42 42 - 64	.37 .37 43	4
Rowland	0 - 10 10 - 44 44 - 60	.43 28 .17	4
Rumford	0 - 17 17 - 60	.20 - 24 17	4
Rushtown	0 - 50	.17	4
Ruston	0 - 16 16 - 41 41 - 47 47- 92	20- 24 32 .24 .32	3
Rutledge*			

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Soil	Depth	"K"	"T"
Sassafras 1/	8 - 17	.28	4
	17 - 37	.32	
	37 - 60	.17	
Sees	0 - 50	.37	3
Sekil	0 - 14	.37	2
	14 - 38	.28	
Shelocta	0 - 20	.28	4
	20 - 60	.32	
Starr	0 - 10	.24	4
	10 - 60	.28	
State	0 - 60	28	4
Susquehanna	0 - 5	.17 - .43	3
	5 - 77	.32	
Talladega	0 - 9	.28	2
	9 - 22	.28	
Tallapoose	0 - 4	.24	1
	4 - 10	.32	
	10 - 30	.28	
Tate	0 - 7	.28	4
	7 - 46	.32	
	46 - 72	.24	
Tatum	0 - 8	.28 - .37	3-4
	8 - 47	.28	
	47 - 60	.47	
Tetotum	0 - 8	.32 - .37	3
	8 - 48	.37	
	48 - 80	.28	
Thurmont 1/	0 - 8	.32	4
	8 - 48	.28	
	48 - 60	.24	

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Soil	Depth	"K"	"T"
Toccoa*			
Toxaway*			
Trego	0 - 11	.43	3
	11 - 36	.32	
	36 - 60	.28	
Turbeville	0 - 10	.28 - .32	2-3
	10 - 72	.28	
Tusquitee	0 - 10	.24	4
	10 - 48	.20	
	48 - 60	.24	
Tygart	0 - 10	.43	3
	10 - 46	.37	
	46 - 60	.32	
Tyler	0 - 9	.43	3
	9 - 18	.37	
	18 - 54	.32	
Ungers	0 - 8	.28 - .32	4
	8 - 40	.17	
	40 - 54	.17	
Unison	0 - 8	.28 - .32	4
	8 - 50	.28	
	50 - 72	.28	
Upshur	0 - 7	.43	3
	7 - 42	.28	
	42 - 73	.28	
Vance	0 - 5	32	3
	5 - 23	.37	
	23 - 60	.28	
Wagram	0 - 24	.15	5
	24 - 75	.20	
Wahee*			
Warners*			

1/ Channery, cherty, shaley, gravelly, flaggy, cobbly, rocky phases are reduced 1 class in "k" value.

Soil	Depth	"K"	"T"
Watauga	0 - 7	32	3
	7 - 28	28	
	28 - 72	37	
Watt	0 - 12	43	3
	12 - 26	28	
Weaver*			
Wedowee	0 - 4	24	2
	4 - 40	28	
Wehadkee*			
Weikert 1/	0 - 18	28	2
Westmoreland 1/	0 - 8	32 - 37	3
	8 - 32	28	
	32 - 62	17	
Westphalia 1/	0 - 10	49	3
	10 - 18	43	
	18 - 50	43	
White Store	0 - 6	43	3
	6 - 40	32	
Whiteford 1/	0 - 32	32	3
Whitley	0 - 9	32	3
	9 - 36	32	
	36 - 62	32	
Wickham	0 - 7	20	5
	7 - 40	24	
Wilkes	0 - 6	28	2
	6 - 13	32	
	13 - 40	28	
Woodstown	0 - 43	28	4

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Soil	Depth	"K"	"T"
Worsham*			
York	0 - 12	.32	3
	12 - 25	32	
	25 - 80	.43	
Zion	0 - 9	.37	2
	9 - 36	.28	
	36 - 40	17	

NOTE: The classes of "K" factors used in Virginia are 17, .20, .24, 28, 32, .37, 43, and .49.