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Erosion and Sediment Control

Surface Mining in the Eastern U.S.

Volume 1: Planning

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EROSION AND SEDIMENT CONTROL

Surface Mining in the Eastern U.S.

Planning

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CONTENTS

Volume I

LIST OF FIGURES

LIST OF TABLES

Section I

INTRODUCTION

The development of technology for the control of erosion and sedimentation has been underway for many years. Originally, the research efforts focused primarily on agriculture. Subsequently, the increasing magnitude of erosion and sedimentation problems resulting from an accelerated rate of urban expansion was recognized, and control technology was developed and tailored to those conditions. Recently, increasing public concern, combined with the greater reliance being placed on coal as America strives for energy independence, have resulted in State and Federal laws making sediment controls mandatory for surface coal mining.

PURPOSE AND SCOPE

The primary purpose of this manual is to provide guidelines that will help those engaged in surface coal mining prevent the uncontrolled movement of soil and the offsite damage it causes. The manual has been written for use by technicians, professionals, and laymen to:

- Provide them with an understanding of the mechanics of soil erosion and sedimentation and the physical factors which determine the nature and extent of these processes
- Provide them with a thorough understanding of erosion and sediment control rationale
- Familiarize them with basic control procedures, practices, and products
- Provide them with basic information on the design, construction, and utilization of control structures

This document is not a design manual, but rather a manual that presents the "how" and "why" of erosion and sediment control technology and provides general guidelines for formulating and implementing a control plan for a surface mining operation.

In addition to its primary objectives, it is expected that the manual will produce several secondary benefits. These include: (1) savings in the cost of development and maintenance activities, through proper preplanning of the mining operation; (2) avoiding offsite damage that often leads to legal action to recover damage.

The control information presented is directed primarily toward preventing excessive soil loss and resulting damage associated with coal surface mining operations in the eastern portion of the United States, specifically the Appalachian, eastern interior, and western interior coal regions (fig. I-1). However, much of the material and certainly all of the basic erosion and sediment control philosophy are applicable to all categories of surface mining in all regions of the country.

USE OF THE MANUAL

The manual consists of two volumes. The six sections in volume I cover all the basic concepts of erosion and sediment control. The text has been designed to provide the technician and the layman with a thorough explanation of the need for control, basic control principles, available technology for erosion and sediment control, and procedures for preparing and implementing a control plan.

Section II discusses and defines the nature and extent of the sediment problem and identifies the major sources of sediment generated by surface mining operations.

Section III presents the control rationale and discusses the basic philosophy underlying erosion and sediment control. The foundations of this control philosophy are made up of five erosion and sediment control principles that form a recurring theme throughout the manual.

Sections IV and V address erosion and sediment control technology. The various control practices are grouped in a functional order. The control methodology is discussed in groups having a specific purpose rather than individually. For example, erosion control practices have been grouped into the two basic functions: runoff control and soil stabilization. The intent of these two sections is to provide the reader with an insight into causative factors and basic control strategy. Emphasis is placed on providing a thorough understanding of the "how" and "why" of major categories of control rather than individual practices. References frequently are made to specific practices where appropriate. Many of these practices are discussed in greater detail in volume II.

The preparation of a control plan is covered in section VI. A step-by-step procedure for the preparation of a control plan is discussed. In presenting the procedure, discussions of legal and technical requirements, information requirements, control strategy development, preliminary sketch plan evaluation, and final control plan preparation are provided.

Section VII deals with implementation of the control plan. Inspection requirements and responsibilities are discussed, and guides for inspection and evaluation of erosion and sediment control measures are provided.

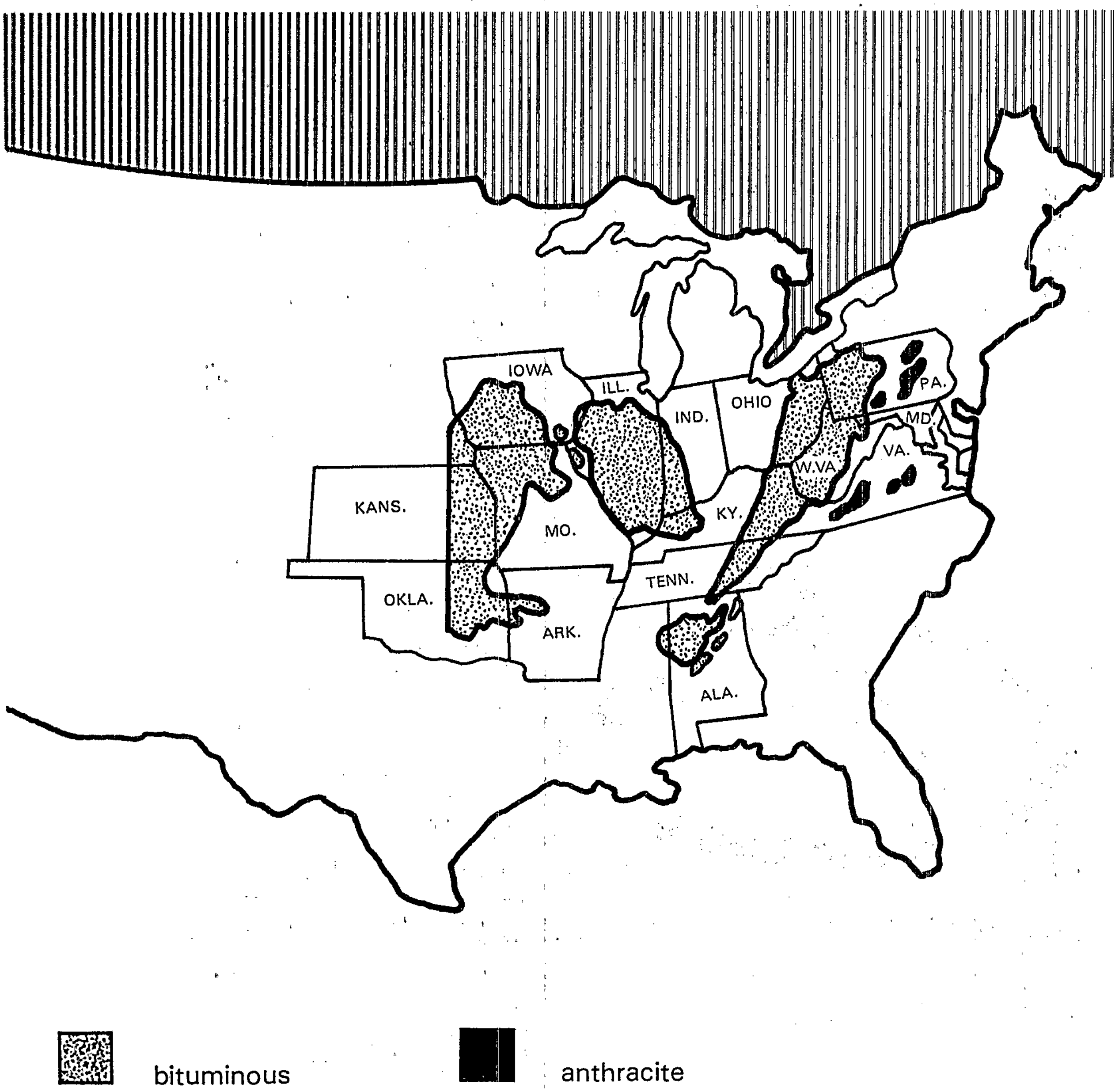

Figure I-1. Geographic area covered by manual.

Section II
THE PROBLEM

SEDIMENT AS A POLLUTANT

Surface mining operations, like all other large-scale, earth-moving operations, have the potential to generate large volumes of sediment. As long as the sediment generated is contained on the mining site, it does not present a problem. However, if it washes into neighboring watercourses, it becomes a resource-out-of-place and a pollutant by definition, as illustrated in figure II-1. Sediment is widely regarded as the greatest source of water pollution in the United States. The following is a list of some of its detrimental effects:[1]

- Occupies water storage in reservoirs
- Fills lakes and ponds
- Clogs stream channels
- Settles on productive land
- Destroys aquatic habitat
- Creates turbidity that detracts from recreational use of water and reduces photosynthetic activity
- Degrades water for consumptive uses
- Increases water treatment costs
- Damages water distribution systems
- Acts as a carrier of other pollutants (plant nutrients, insecticides, herbicides, heavy metals)
- Acts as a carrier of bacteria and viruses

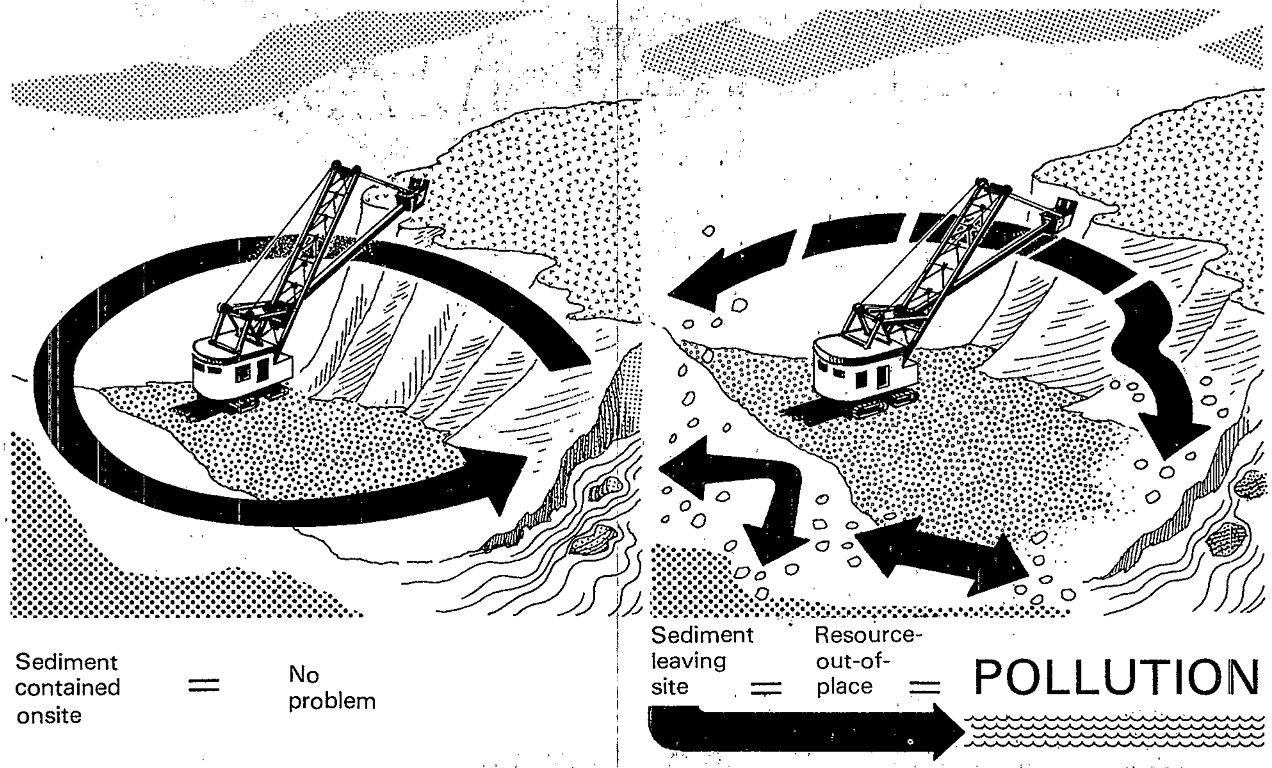

Figure II-1. Sediment as a pollutant.

Sediment can be transported long distances by high flows. But, being heavier than water, it is deposited ultimately in stream channels (fig. II-2—notice sediment buildup in lower left corner), ponds, reservoirs, and on floodplain lands. These deposits are an obstruction to navigation, water supply storage, flood control, and power generation in downstream areas. Sediment deposition also destroys the habitat of many forms of aquatic life and decreases the value of floodplain areas for recreational and agricultural uses.

Sediment is displaced soil. However, most soils in the Eastern United States do not look at all like the deposits of sand and gravel in stream and river beds. This is because the top soil layers are composed of much smaller particles that can be transported over greater distances and remain suspended in water for longer periods of time. The suspension of these particles causes turbidity that degrades the usefulness of water for many purposes and increases the costs of water treatment. Turbidity also has substantial biological effects in decreasing the amount of sunlight that reaches aquatic plants and in decreasing the oxygen that is available to fish.

That small particles of suspended sediment muddy the water is only the tip of the iceberg. These small particles are also capable of carrying some of the microscopic elements in soils along with them. Suspended sediment particles transport nutrients, fertilizers, pesticides, heavy metals, and disease organisms. This aspect of sediment pollution may have severe effects on water quality resulting in public health hazards and irreversible changes in aquatic biological systems.

Sediment pollution is costly. The annual damage from sediment in streams was estimated to be $262 million in 1966.[2] The breakdown of this cost is shown in figure II-3.

Figure II-2. Sediment deposited in a natural stream.

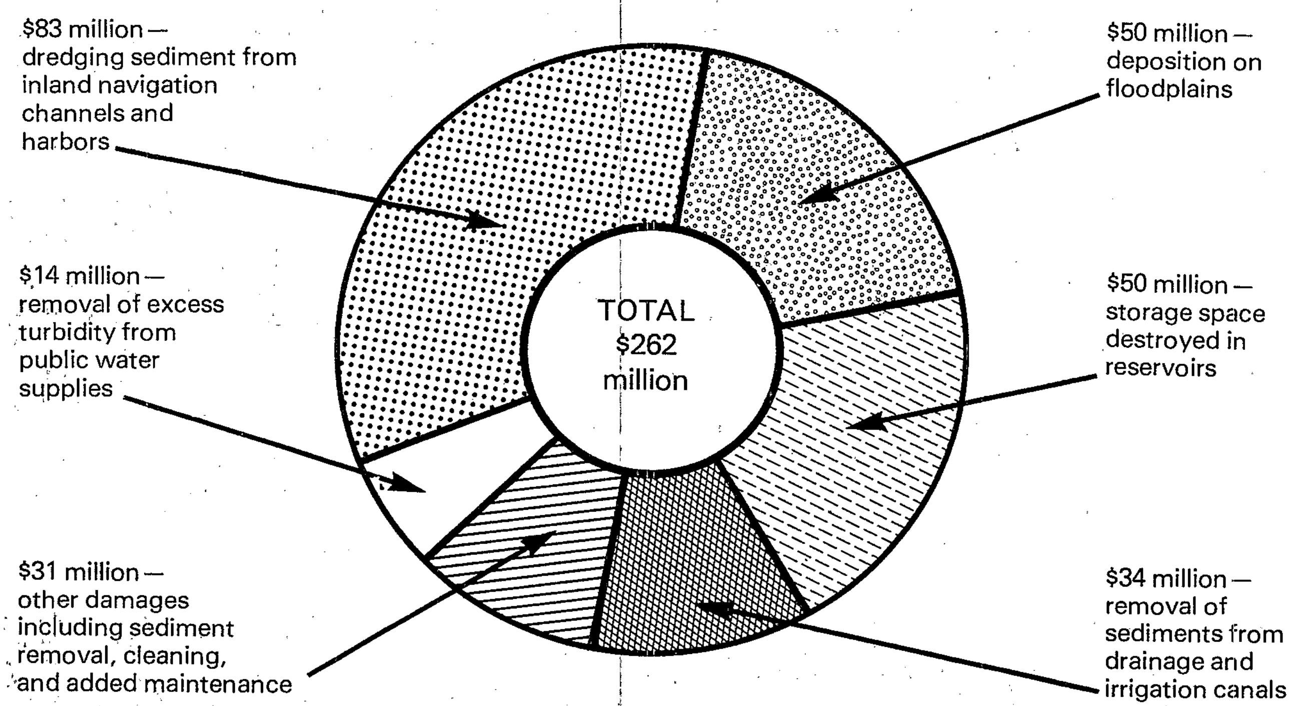

Figure II-3. Annual costs of sediment pollution.

SOURCES OF SEDIMENT POLLUTION

Land-disturbing activities associated with mining, construction, agriculture, and silviculture are the major sources of sediment. Farming, particularly crop farming, is the chief source of sediment in the United States. Fifty percent or more of the sediment deposited in streams and lakes as a result of man's activities is attributed to agricultural sources. Construction and surface mining activities, though not as widespread, can yield large quantities of sediment to nearby waterways, causing severe adverse effects. Table II-1 lists representative rates of erosion from various types of land uses. It can be seen that on the basis of a uniform area of disturbance, active surface mining operations and construction operations have the highest rates of erosion.

Table II-1.—*Representative rates of erosion from various land uses*

Land use	Metric tons per km^2 per year	Tons per mi^2 per year	Relative to forest = 1
Forest	8.5	24	1
Grassland	85.0	240	10
Abandoned surface mines	850.0	2,400	100
Cropland	1,700.0	4,800	200
Harvested forest	4,250.0	12,000	500
Active surface mines	17,000.0	48,000	2,000
Construction	17,000.0	48,000	2,000

Source: *Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants,* EPA-4030/9-73-014, Washington, D.C., U.S. Environmental Protective Agency, Oct. 1973.

SOURCES OF SEDIMENT FROM SURFACE MINING

The major sources of sediment in surface mining operations are areas being cleared, grubbed, and scalped; roadways; spoil piles and areas of active mining; and areas being reclaimed. Some common causes of sediment yield from these sources are discussed below.

Areas Being Cleared, Grubbed, and Scalped

Factors contributing to soil loss and, ultimately, water contamination from clearing and grubbing operations (fig. II-4) are:

- Failure to install perimeter control measures prior to the start of clearing and grubbing
- Exposure of soils on steep slopes
- Overclearing—clearing too far above the highwall or below the outcrop line
- Clearing and grubbing too far ahead of the pit, exposing the soil for an excessive length of time
- Improper placement and/or protection of salvaged and stockpiled topsoiling material
- Creation during clearing and grubbing operations of a soil surface that impedes infiltration and/or concentrates surface runoff (for example, leaving ripper marks or dozer cleat marks that run up and down the slope rather than along the contour)

Figure II-4. Clearing a steep slope ahead of a contour-mining operation.

Roadways (Haul and Access Roads)

Roadways are a major source of sediment from surface mining operations. This source is often given inadequate consideration in the formulation of an erosion and sediment control plan, yet roadways are often the major source of sediment, as well as a conduit for sediment washing down from other areas of the mine into the natural drainage system. Table II-2 provides an interesting comparison between the rates of erosion for different areas, including haul roads, within a monitored watershed in Appalachia.

Table II-2.—*Comparative rates of erosion*

Area	Yield (ton/mi^2)	Factor
Unmined watershed .	28	1
Mined watershed . . .	1,930	69
Spoil bank	27,000	968
Haul road	57,600	2,065

Within the mining area itself, roadways generally remain a source of sediment throughout the life of the mine, whereas adjoining spoil areas can be graded and stabilized with vegetation in a relatively short period of time. Roadways constructed outside the actual mine site to gain access to the operation are also a major source of sediment pollution over the life of the mine, and often beyond, if proper control measures are not employed. Long access roads significantly disrupt the natural drainage system. Roadways serve to intercept, concentrate, and divert surface runoff. This results in severe soil loss from roadway surfaces, ditches, cut slopes, outslopes, and safety berms. Additionally, the overall increase in the rate of runoff resulting from the construction of a relatively impermeable roadway surface, the clearing and steepening of slopes, and the interception and concentration of sheet runoff from upland areas will accelerate erosion within natural drainageways. Accelerated onsite and offsite erosion will continue to be a source of water contamination well beyond the life of the mine if, when the mine is abandoned, measures are not taken to stabilize exposed surfaces permanently with vegetation and to minimize disruption of the natural drainage system.

Factors contributing to soil loss from roadways and offsite areas affected by the roadways are outlined below:

- Poor location of the roadway, resulting in one or more of the following adverse conditions:
  - —The presence of excessively long or steep grades contributes to erosion by concentrating runoff and increasing its flow velocity.
  - —Disturbance, either by filling or excavation, of unstable slopes or areas having a high ground water table may result in landslides, muddy roadbed conditions, and revegetation problems.
  - —Failure to preserve vegetated buffer (filter) areas along waterways allows the movement of sediment from the roadway into the waterway.
  - —Creation of unnecessary, or unsuitable, stream crossings, contributes to erosion of the banks and bed of the affected waterways.
- Improper construction of the roadbed:
  - —Rutting and saturation of the roadway results from failure to provide adequate bearing capacity and/or subsurface or surface drainage (fig. II-5). These conditions are conducive to gully erosion and landslides.
  - —Failure to provide a surfacing material, such as clinker or crushed stone, or good compaction seal on suitable material, exposes the soil to the erosive action of water, wind, and traffic damage.
- Improper layout and construction of drainage structures:
  - —Failure properly to size, shape, and stabilize ditches: Improper sizing and shaping can result in increased flow velocities, which increase soil loss and the ability of the runoff to carry sediment into adjoining waterways. Lack of adequate stabilization with structures and/or vegetation makes the channel more susceptible to erosion and also provides for increased flow velocity.
  - —Improper handling and disposal of concentrated runoff: Failure properly to install culverts, or other conduits, to carry concentrated flow beneath the roadway can result in gully erosion within the ditch, flooding, and subsequent saturation of the roadway. In some instances (especially where sidehill fills are present), landslides may result. Disposal of concentrated flow, such as the runoff discharged from culverts, can cause severe gully and stream-channel erosion if stabilization and energy dissipation measures are not used (fig. II-6).

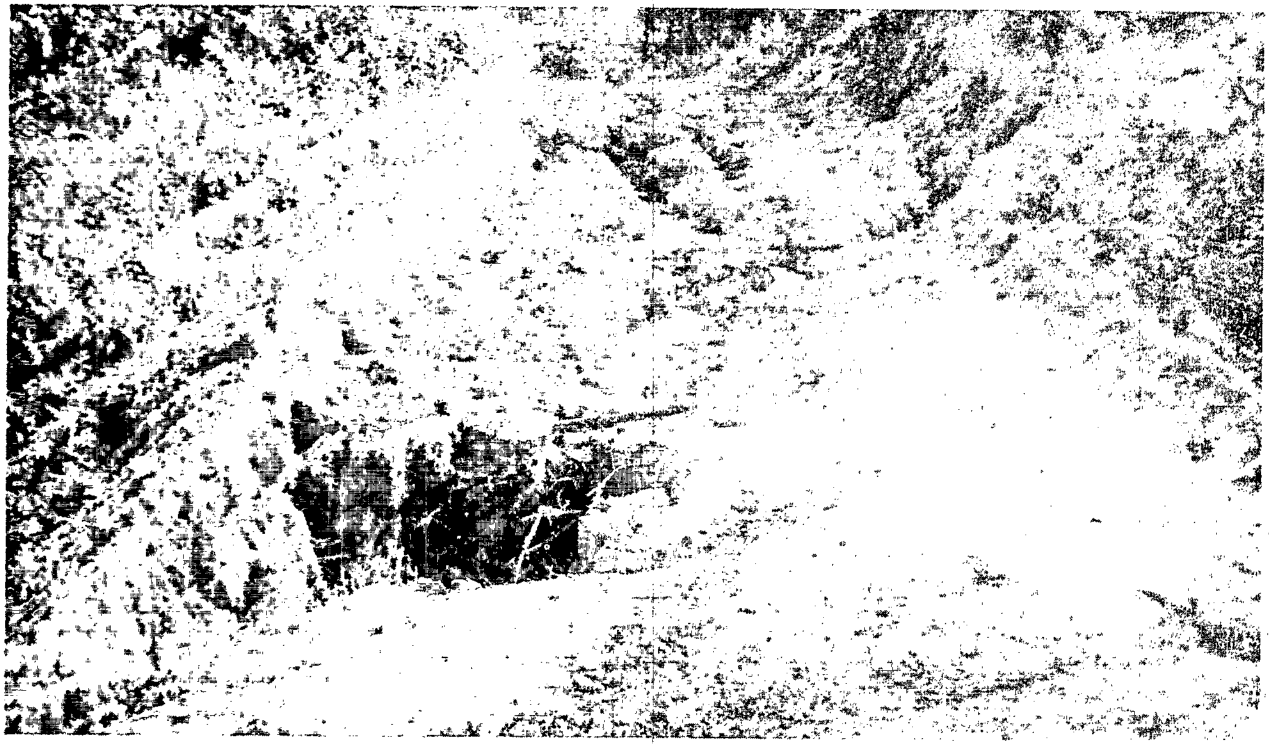

Figure II-5. Poorly drained and stabilized haul road.

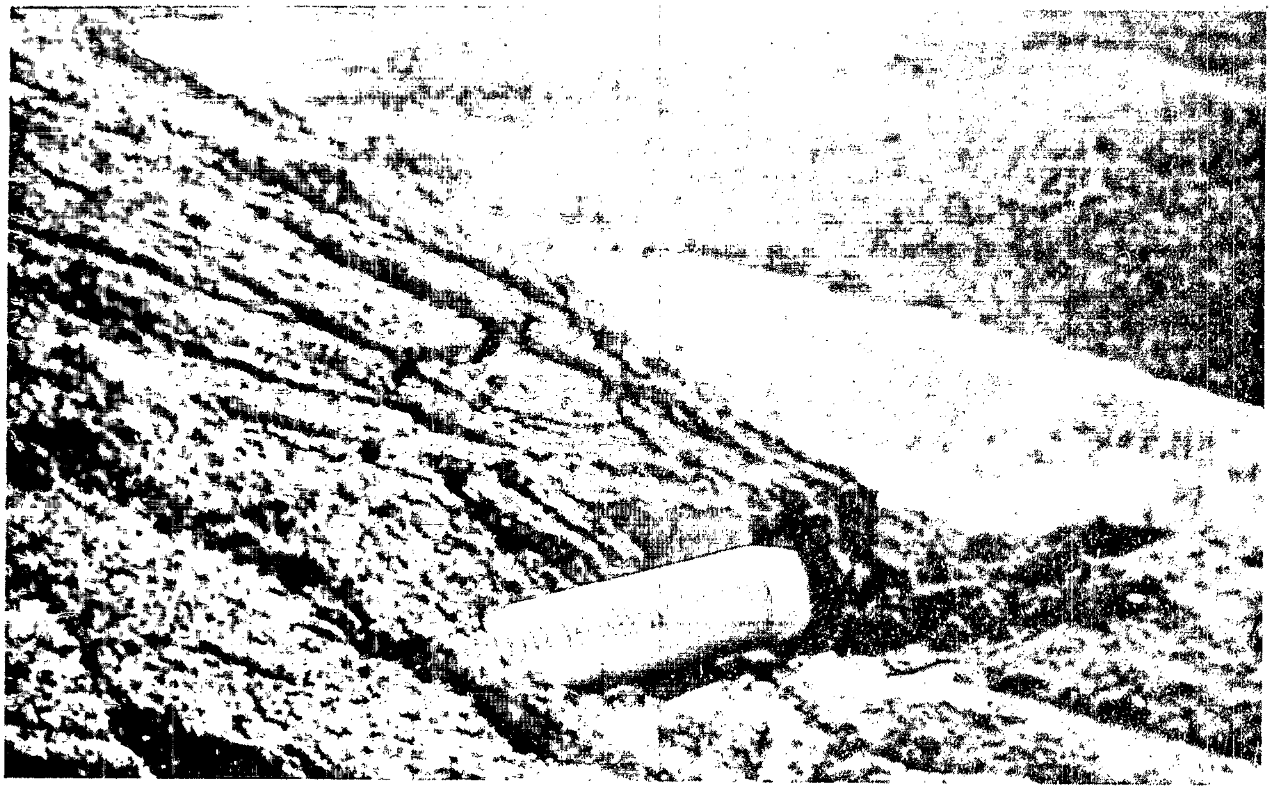

Figure II-6. Erosion at unstabilized culvert outlet.

- Poor maintenance practices:
  - —Failure to control dust during dry periods (fig. II-7): Dust particles deposited in ditches, on the roadbed, and uphill from the roadway are washed readily into adjoining drainageways during rainfall events.
  - —Pushing soil into the ditch when performing maintenance grading.
- Inadequate stabilization of cut and fill slopes:
  - —Construction of excessively steep slopes: Slopes steeper than 2:1 or 50 percent are difficult, if not impossible, to stabilize adequately with vegetation. Excessively steep slopes also increase the likelihood of landslides.
  - —Failure to establish vegetation properly: Improper selection and application of plant materials, soil supplements, and mulches along with negligent maintenance practices result in only partial protection of steep slopes.
- Failure to protect safety berms:
  - —Shaping the roadbed to allow runoff to concentrate and flow along the berm: Berms located along crowned roadways and constructed of loose overburden that is devoid of vegetative cover are particularly vulnerable to erosion.
  - —Absence of stabilized outlets, or improper placement of outlets, along the berm: Failure to provide stabilized breaks at periodic intervals along the berm will contribute to an increase in flow velocity and erosion.

Figure II-7. Fugitive dust from haul road.

Unreclaimed Spoil Piles and Areas of Active Mining

Surface mining disrupts the natural drainage system. If the disruption prevents runoff from leaving the disturbed site, the likelihood of sediment being carried into adjoining waterways is greatly reduced. However, should surface drainage from the disturbed area have uninterrupted access to the adjoining drainage system, then serious downstream sedimentation problems are a distinct possibility. The first condition is likely to be encountered over much of the mine site where area strip mining or other forms of area mining are performed. The latter condition is more prevalent with contour strip mines, particularly where a portion of the spoil is placed on the outslope.

At area strip mines, the spoil cast below the outcrop line usually has the greatest potential for causing offsite sediment damage. Water pumped from the pit during rainfall events is another significant source of sediment and other contaminants.

At contour strip mines similar conditions exist, but the overall potential for sediment damage is generally much greater. Several factors contribute to the magnitude of the problem. The most significant one is that contour mines have a narrow, linear geometry and, therefore, more spoil area drains directly into the offsite drainage system. Also, the bench area being actively mined, unlike the pit area of an area strip mine, often drains directly into the offsite drainage system. Another factor, one of extreme significance, is that the receiving waterway is generally closer to the source of sediment and separated from the source by relatively steep terrain. Additionally, the contour strip mine site receives more potentially erosive runoff from undisturbed areas at higher elevations due to the shallow soils and the linear exposure of the mined area to drainage areas above it.

In recent years, mountain-top-removal mining has been, in some areas, an alternative to contour strip mining. Due to the variability in mountain-top-removal operations, it is difficult to generalize as to the overall potential for offsite sediment damage from such operations. However, considering the areal nature of these operations and the overall reduction in relief that is achieved, the potential for offsite sediment damage is likely to be less than for a contour strip mine disturbing an equal area of land. This is particularly true when surface drainage is controlled internally (that is, within the mine site). These advantages could be offset in some instances by problems with chemical and acid pollution and landslides.

From the standpoint of soil loss and sediment damage, the most critical areas at a mountain-top-removal site are the spoil slopes around the perimeter of the site, roadways exiting from the mine, and valley or head-of-hollow fills. The fills are especially critical in that they are placed in drainageways and, consequently, are highly susceptible to piping (subsurface removal of soil), and landslides. Loss of soil from the face of the fill slope due to rainfall and runoff can be another serious problem.

Areas Being Reclaimed

While reclamation is a means of achieving overall environmental, economic (productivity), and cultural (esthetic) benefits, certain reclamation activities can be a major source of damaging sediment if they are not performed properly.

From the standpoint of potential sediment damage, the most crucial stage in the reclamation of spoil areas is from the start of grading operations to the stabilization of the spoil with vegetation and structural measures (fig. II-8). Except when the intention is to construct internal water impoundments, grading reestablishes the premining drainage system. As a result, the entire graded area and portions of the spoil piles along the perimeter become a potential source of offsite sediment damage. This condition is most significant where forms of area mining are performed—particularly at area strip mines.

The configuration of the graded areas, and the measures taken in reestablishing drainageways, also influence soil loss and offsite damage. The construction of excessively long or steep slopes, and the failure to stabilize structurally the channels of reconstructed drainageways, will aggravate the problem.

The measures taken to revegetate the graded spoils will also have a major influence on soil loss and offsite damage. Improper tillage practices, such as tilling up and down a slope rather than along the contour, will greatly increase soil loss. Even more significant are the long-term vegetative consequences resulting from improper seedbed preparation, plant material selection, and followup maintenance.

Receiving Waterways

Waterways located immediately downstream of surface mining operations are another potential source of sediment. These stream channels are not within the limits of the mining operation and are often not considered. Emphasis is generally placed on controlling erosion and sediment from the areas being mined. However, the surface mining operations can produce substan-

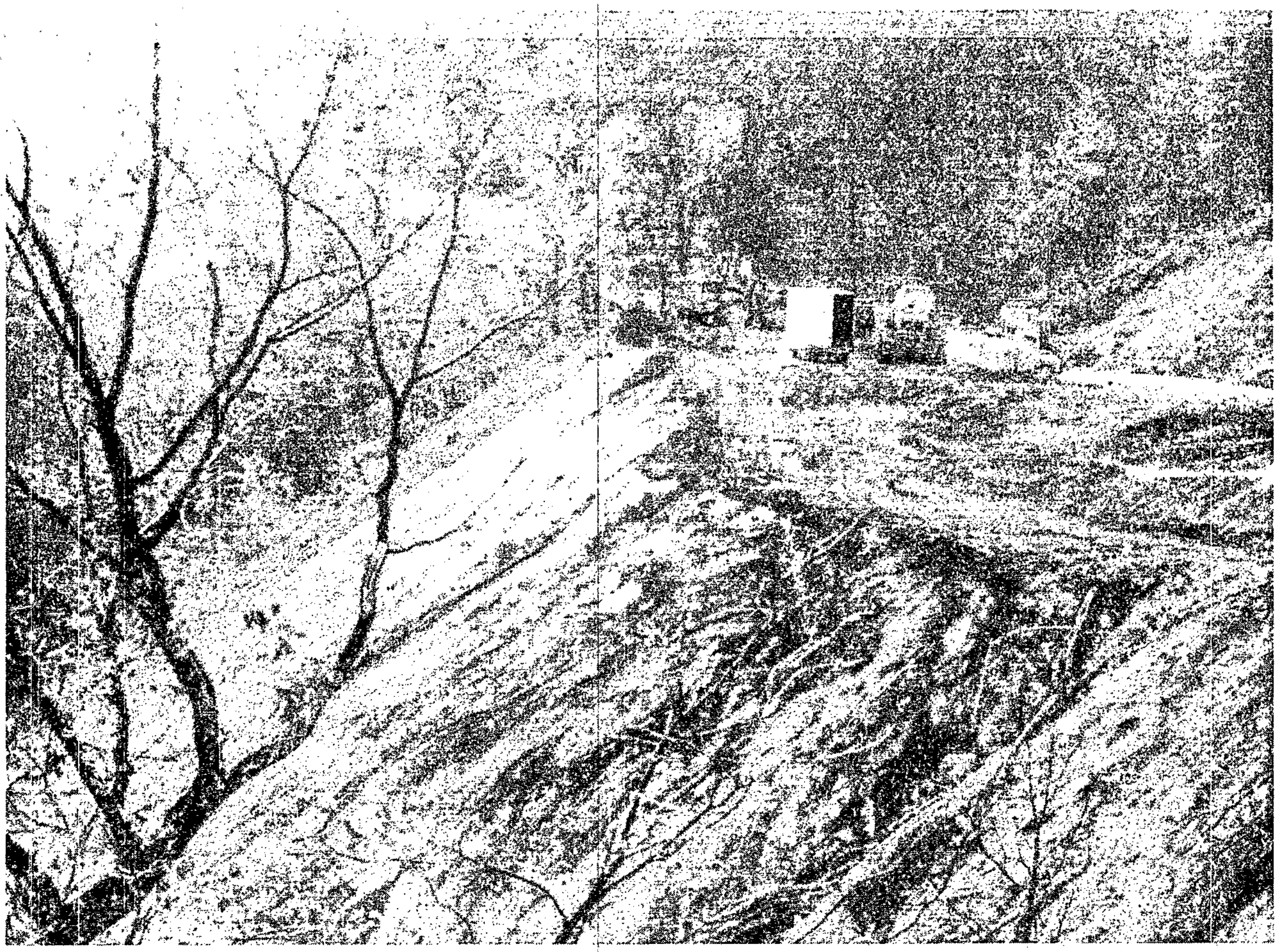

Figure II-8. Newly graded, long, steep slope, highly vulnerable to erosion.

tial modifications to the hydrologic equilibrium, especially if several operations are conducted concurrently in the same watershed. Permitting of surface mining operations is conducted on an individual basis. At present there are no limits on the number of operations and, therefore, the percentage of areal disturbance on a watershed basis.

The two most significant hydrologic modifications that impact the receiving stream channels are increases in the rates and total volume of surface runoff. Sudden changes in these two parameters of the hydrologic equilibrium coupled with the accompanying increase in sediment concentrations in the surface runoff adversely impact the stability of the stream channels. An adverse chain reaction of downcutting of the channel bottom and undercutting and sloughing of the stream banks can be triggered, which may continue to contribute sediment long after the surface mining operations are complete.

REFERENCES

[1]A. R. Robinson, *Sediment, Our Greatest Pollutant,* American Society of Agricultural Engineers, St. Joseph, Mich., Dec. 1970.

[2]J. B. Stall, "Man's Role in Affecting the Sedimentation of Streams and Reservoirs," *Proceedings of the 2nd Annual American Water Resources Conference,* American Water Resources Association, University of Chicago, pp. 79-85.

Section III

CONTROL RATIONALE

OVERVIEW

The overall goal of this manual is to help achieve effective and reasonable control over erosion and sediment problems resulting from surface coal mining activities by using the best practical combination of available technology and human resources.

Effective and reasonable control means that every effort should be made to achieve the greatest control without placing unreasonable demands on other activities at the mine. Accomplishing this requires a clear understanding of all elements of the mining operation and their interrelationships. It also means that environmental control and production objectives must be integrated when mining operations are planned.

As with other major earth-disturbing activities attributed to man, environmental damage resulting from surface mining operations must be controlled. This does not include controlling natural sedimentation processes, but only the sediment generated as a result of man's activities.

Erosion and sediment control requires: (1) a combination of workable laws, regulations, and procedures; (2) up-to-date practices and techniques; and (3) responsible people working together. Laws, regulations, and procedures must be based on technological constraints as well as environmental, social, and economic needs. However, even the best laws, regulations, and procedures are useless unless they are implemented properly. This requires thorough understanding of up-to-date control practice and techniques, a sense of public responsibility, and a cooperative attitude on the part of operators and regulatory groups.

EROSION AND SEDIMENT CONTROL PRINCIPLES

Five basic, commonsense principles govern the development and implementation of a sound erosion and sediment control plan for any surface coal mine.

- Plan the operation to fit the topography, soils, waterways, and natural vegetation at the site (see sec. VI).
- Expose the smallest practical area of land for the shortest possible time (see sec. VI).
- Apply soil erosion control practices as a first line of defense against offsite damage (see sec. IV).
- Apply sediment control practices as a second line of defense against offsite damage (see sec. V).
- Implement a thorough maintenance program before, during, and after operations are completed (see sec. VII).

These principles apply to both mining and construction and form the framework upon which the erosion and sediment control strategy for a particular mining operation is built.

Preplanning

This principle stresses the need to plan the mining operation to minimize short-term and long-term environmental damages. This implies siting the operations to avoid damage to critical site features, as well as considering site conditions, such as overburden properties and topographic features, in developing a reclamation plan. Figure III-1 shows a mined area that has been returned to its former land use through proper reclamation.

Since the primary resource (coal) is fixed, there is little flexibility in deciding where a particular mine is to be sited, other than to avoid a location where the overall environmental cost would be greater than the value of the coal recovered. Slightly more flexibility exists, however, in determining how the site will be mined. For example, should a natural outslope be excessively steep or otherwise unstable, a problem frequently encountered in the Appalachian States, the operator should use a "haulback" method of contour strip mining rather than conventional contour mining (fig. III-2). The presence of a waterway below the coal outcrop, regardless of the condition of the intervening

Figure III-1. Reclaimed mined land.

slope, could also, from the standpoint of soil loss and potential sediment damage, influence the mining methods used.

Flexibility also exists in determining the surficial features (relief, drainage, soils, plant cover, etc.) that remain after mining is complete, as illustrated in figure III-3. To avoid long-term, postmining sediment problems, these features should be designed and installed in a manner compatible with the offsite drainage system, local climatic conditions, and the physical and chemical characteristics of the spoil material. This is accomplished by conducting a thorough site investigation at the time of the premining resource (coal) investigation (sec. VI). This information is then used in determining what overburden materials must be segregated (both toxic materials to be buried and topsoiling material), the postmining land use, the allowable length and steepness of spoil slopes, the location and configuration of the postmining surface drainage system, and the types of vegetation to be used.

A thorough premining investigation of existing site features is also an essential first step in the siting, and design, of roadways leading to and from the mine. Recommended procedures for conducting the premining investigation are discussed in detail in section VI. By minimizing damage to critical features in the siting of a roadway and in designing the stormwater-handling system, both sedimentation and operational problems can be significantly reduced—providing utility and safety are also considered. A well-sited roadway is one that avoids currently or potentially unstable slopes (i.e., areas containing a high ground water table, thick alluvial soils, unstable bedrock, or old landslides), minimizes disturbance of highly erosive or plant toxic soils, reduces cut-and-fill requirements by following the ground contour, avoids unnecessary stream crossings, and preserves an adequate, undisturbed buffer along streams and other waterways.

An important factor to be considered in the design of the drainage system for the roadway,

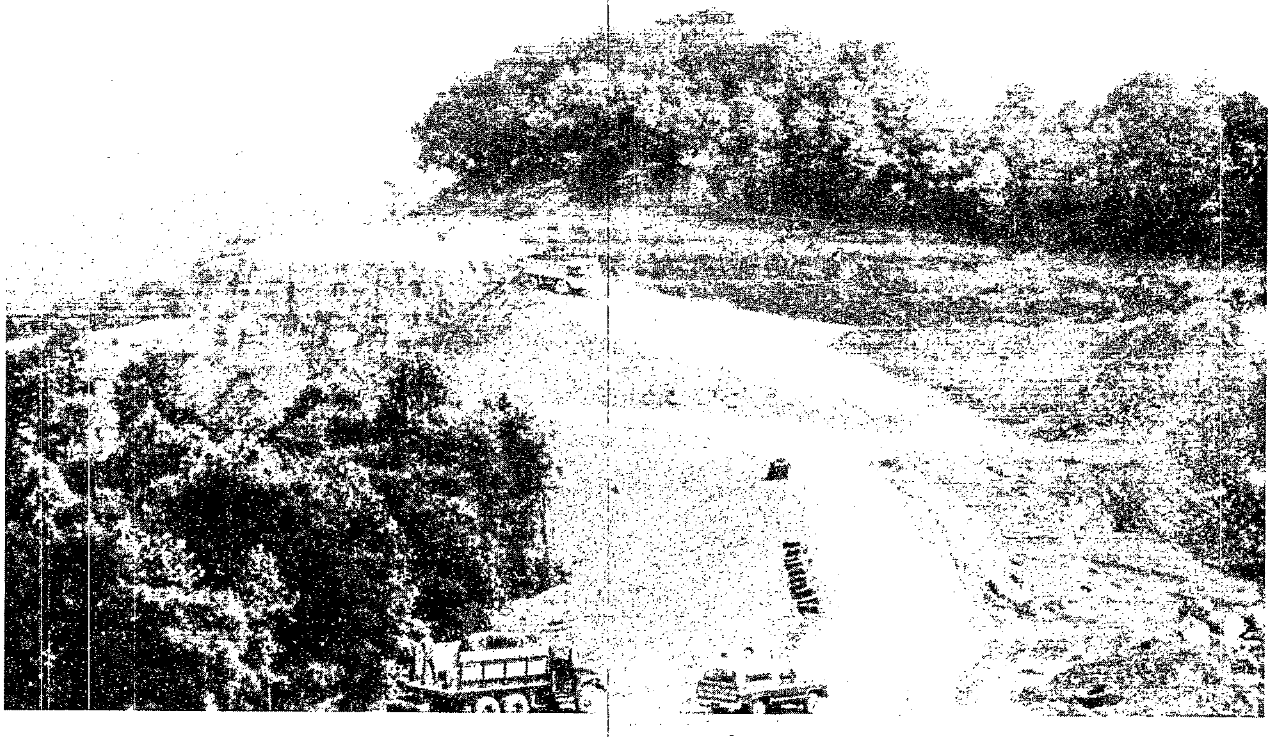

Figure III-2. Haulback contour mining in Appalachia, used to minimize site disturbance.

Figure III-3. Mined land returned to approximate original contour and used for farming.

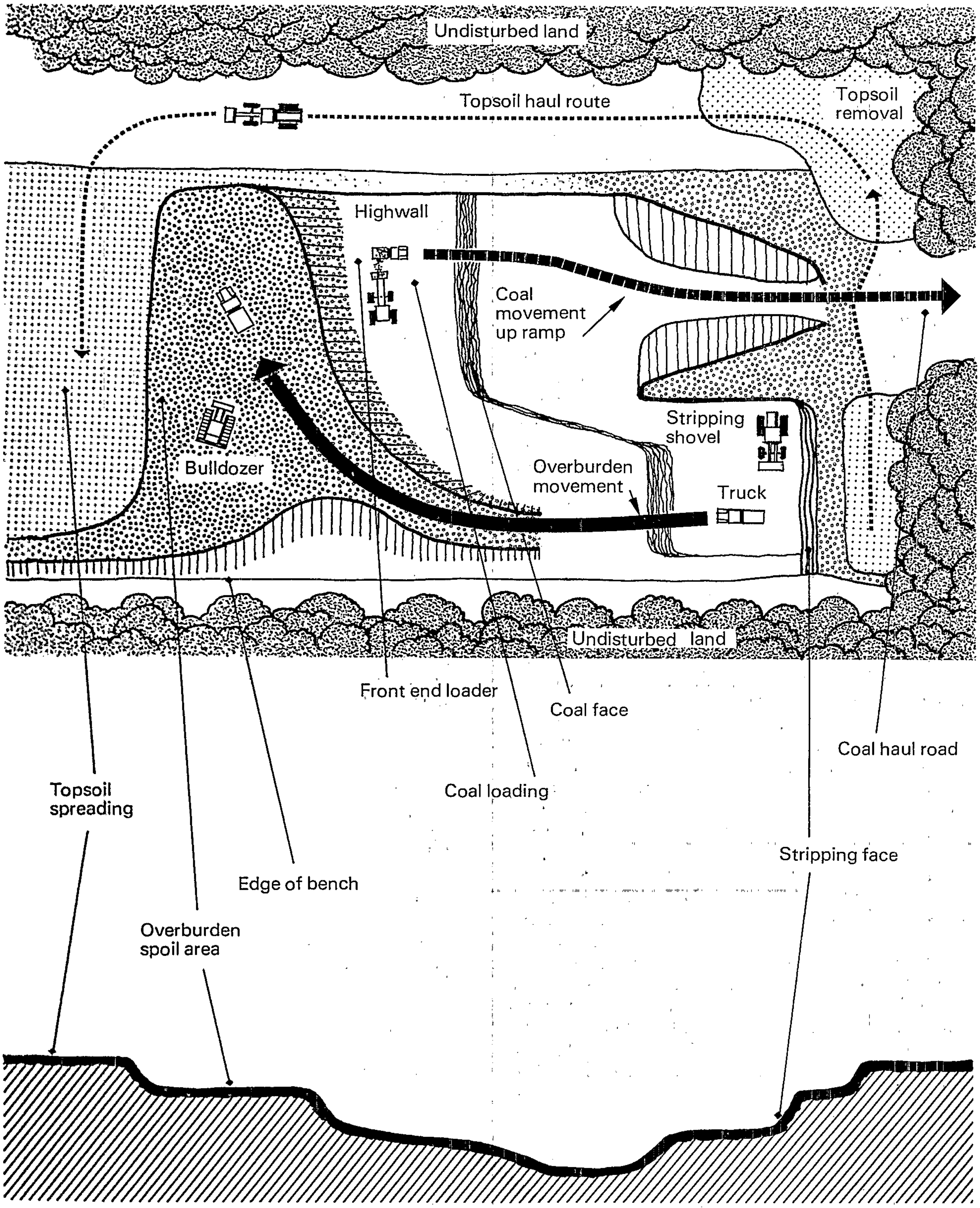

Figure III-4. Staged reclamation to minimize area of exposure. (Adapted from W. E. Coates, "Landscape Architectural Approach to Surface Mining Reclamation," Research and Applied Technology Symposium on Mined-Land Reclamation, National Coal Association (sponsor), Mar. 1973.)

is the location of stable areas on which to dispose safely of surface runoff collected and concentrated by the roadway. These include: (1) well vegetated and relatively flat areas that will tend to slow, spread, and filter the water discharged from culverts and other drainage structures; (2) well armored (bedrock or coarse, stoney soil), rough, and partially vegetated surfaces that are highly resistant to erosion and dissipate flow energy by spreading and slowing the runoff; and (3) natural drainageways that can handle increased flow with little or no increase in channel erosion.

Scheduling Mining Operations

The second erosion and sediment control principle is to expose the smallest practical area of land for the shortest possible time. The reasoning behind this principle is rather simple—1 acre of exposed land on a hillside will yield less sediment than 2 acres of exposed land on the same hillside, and an area exposed for 6 months will yield less sediment than the same area exposed for 1 year.

The manner in which various mining activities are scheduled and, in the case of area strip mining, the geometry of the pit will have a major influence on both the amount of land exposed at any one time, and the length of time it remains exposed. The mining activities having a major effect are, clearing, grubbing, scalping, and reclamation (fig. III-4).

The clearing, grubbing, and scalping of excessively large areas of land ahead of the active pit or bench is an unnecessary invitation to sediment problems. These initial earth-disturbing activities should progress with the pit or bench, and only far enough ahead to prevent a disruption in the overall flow of events at the mine.

Reclamation should be kept current with extraction operations and follow as close to them as possible. This reduces the amount of mine area exposed at any one time and length of time the spoil remains exposed. Scheduling of reclamation operations is an essential element in controlling erosion and sediment on any surface mining operation. Freshly graded areas, particularly steep or long slopes, are highly erodible and require quick stabilization. Care should be taken to final grade and stabilize spoil areas promptly, particularly outslopes, and concentrate land preparation (clearing, grubbing, etc.), extraction, and reclamation activities to as small an area as practical.

Where "head-of-hollow" fills are constructed, the face of the fill should be stabilized promptly at the completion of the construction of each step or bench, beginning at the toe of the fill, and progressing upwards (fig. III-5). Staging the revegetation operations in this manner provides a filter for trapping sediment from runoff coming from higher unprotected areas, as well as preventing rainfall and runoff from removing soil from lower sections of the slope.

The total amount of land exposed to the erosive actions of water and wind and the length of time the disturbed area remains exposed are also influenced by the geometry of the pit or bench cut. This fact has been recognized by various States in their regulations. A reduction in either the length or width of the pit, or cut, all other factors (i.e., rock strata, coal thickness, etc.) remaining nearly equal, will decrease both the area of land exposed and the length of exposure. This is a particularly significant consideration when planning an area strip mine.

Erosion Control

The third important control principle is to apply soil erosion control practices as a first line of defense against offsite damage. This principle relates to using practices that control erosion on a disturbed area to prevent excessive sediment from being produced. The operator's success in preventing sediment from being generated will have a direct bearing on the cost and effectiveness of sediment containment measures and, ultimately, on the extent of offsite damage from sediment. Control does not begin with the perimeter sediment basin, as is too often thought; it begins at the source of the sediment and extends down to the basin.

Soil particles become sediment when they are detached and moved from their initial resting place. This process, which is called erosion, is accomplished for the most part by the impact of falling raindrops and the energy exerted by moving water and wind, especially water. A reduction in the rate of erosion (soil loss) is achieved by controlling the vulnerability of the soil to erosion processes or the capability of moving water or wind to detach soil particles. In humid areas, this is accomplished through the use of "soil stabilization" and "runoff control" practices. Soil stabilization practices include a variety of vegetative, chemical, and structural measures used to shield the soil from the impact of raindrops or to bind the soil in place, thus preventing it from being detached by surface runoff or wind action (fig. III-6). Runoff control practices, on the other hand, include a number of measures designed to reduce the amount of runoff that is generated on a mine site, prevent offsite runoff from entering the mine site, or slow the runoff moving through and exiting from the mine site (fig. III-7). A

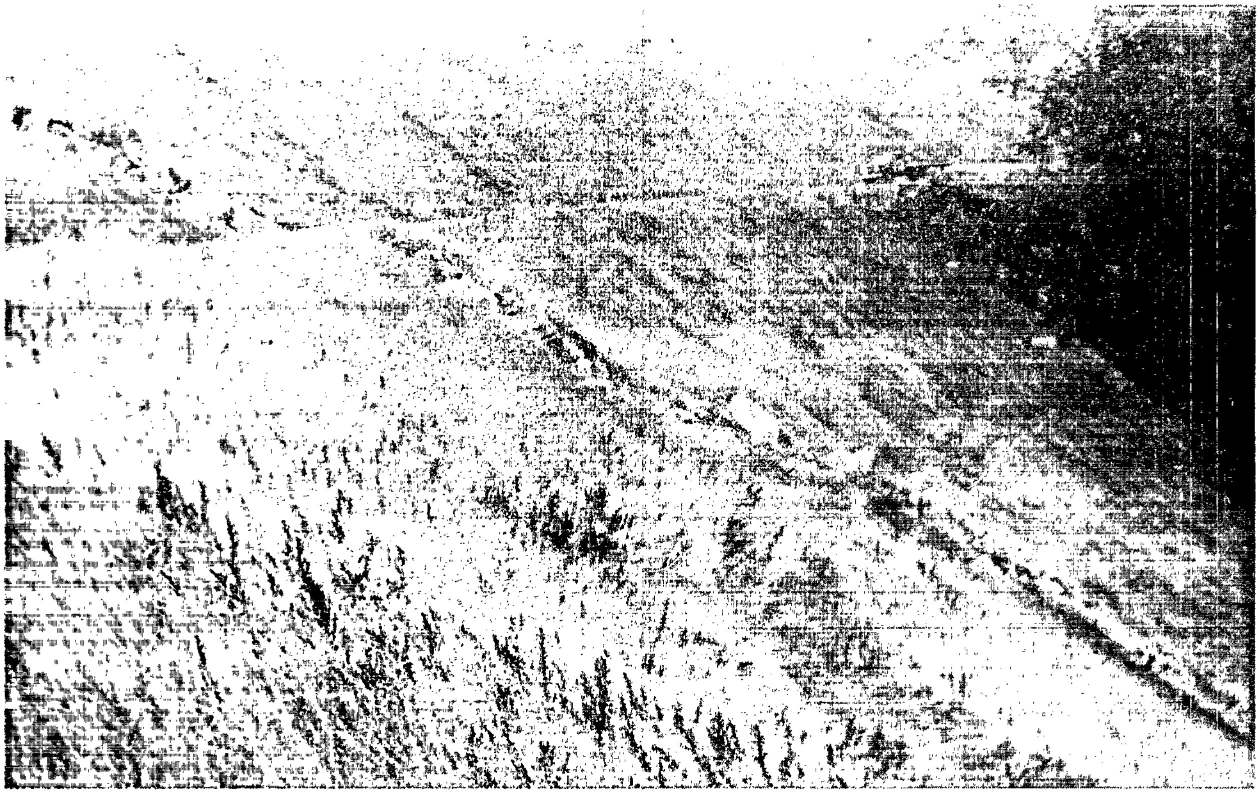

Figure III-5. Well-stabilized outslope on head-of-hollow fill.

Figure III-6. Closeup of mine spoil stabilized with vegetation to reduce soil loss.

more detailed discussion of erosion control practices can be found in section IV and in volume II.

Sediment Control

The fourth principle is to apply sediment control practices as a second line of defense against offsite damage. Even with the best erosion control plan, some sediment will be generated, and controlling it is the objective of this principle.

Whereas erosion control practices are designed to prevent soil particles from being detached, sediment control involves using practices that prevent the detached particles from leaving the mine site and getting into receiving waterways. This is accomplished by reducing the ability of surface runoff to transport sediment and by containing the sediment onsite.

Sediment control practices are designed to slow the flow of water by spreading, ponding, or filtering. By so doing, the ability of the water to transport sediment is reduced, and sediment settles out of suspension. Commonly used control practices include: (1) the preservation or installation of vegetated buffer areas downslope of the mine to slow and filter runoff (fig. III-8); (2) the construction of small depressions or dikes to catch sediment (particularly coarse-textured material) as close to its point of origin as possible; and (3) the construction of larger basins at the perimeter of the mine site to capture additional sediment from the runoff (fig. III-9).

The amount of sediment removed from the runoff is mostly dependent upon (1) the speed at which the water flows through the filter, trap, or basin; (2) the length of time the water is detained; and (3) the size, shape, and weight of the sediment particles.

Maintenance and Followup

The final important control principle is to implement a thorough maintenance and followup operation. This principle is vital to the success of an erosion and sediment control program. A site cannot be controlled effectively without thorough, periodic checks of all erosion and sediment control practices. When inspections reveal problems, modifications, repairs, cleaning, or other maintenance operations must be performed expeditiously (fig. III-10).

Particular attention must be paid to water-handling structures (such as, diversions, sediment traps, grade control structures, and

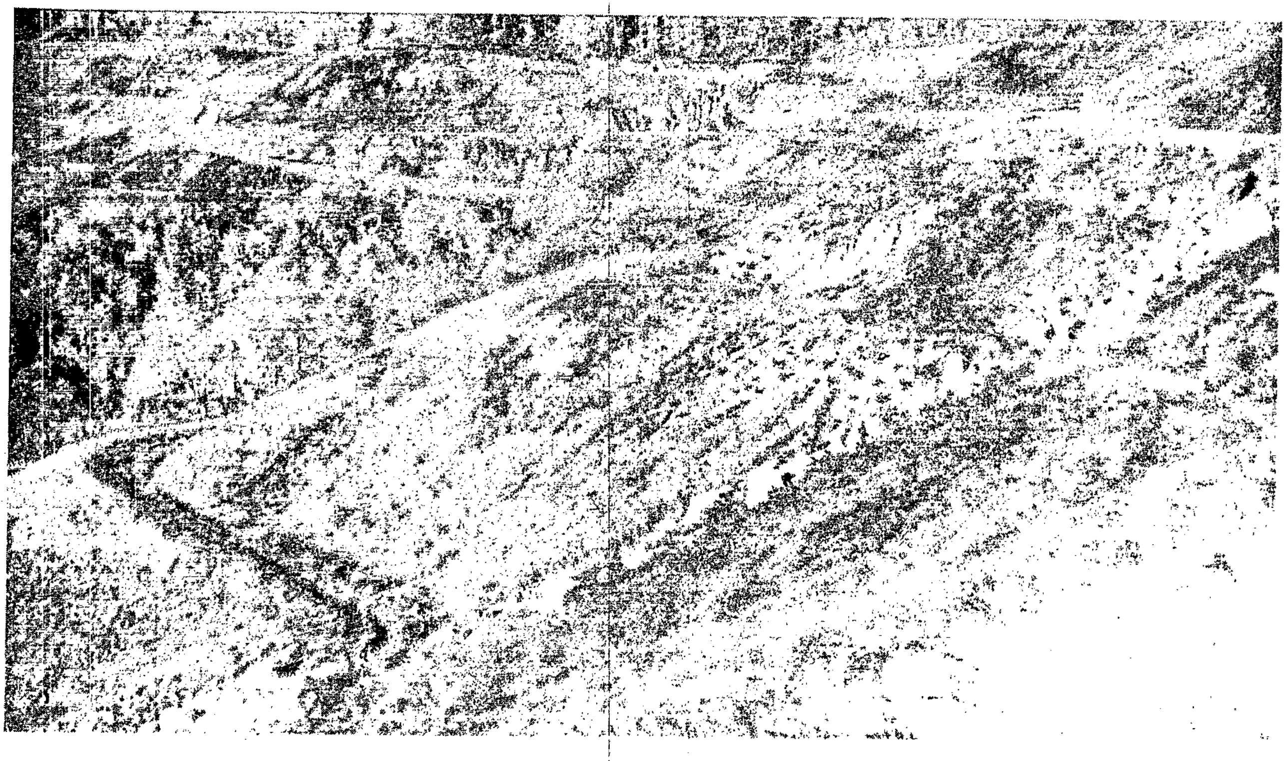

Figure III-7. Reverse benches or terraces used to control runoff on long slopes.

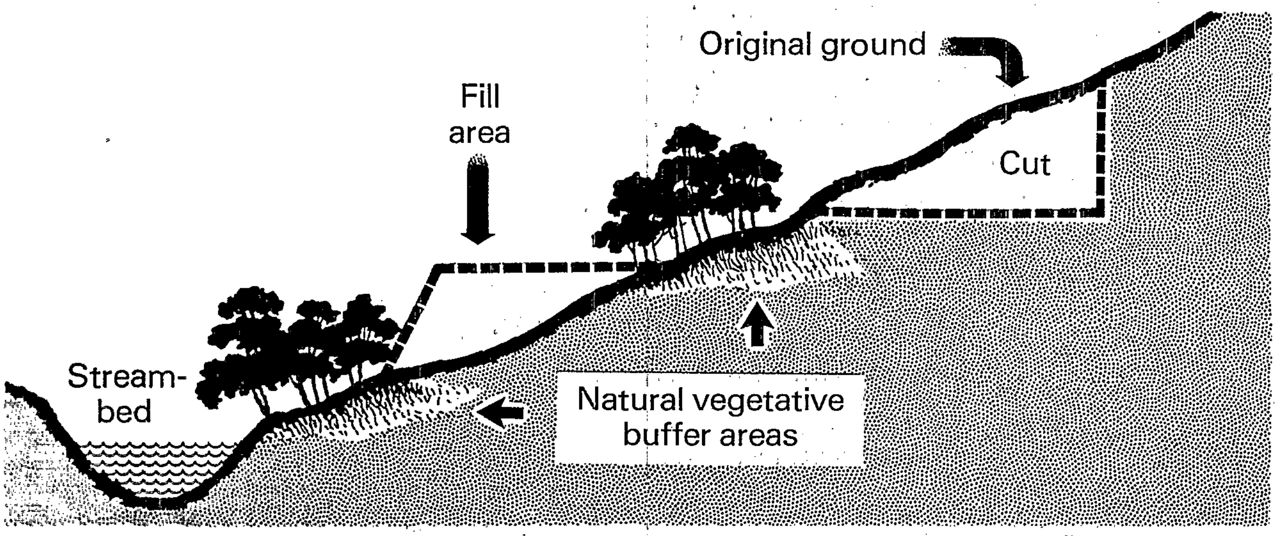

Figure III-8. Vegetative buffer.

Figure III-9. Sediment basin used to trap sediment coming from mine site.

sediment basins) and areas being revegetated. Breaches in the structures or areas being revegetated must be repaired quickly, preferably before the next rainfall. When sediment containment structures fill to capacity, they must be cleaned promptly, and the sediment disposed of in a manner that will not allow it to be reintroduced into the drainage system. Disposal may include burying the sediment in the mine, spreading it thinly on stable slopes just prior to seeding and mulching, or placing it upslope behind stabilized soil dikes.

The maintenance program must also consider postmining conditions. To avoid the possibility of major damage occurring after the coal has been mined, the control plan should contain provisions for removing sediment traps and basins from the drainageways once a stable ground cover has been established on the site. Unless required for other purposes, and the postmining landowner is willing to continue maintenance, all access roads should be planted with vegetation, and stable, open drainageways provided to carry runoff across the right-of-way to stable disposal areas.

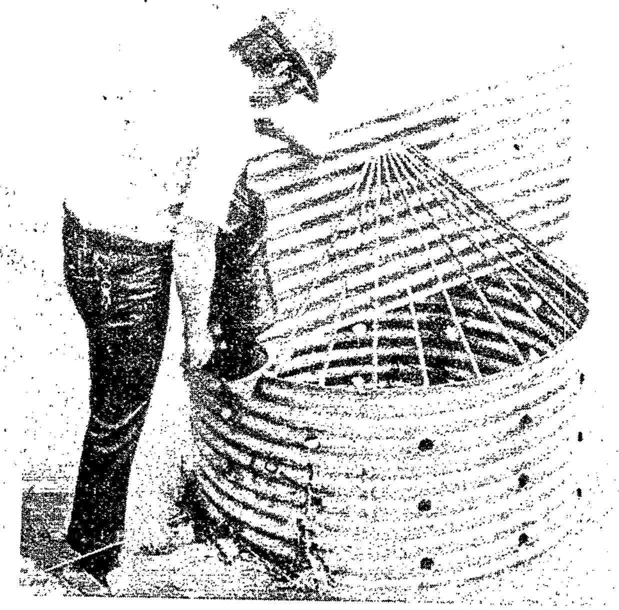

Figure III-10. Inspection of riser pipe on sediment basin.

Section IV
EROSION CONTROL

This section presents the basic concepts and practices associated with controlling erosion at surface mine operations. The section begins with a presentation of the basic types of erosion that are commonly encountered. These include sheet erosion, rill and gully erosion, stream channel erosion and wind erosion. Next, the various factors that influence erosion are discussed. They include climate, vegetative cover, soil characteristics and topography. The remainder of the section presents the numerous practices available to control soil erosion on coal surface mining operations. The practices have been organized into two major groupings—erosion control practices and soil stabilization practices. In addition, the methodology for vegetative establishment and maintenance requirements of erosion control practices and materials are provided.

TYPES OF EROSION

Soil erosion is the detachment and movement of soil by the action of water, ice, gravity, or wind (fig. IV-1). Of these, erosion by water is by far the problem most frequently encountered. This manual addresses itself principally to the types of erosion that are caused by the forces of falling and moving water. Three basic types of overland erosion by water are usually recognized: splash or sheet, rill, and gully. Stream channel erosion also occurs.

Sheet Erosion (fig. IV-2)

The impact of raindrops upon a soil surface causes soil particles to be dislodged. Under conditions of heavy rainfall, the detaching action of the raindrop is an important part of the erosion process. Raindrop impact and the resulting splash can throw a soil particle as high as 2 feet and move it horizontally 4 or 5 feet. A very heavy rain may detach as much as 100 tons of soil from an acre of exposed surface.[1] Rain striking a bare soil surface results in the following conditions:

- Soil structure at ground surface is destroyed, and crusting and hardening of the soil surface occur.
- Soil particles are detached, displaced, and transported in runoff water.

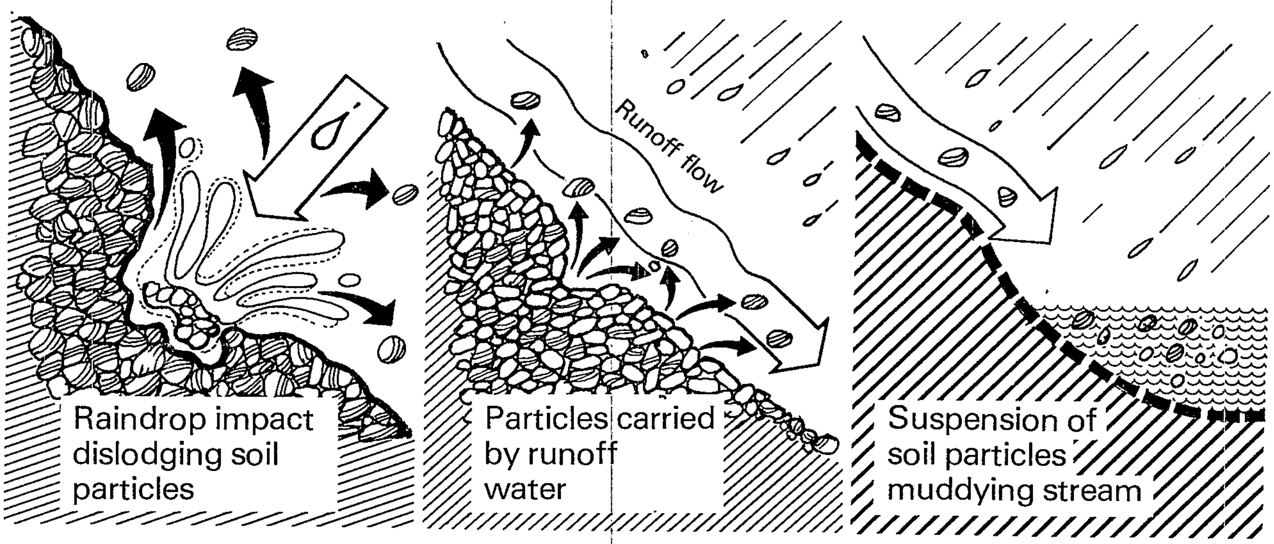

Figure IV-1. Soil erosion process.

Figure IV-2. Severe sheet erosion from raindrop impact and splash.

Figure IV-3. Rill erosion.

- Infiltration decreases as a result of surface compaction and sealing; this causes increased runoff and further detachment of soil and transportation, and downslope deposition of sediment.

Rill and Gully Erosion

Rill and gully erosion are very similar and differ principally in size. Rill erosion refers to the removal of soil by water from small, well-defined channels when there is concentrated flow (fig. IV-3). This type of erosion is intermediate between sheet and gully erosion, and is most noticeable on bare, freshly graded, or newly seeded spoil. Rills develop where runoff concentrates because of topographic variations, tillage marks, or random irregularities that affect flow patterns. Rills can be eliminated with normal tillage equipment.

Gullies are the result of unchecked erosion and cannot be removed by tillage equipment. Gully erosion occurs when water accumulates in narrow channels and, over short periods, removes the soil from these channels to depths ranging from 1 or 2 feet to as much as 75 to 100 feet (fig. IV-4).

Figure IV-4. Severe gully erosion on mine spoil.

Stream Channel Erosion

The erodibility of a stream channel is influenced by the nature of the bottom and side material, the stream gradient, and the alignment. Runoff water entering into a stream or channel not only transports material, it also becomes an eroding agent (fig. IV-5). Stream channel erosion (scour) results from three processes:

- *Hydraulic action* involves the force of the water striking against the bottom and banks of the waterway. Streams with steep gradients, unarmored channels, and sinuous courses are most susceptible to erosion by hydraulic action.
- *Solution* is the actual dissolving of material by the water.
- *Corrasion* is the hitting or rubbing of soil and rock particles in transport against the sides and bottom of the channel resulting in the detachment of in-place particles. Corrasion is most prevalent in fast-flowing streams.

The nature of the bottom and side material, in particular its texture and structure, will influence the rate of channel erosion. Strongly bonded, cohesive soils are generally less erodible than loose, fine-textured, granular soils.

Wind Erosion

Wind erosion occurs primarily when the soil's moisture content is lowered, and wind is able to detach and transport light, dry particles. Dust is a problem at many mines. The major source of dust from wind erosion at surface mines is generally haul roads. Other sources of fugitive dust include excavation activities, blasting, loading, and hauling. Trucks passing over dry soil raise dust that is transported by wind to offsite areas and directly or indirectly, to some extent, into waterways.

FACTORS INFLUENCING EROSION

There are four basic sets of factors that determine the erosion potential of any area. These are climate, vegetative cover, soil properties, and topography. Although these four factors are discussed separately, it is their combined influence that determines the erosion potential.

Climate

Precipitation, temperature, and wind are the principal climatic elements that influence erosion. Precipitation and its associated runoff are the most important of these elements from the standpoint of erosion control. The seasonal distribution, frequency, duration and intensity of rainfall that occur vary for each particular region.

Runoff is that portion of the rainfall or other precipitation that makes its way toward stream channels as surface and subsurface flows. Surface runoff occurs only when the precipitation exceeds the rate at which water can infiltrate the soil (fig. IV-6).

Temperature influences runoff. Precipitation that falls in the form of snow does not create erosion. However, in the springtime the combination of snowmelt and partially frozen ground results in considerably higher runoff volumes, thus creating a serious erosion hazard.

Figure IV-5. Stream channel erosion.

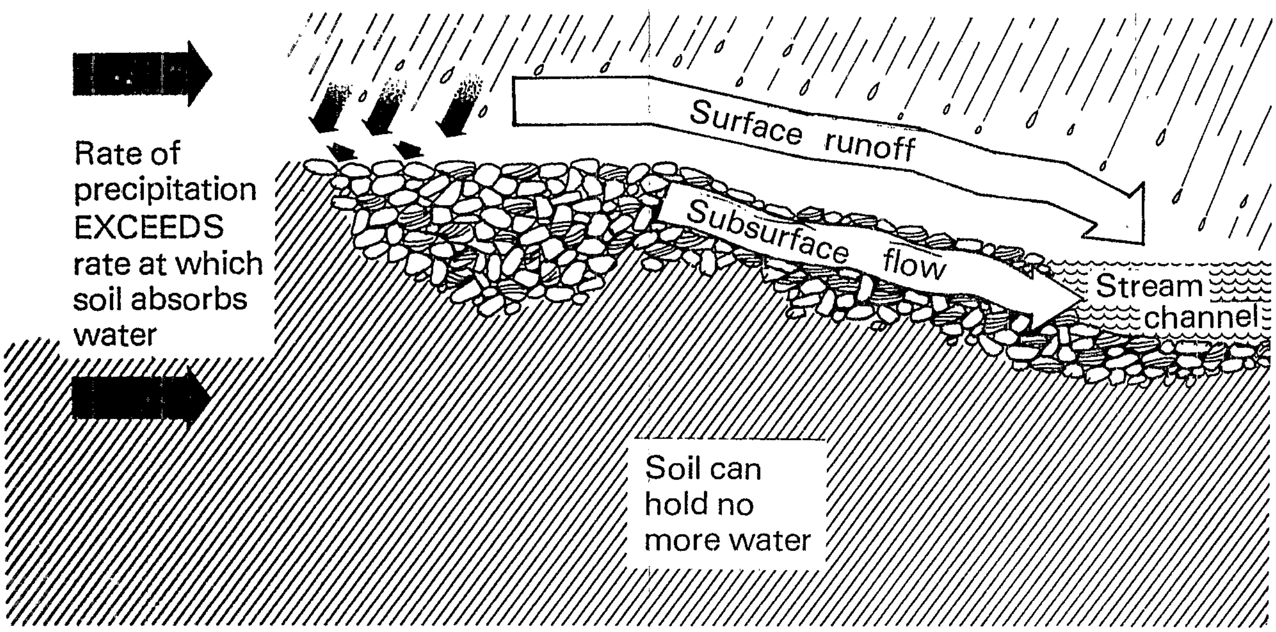

Figure IV-6. Surface runoff.

Vegetative Cover

Vegetation plays an important part in reducing erosion. When vegetation is removed from the soil surface, the primary defense against soil erosion is destroyed. The benefits of a cover of vegetation are:

- The soil is shielded from raindrop impact, thus preventing the removal of soil particles and sealing the surface soil.
- The surface cover slows the movement of surface water, thus giving the water additional time to infiltrate into the soil.
- The root system binds the soil together and makes it more pervious (fig. IV-7).

Figure IV-7. Soil particles are bound together by root system.

Soil Characteristics

Runoff and erosion vary from site to site depending upon the characteristics of a particular soil. The erosion potential of a soil is dependent on:

- Soil structure
- Soil texture
- Organic matter content
- Moisture content
- Permeability

Soil Structure. Soil structure is the arrangement of particles into groups. The structure of any soil affects the intake of water and air. Whenever the surface layer of soil becomes puddled, crusted, or otherwise compacted, the danger of runoff and erosion increases. Forested and cultivated soils often have subsurface layers of consolidated material called "hardpans," which inhibit the downward movement of water. The removal of overburden, as in the case of mining, breaks up hardpan layers and allows for a more porous and unconsolidated soil to be reconstructed.

Soil Texture. Soil texture refers to the sizes and proportions of various sizes of particles making up a particular soil. Soil textural classes are generally made up of sand, silts, and clays. Sand particles are the largest, silts are intermediate, and clays are the finest. The various sizes of soil particles and soil textural class names are given in tables IV-1 and IV-2.[2]

Table IV-1.—*Size limits of soil separates*

U.S. Department of Agriculture scheme	
Name of separate	Diameter (range)
	Millimeters
Very coarse sand[a]	2.0 -1.0
Coarse sand	1.0 -0.5
Medium sand	0.5 -0.25
Fine sand	0.25-0.10
Very fine sand	0.05-0.05
Silt	0.05-0.002
Clay	Below 0.002

[a]Prior to 1947 this separate was called fine gravel. Now fine gravel is used for coarse fragments from 2 mm to 1.27 cm in diameter.

Source: U.S. Department of Agriculture, Soil Survey Staff, *Soil Survey Manual,* USDA Handbook No. 18, Aug. 1951.

Table IV-2.—*Basic soil textural class names*

General terms	Basic soil texture class names
Sandy soils: Coarse-textured soils	Sands Loamy sands
Loamy soils:	
Moderately coarse-textured soils	Sandy loam Fine sand loam
Medium-textured soils	Very fine sandy loam Loam Silt loam Silt
Moderately fine-textured soils	Clay loam Sandy clay loam Silty clay loam
Clayey soils: Fine-textured soils	Sandy clay Silty clay Clay

Source: U.S. Department of Agriculture, Soil Survey Staff, *Soil Survey Manual,* USDA Handbook No. 18, Aug. 1951.

Sand, when dominant, forms a coarse-textured or "light" soil that allows water to infiltrate more rapidly. Silts and clays make up fine-textured or "heavy" soils, and are often quite cohesive and slow to erode. These soils are frequently the worst polluters, because fine-grained particles travel farther and may be held in colloidal suspension. Also, the clay-sized particles are the most difficult to settle out of suspension and may require tremendously large basins in order to conform to water quality criteria. Soils that are high in silt and fine sand and low in clay and organic matter are generally the most erodible.[3]

Organic Matter. Organic matter is plant and animal residue in various stages of decomposition. The organic matter content of a soil affects its erodibility. As the amount of organic matter increases, the ability of the soil to absorb surface water increases and runoff is reduced, thus minimizing erosion.

Moisture Content. The moisture content of a surface soil is a reflection of its moisture-holding capacity. The ability of a soil to hold water depends on its texture, permeability, depth, and organic matter content. Soils that are able to hold large quantities of water are desirable from a plant growth standpoint, although some clays with excessive moisture-holding capacity could be a problem. Soil wetness also influences runoff. As a soil fills with water, runoff increases.

Permeability. The permeability of soil refers to its ability to allow water and air to move through it. Soils with a high degree of permeability on a short slope may have slow runoff, while a soil with less permeability on an identical slope may have rapid runoff.

Topography

Topographic considerations for erosion control include slope steepness and length. As slope steepness increases, there is a corresponding rise in the velocity of the surface runoff, which in turn results in greater erosion (fig. IV-8). A doubling of the velocity of water produced by increasing the degree and length of the slope enables water to move soil particles 64 times larger, allows it to carry 32 times more soil material, and makes the erosive power, in total, 4 times greater.[1]

Long, unbroken slopes allow surface runoff to build up and concentrate in narrow channels, producing rill and gully erosion. For equal areas, doubling the length of a slope increases the soil loss 1.5 times. Long slopes in gently sloping terrain will also erode easily unless broken up by diversions, structures, or other means.

RUNOFF CONTROL

Stormwater runoff is the principal cause of soil erosion. Stormwater runoff control is achieved through the proper use of vegetative and structural practices, and construction measures that control the location, volume, and velocity of runoff, in combination with a sound program for scheduling various mining operations to minimize problems associated with seasonal climatic fluctuations. Proper stormwater handling for erosion control can be accomplished in one or a combination of the following ways:

- Reduction and detention of the runoff
- Interception and diversion of runoff
- Proper handling and disposal of concentrated flow

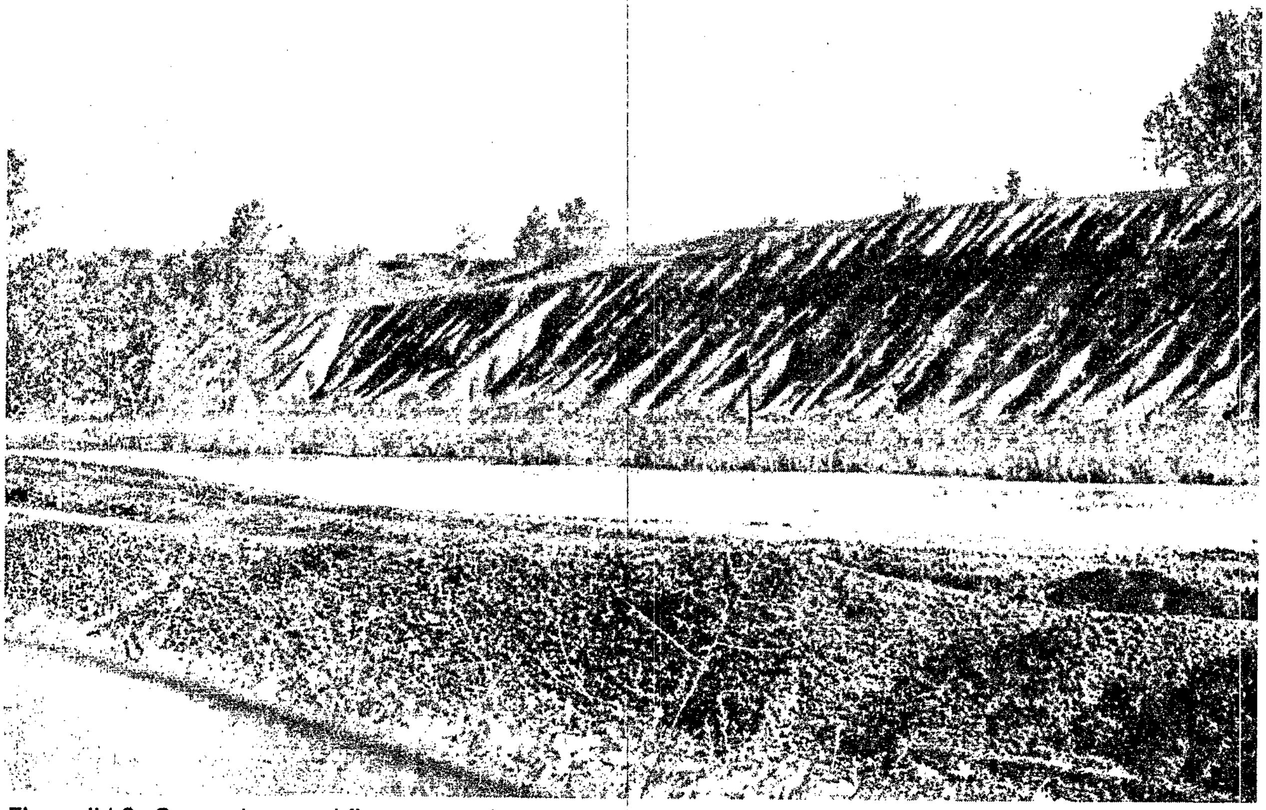

Figure IV-8. Steep slope and fine-textured, structureless nature of a loessial soil contributed to severe erosion at this mine in the Midwest.

Reduction and Detention

A reduction in both the amount of runoff and its speed of movement can be accomplished by staging the operations to reduce the time and area of exposure, by manipulating the slope length and gradient to reduce the velocity of flow and rate of runoff, and by manipulating the surface soil to detain the water and to increase the infiltration rate.

Staging Operations. The staging of clearing, grubbing, scalping, grading, and revegetation operations to minimize the amount of disturbed surface area is an effective way of reducing the volume of surface runoff. Barren soil produces much more surface runoff than a soil that is well protected with vegetal cover. The various stages of the mining operation should be scheduled so that clearing, grubbing scalping, grading, and revegetation are kept concurrent with extraction operations, and a minimum area is exposed at any one time. To the extent possible, areas of natural vegetation should be preserved to act as buffer zones along streambanks, below spoil disposal sites, around the perimeter of disturbed areas, and above and below access roads. These areas will slow and filter the runoff coming from the disturbed areas and, thus, trap some sediment.

Grading and Shaping of Soil Surface (fig. IV-9). The soil surface can be graded and shaped to reduce and detain runoff. This includes roughening and loosening the soil, mulching and revegetation, and topsoiling and soil amendment. All final grading should be performed on the contour. Backblading that results in a smooth compacted surface should always be avoided.

A properly roughened and loosened soil surface will enhance water infiltration, slow the movement of surface runoff, and benefit plant growth (fig. IV-10). Common methods of loosening and/or roughening a soil surface include scarification, tracking, and contour benching or furrowing. Other methods being practiced include gouging, dozer basins, and chiseling. Scarification is usually accomplished by discing or harrowing along the ground contour, but can also be performed by a crawler tractor equipped with grosser bars, or by dragging the bucket teeth of a front-end loader over the ground.

Tracking is performed on steep slopes where equipment cannot be safely moved along the ground contour (fig. IV-11). It is accomplished by running a cleated crawler tractor up and down the slope. The cleats leave shallow grooves that run parallel to the contour.

Contour terracing (benching), or furrowing,

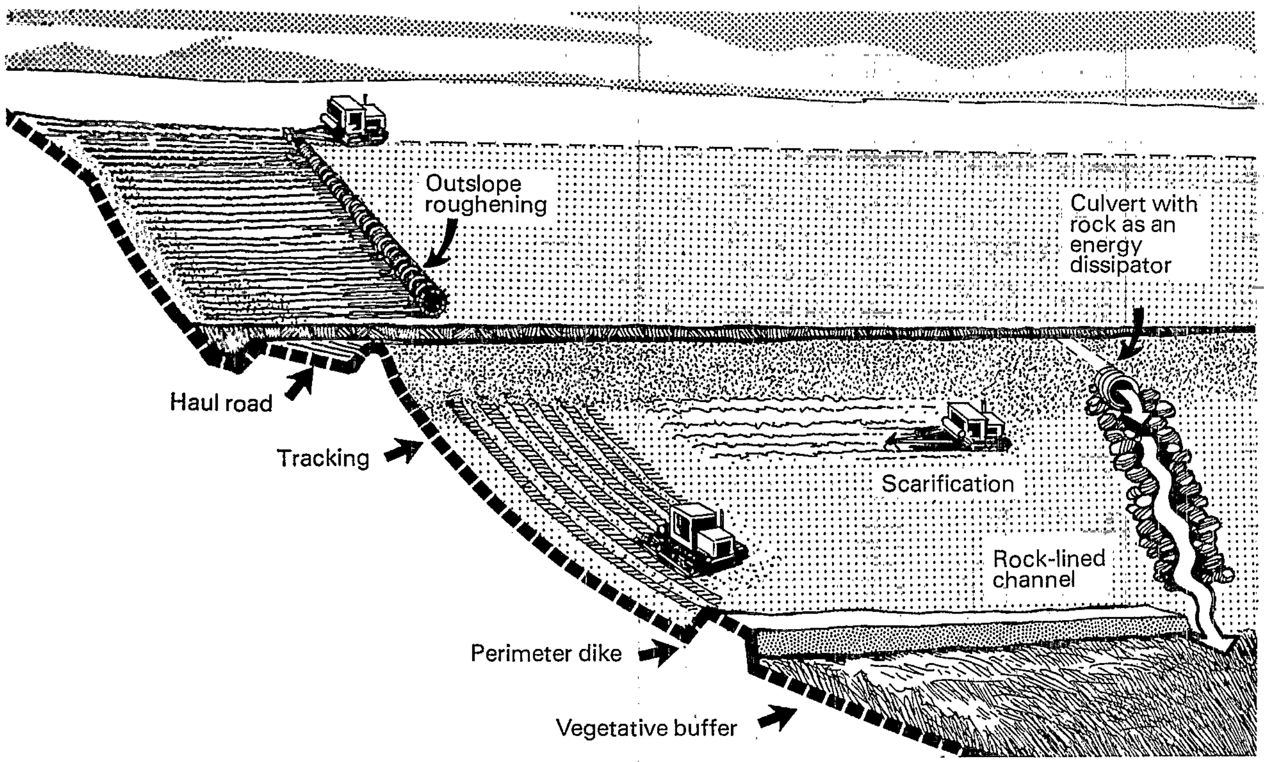

Figure IV-9. Grading and shaping of soil surface.

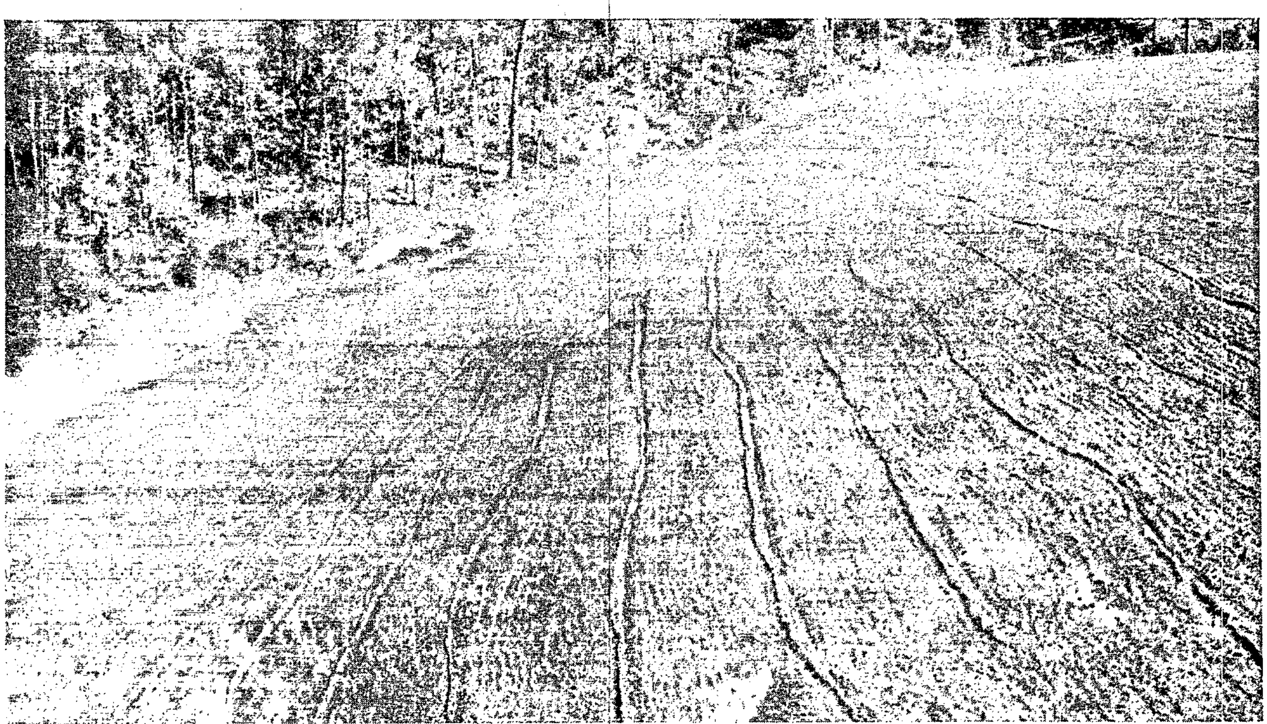

Figure IV-10. Properly roughened (along the contour) fill slope.

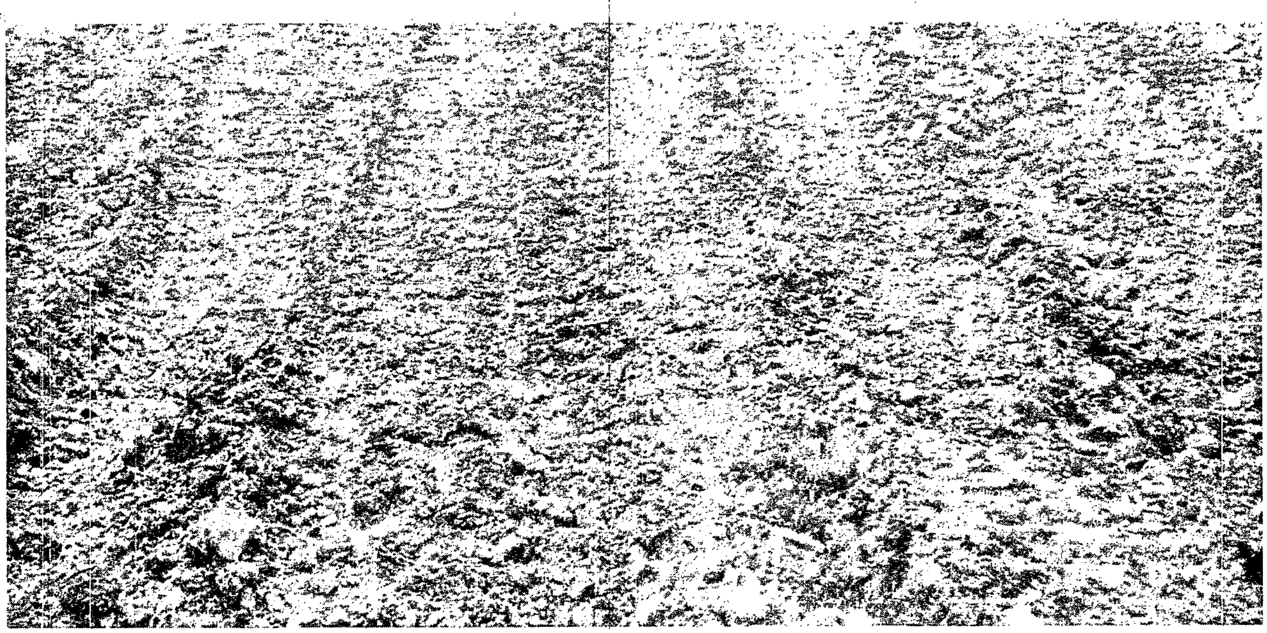

Figure IV-11. Mine spoil roughened by tracking.

is performed in conjunction with other roughening techniques on long slopes to disrupt and slow surface runoff. Terracing is done with a bulldozer running parallel to the contour and allowing dirt to dribble off the end of the blade creating small depressions and ditches that interrupt the flow of surface water down the slope. Furrowing is accomplished by similarly plowing parallel to the contour. In both cases, the resulting depression must run along the contour of the ground, otherwise the intercepted runoff will concentrate in lower areas and result in gully erosion.

Gouging is a surface configuration composed of many depressions, and is accomplished with a specially constructed machine that has hydraulically operated disc scoops, 25 inches (63.5 cm) in diameter, that alternately raise and lower while being drawn by a tractor. The three disc scoops create elongated basins on the contour approximately 14 to 16 inches (35.5 to 40.6 cm) wide, 3 to 4 feet (0.91 to 1.21 meters) long, and 6 to 8 inches (15.2 to 20.3 cm) deep. This pattern is amenable to gradual slopes and flat areas. It creates a cloddy seedbed ideal for broadcast seeding.

Dozer basins are large depressions designed to accomplish what terracing is intended to do, but without the characteristic precision, hazards, and expense. Dozer basins are 15 to 20 feet (4.56 to 6.08 meters) long, and are formed by dropping the bulldozer blade at an angle at intervals and bulldozing on the contour. The resulting basins are approximately 20 to 25 feet (6.08 to 7.6 meters) from center to center, and are about 3 to 4 feet (0.91 to 1.21 meters) in depth. Basins are constructed in parallel rows with about 20 feet (6.08 meters) between rows. Precipitation intercepted within each mine drainage accumulates in the basin bottom in quantities sufficient to saturate the basin limits thoroughly. The increased soil moisture availability assures the establishment of a nucleus stand of vegetation the first growing season; from this nucleus, it can spread between basins to make a complete cover.

Deep chiseling is a surface treatment that loosens compacted spoils for a depth of 6 to 8 inches (15.24 to 20.32 cm). The process creates a series of parallel slots on the contour to impede water flow effectively and increase the infiltration rate. Deep chiseling uses a modified Graham-Hoeme plow with 12 chisels to form a rough cloddy seedbed. This treatment is effective on relatively flat slopes, and is very beneficial in loosening spoil before gouging or following dozer basin construction.

In addition to the mechanical measures described above, the permeability of the surface soil can be enhanced through topsoiling and soil conditioning. Topsoiling consists of spreading a top layer of soil material capable of supporting plant growth. The best soil material available for plant growth should be identified prior to mining, segregated, and saved during overburden removal. Soil amendments such as those found in lime or organic matter can be worked into the surface soil to loosen particle bonds, promote plant growth, and increase infiltration.

The prompt establishment of a cover of vegetation and/or the placement of a fibrous, organic mulch on freshly graded soil surfaces will also detain and reduce surface flow. In addition, it will stabilize the soil in two ways. It provides protection from the impact of raindrop splash, thereby preventing the soil surface from being compacted and sealed. Also, it impedes the flow of surface runoff and reduces the velocity, which in turn reduces erosion and increases infiltration.

Manipulation of Slope Length and Gradient. The rate of runoff and, thus, the rate of soil erosion can also be controlled by manipulating the gradient and length of slope. This measure is particularly important in area mining and mountain top mining, in that considerable flexibility often exists in shaping the spoil areas.

Slope design should be based on the erodibility of the surface soils as well as stability against landslides. Restoring the approximate original contour may not be desirable in all cases. A reduction in relief and an overall flattening of the topography may be desirable from an erosion and sediment control standpoint. It must be remembered that shorter or flatter slopes are less erodible.

Where there is little flexibility as to the overall configuration of the slope, as is often the case with contour mining, diversion structures, such as reverse benches or terraces, ditches, and dikes, can be deployed above, on top, and along spoil slopes to decrease the overall length of the slope (fig. IV-12 and IV-13).

The shape of a slope also has a major bearing on soil loss and the potential for offsite damage due to sediment. Assuming the gradient remains constant, the base of a slope is more susceptible to erosion than the top. This is because the runoff becomes more concentrated and picks up momentum as it approaches the base. Constructing a convex slope magnifies the problem, whereas a concave slope reduces it. Leaving a relatively flat area near the base of the slope not only reduces erosion, it also traps sediment coming from upper portions of the slope.

Interception and Diversion

Another key concept in controlling soil erosion is to intercept runoff before it reaches a critical area and to divert it to a safe disposal area. Interception and diversion are accomplished through the use of various diversion structures, including reverse benches or terraces, ditches, earth dikes, and combined ditch and dike (diversion) (fig. IV-14). Section I, volume II, contains information on the design, construction, and use of various types of diversion structures.

Interception and diversion practices perform two important functions at surface coal mines; they:

- Isolate onsite critical areas (i.e., raw spoils,

partially stabilized spoils, highwall, access roads, and other areas) from offsite runoff
- Control runoff velocities on steep or long spoil slopes and abandoned access roads

By placing a reverse bench or ditch above the mine site, offsite runoff can be intercepted and diverted around the disturbed area or to structures that will safely carry the runoff through the mine. The use of perimeter diversion structures is an especially important erosion deterrent at contour strip mines.

Diversion structures can also be used to control runoff generated within the mine. On excessively long or steep slopes, reverse benches are often used to protect lower portions of the slope from erosion due to runoff. As with perimeter structures, the internal diversion structure intercepts runoff coming from higher elevations, thus preventing it from reaching the critical lower slope, and diverts it to an offsite disposal area or a downdrain structure (fig. IV-15).

Proper design, construction, and maintenance of diversion structures are musts. They must be designed and constructed to carry the intercepted runoff at nonerosive velocities.

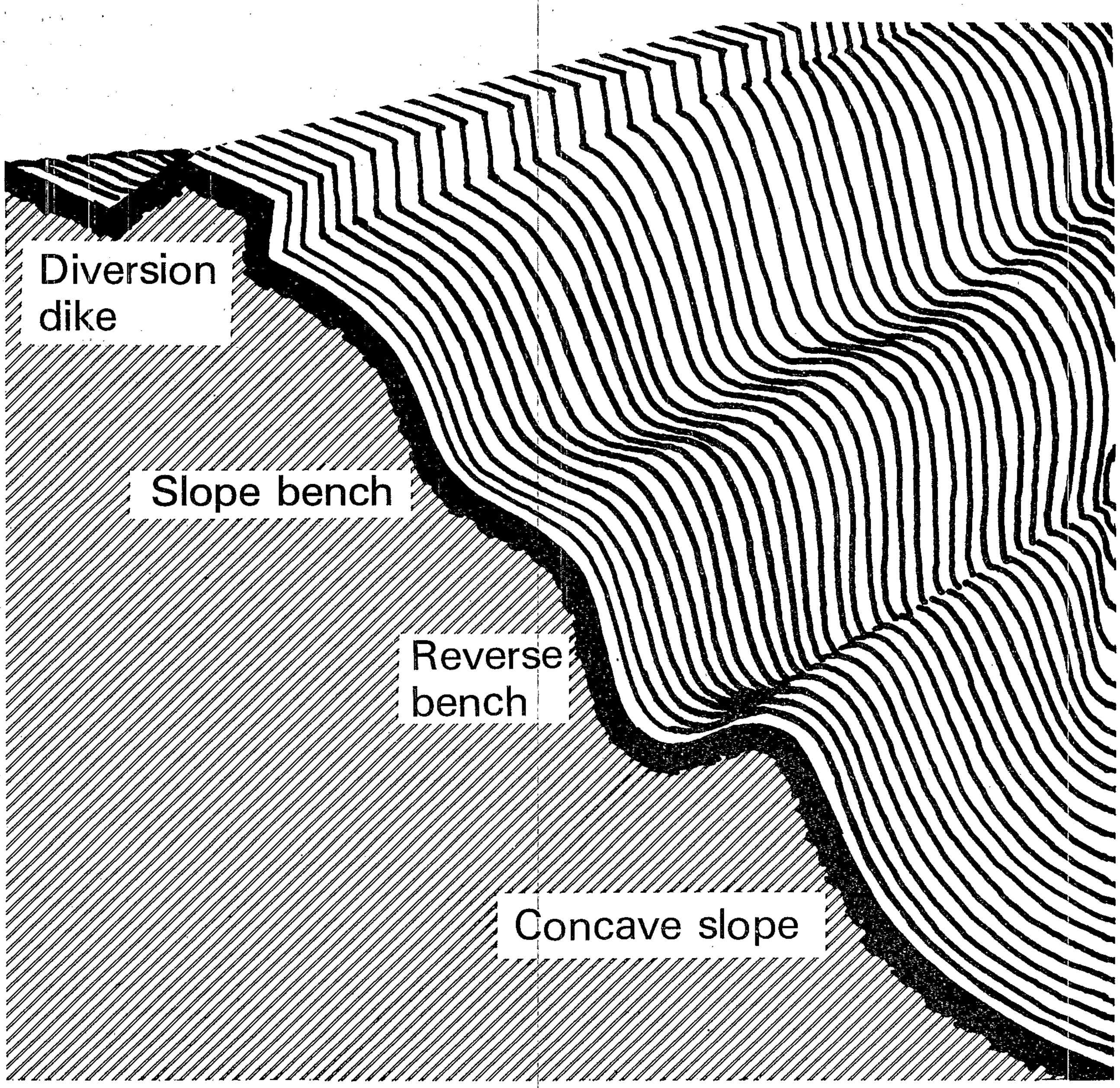

Figure IV-12. Slope reduction measures.

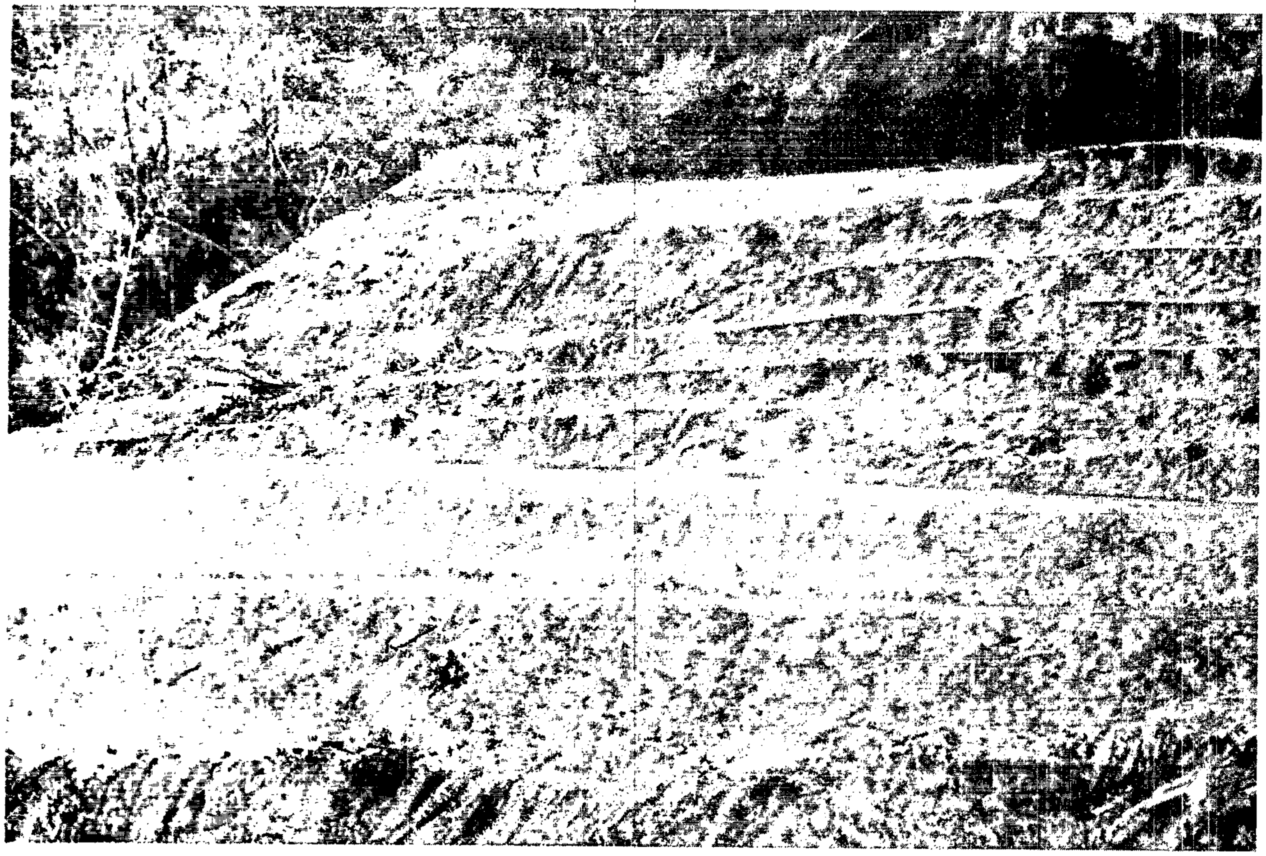

Figure IV-13. Diversion structures (terraces) on long, steep slopes.

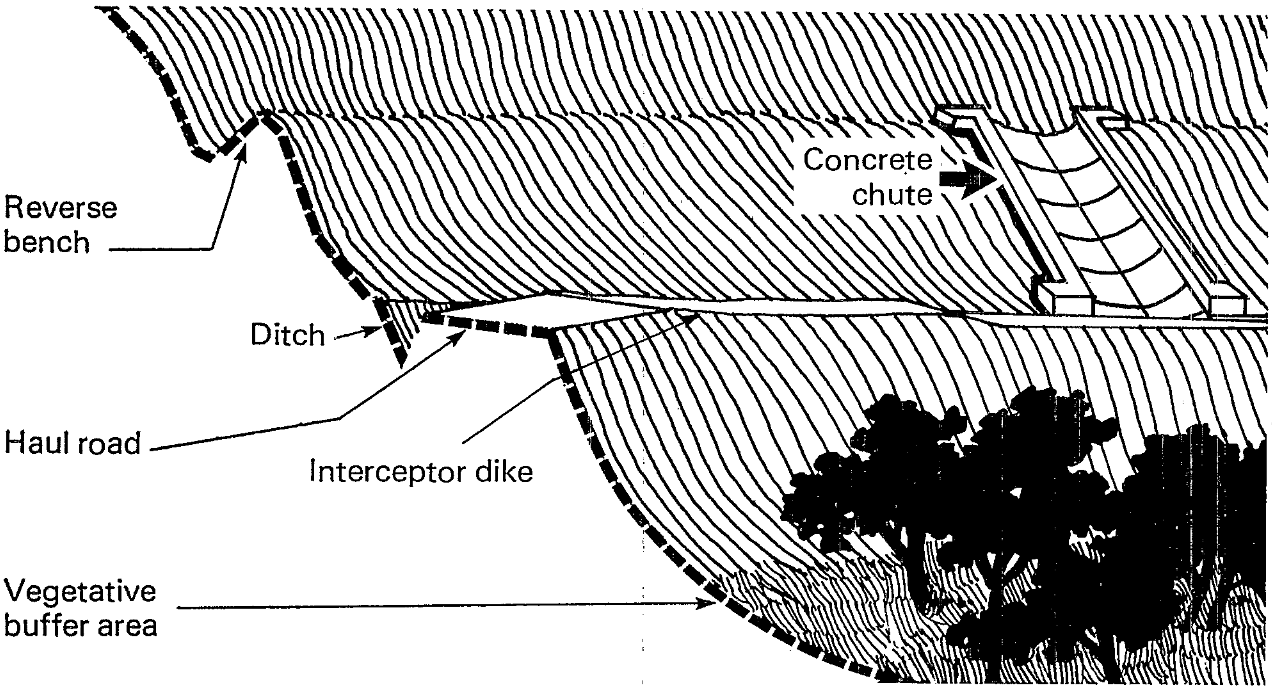

Figure IV-14. Interception and diversion measures.

Figure IV-15. Newly constructed diversion.

Handling and Disposal of Concentrated Flows

The construction of diversion structures and the interception (by mining) of drainageways will necessitate the handling and disposal of concentrated flow. The measures taken in handling and disposing of this highly erosive runoff will have a major influence on the amount of soil erosion occurring both within and downslope of the mine site. Both soil stabilization and runoff control are important factors in the proper handling and disposal of concentrated flow.

As with other major categories of runoff control, proper handling and disposal of concentrated flow involves the use of practices that reduce the rate of runoff and, as a result, its ability to detach and transport soil particles.

In handling concentrated flow, the objective is to detain the runoff by:

- Increasing the flow distance
- Decreasing the flow gradient
- Obstructing the flow

The flow distance can be controlled by constructing the drainageway as long as it is practicable without causing the water to spill out of, or erode, the channel. For manmade drainageways, the flow gradient can be controlled in the same manner. In natural and in manmade drainageways, the grade can also be controlled by the construction of flumes or other flow barriers across the channel. These grade control structures also serve to obstruct the flow and, thus, slow its movement. Bends in the channel, either manmade or natural, also impede the flow.

The placement of debris, such as rock riprap, in the channel to obstruct and dissipate the energy of the flow is also an important control measure. Figure IV-16 shows a riprap-lined drainageway. Critical points for the placement of energy dissipators are the areas below grade control structures, below outfalls, and along the outside of bends in the channel. These controls both reduce the ability of the concentrated flow to cause erosion and shield the channel against erosion.

Impoundments are also an important means of obstructing flow. They are constructed by excavating a depression in the channel or by damming it. Releasing impounded water at a controlled rate over a prolonged time is a practice used to reduce flooding and channel erosion in downstream areas. In addition, the impoundment will also trap sediment. Sediment basins and other sediment traps are discussed in the next section.

Figure IV-16. Stone riprap waterway lining used to dissipate flow and protect channel.

The conveyance of concentrated flow down steep slopes is also an important erosion control aspect of stormwater handling. Structures used to accomplish this safely include various types of pipes, flumes, sectional downdrains, and flexible downdrains. (figs. IV-17 and IV-18). The best type of structure to be used will depend on site factors and the required service life. Design considerations for downdrain structures are provided in section I, volume II.

Proper techniques for disposing of concentrated flow collected in diversion structures include, where applicable, spreading the concentrated flow into nonerosive sheet flow through the use of a level spreader, and the installation of an energy dissipator at the discharge point to dissipate the flow and spread it onto a stable surface. It is extremely important that the disposal area be well stabilized with vegetation and be conducive to sheet flow, rather than concentrated flow. When possible, it is also desirable to discharge the water above a drainageway, rather than directly into it, so as to use the intervening vegetated ground to slow and filter the runoff further.

Other information on the use, design, and construction of level spreaders, energy dissipators, downdrains, and other water-handling and disposal structures can be found in section I, volume II.

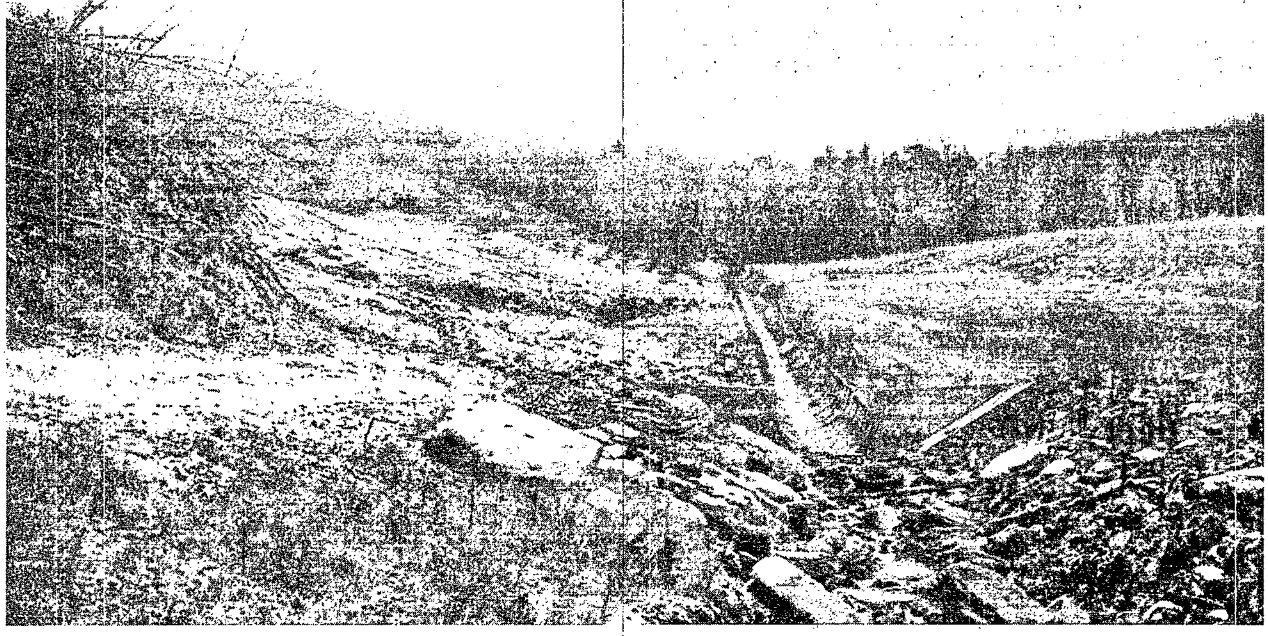

Figure IV-17. Concrete half-round pipe downdrain.

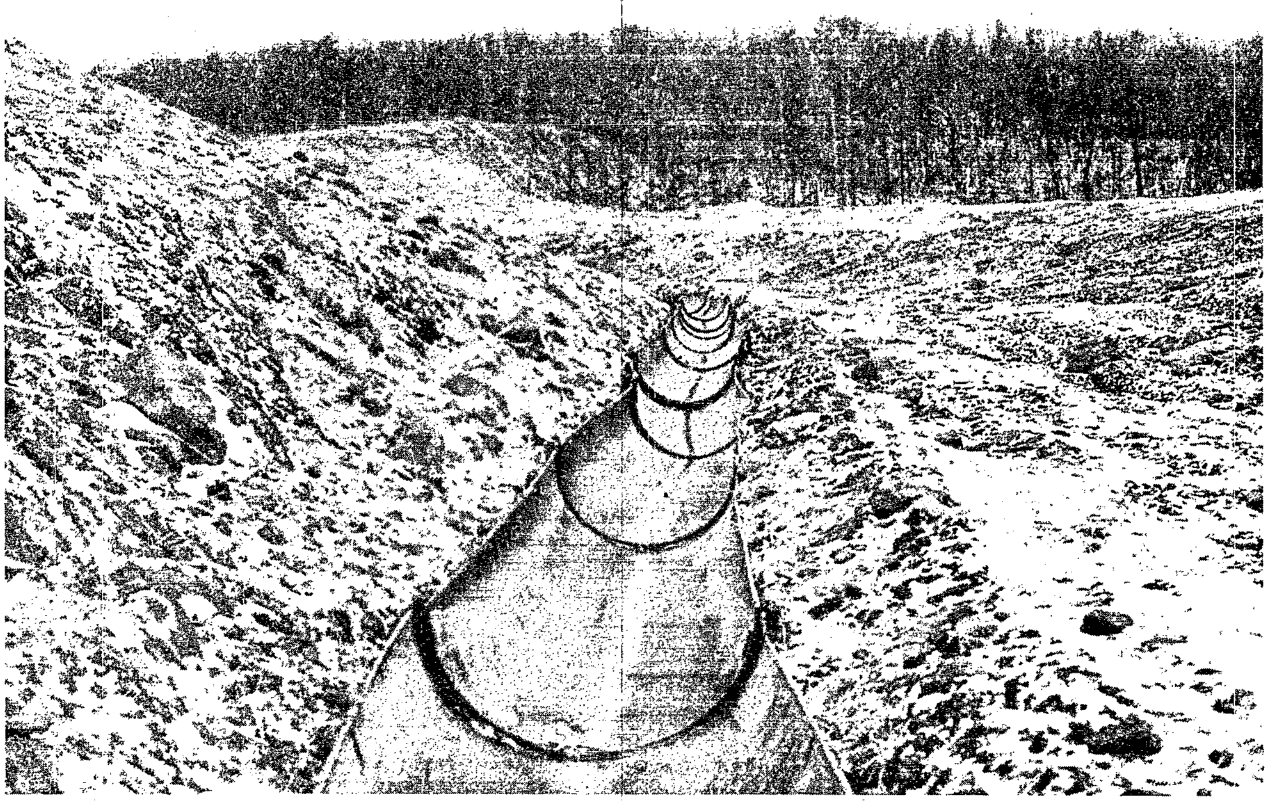

Figure IV-18. Half-round bituminous fiber pipe used for temporary handling of concentrated flow.

SOIL STABILIZATION

Soil stabilization is the other means of preventing soil erosion. Whereas runoff control practices are designed to manage rainfall runoff in a way that reduces its ability to cause soil erosion, soil stabilization practices are designed to protect the soil from the erosive action of falling rain, ensuing runoff, and wind. Protective shielding of the soil surface from the full force of impacting raindrops and the hydraulic and abrasive action of moving surface water and wind is achieved by binding the soil particles together to form a mass that is less easily displaced, and by anchoring the soil in place. Well-established vegetation, for example, performs all of these functions. The leaves, stems, and other above ground portions of vegetation, as well as the organic litter that collects on the ground surface, shield the soil surface, while the roots bind and anchor the soil. Surface coverings of straw, hay, woodchips, gravel, riprap, jute netting, and other material also serve to shield the soil. Other nonvegetative material, such as chemical emulsions, can be used to bind and anchor the soil particles.

Stabilization measures may be either vegetative or nonvegetative, and short term or long term. Vegetative stabilization refers to the use of different types of vegetation to protect the soil from erosion. Nonvegetative stabilization, on the other hand, refers to a multitude of practices that use materials other than vegetation in preventing soil erosion. Keep in mind, however, that a combination of both vegetative and nonvegetative measures is often required.

Short-term stabilization, also termed temporary stabilization, refers to the use of practices that provide protection for a short period of time, usually less than 1 year. Long-term, or permanent stabilization, involves the use of long-lived vegetation or a durable material, such as rock, concrete, or asphalt, to protect the soil against erosion for more than 1 year.

Vegetative Stabilization

Provided proper care is taken in its establishment, vegetation is the most beneficial and durable soil stabilizer (fig. IV-19). It forms a protective cover that shields the ground surface from the direct impact of falling rain, and its roots bind and secure the soil particles. As noted earlier, it also controls runoff by slowing the flow of water along the soil surface and by enabling the soil to absorb more water. By reducing the amount of runoff and its speed of movement, the ability of the runoff to carry away detached soil particles is also decreased.

Figure IV-19. Spoil and drainageway well stabilized with grasses and legumes.

Long-term vegetative stabilization is accomplished by the proper planting of various combinations of grasses, legumes, shrubs, and trees. The type and mixture of individual plant species to be used will depend on soil and moisture conditions, climatic conditions, erosional stresses, and postmining land use. Selection and establishment of vegetation is discussed later in this section.

Short-term vegetative stabilization involves the use of low-cost, quick-growing perennial and annual plants, usually grasses, to provide protection for a short period of time (fig. IV-20). This form of stabilization is often used to protect stockpiled topsoiling material. It is also used for temporary stabilization of spoil graded in late spring or fall when more permanent stabilization cannot be performed properly.

Vegetative establishment is covered later in this section.

Nonvegetative Stabilization

Like vegetative measures, nonvegetative practices are used to reduce the susceptibility of mine soils to erosion. It is difficult to separate the two major types of stabilization, in that they are often used together. An important point to remember is that nonvegetative stabilization is used to reinforce vegetative measures. Where vegetation will provide adequate long-term soil protection, long-term nonvegetative stabilization is not required. Where vegetation will provide partial protection, as is often the case in areas subject to concentrated flow (such as found in a drainageway), a combination of the two types of stabilization is desirable. On the other hand, should vegetation not be able to provide any protection, such as on the bottom or bed of a stream, nonvegetative stabilization is the only protective treatment available (fig. IV-21).

Nonvegetative stabilization covers a wide assortment of short-term and long-term soil stabilization practices, which vary considerably in their cost-effectiveness and ability to withstand erosional stresses. As a general rule, it is probably best to stay with measures that have proven successful in the field. New products or practices appearing worthwhile and offering possible cost advantages should be demonstrated on test plots before being employed extensively.

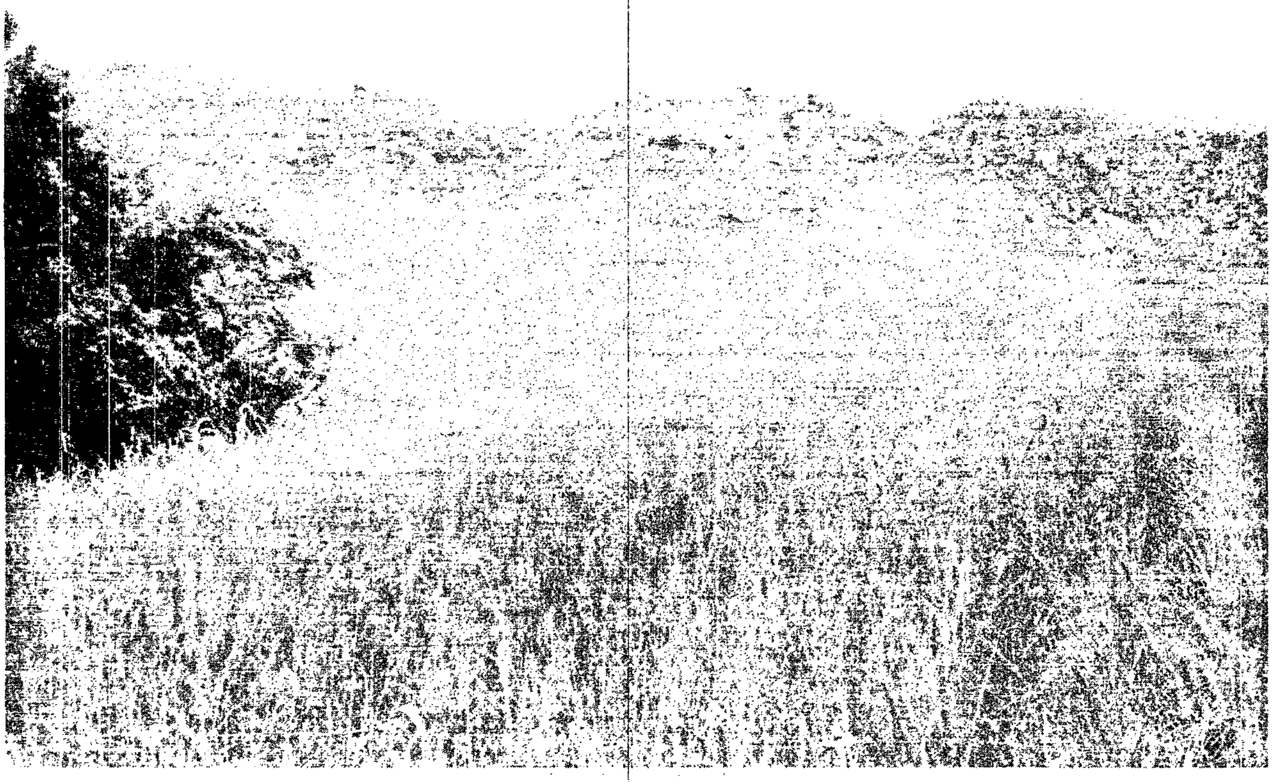

Figure IV-20. Outslope stabilized with short-term annual grasses.

Figure IV-21. Newly seeded and mulched area adjoining ditch lined with stone riprap.

Short-Term Measures. Mulching and chemical stabilization are two major types of short-term, or temporary, nonvegetative soil stabilization (fig. IV-22). Both are employed to provide protection against excessive soil erosion for periods of less than 1 year.

Mulching. Mulching with organic materials such as straw, hay, woodchips, wood fiber, and other natural and manufactured products is the most popular means of providing short-term soil stabilization. Mulch is used in the establishment of a vegetative ground cover to protect the seedbed from excessive erosion prior to germination of the seeds and until the new vegetation is sufficiently established. The mulch provides a favorable environment for seed germination and plant development. Mulches can also be used in place of short-term vegetative stabilization to protect temporarily against excessive soil loss prior to the preparation of a seedbed. Some mulch materials, in particular straw and hay, require stabilization to prevent them from being uncovered by wind and water. This is accomplished by applying asphalt or chemical tacks that bind the mulch material together and to the soil surface or, in the case of straw and hay, by crimping. When performed along the ground contour, crimping is doubly beneficial in that it produces a surface texture that inhibits surface runoff.

In areas subject to concentrated flow, nettings of fiber glass, plastic, and other material stapled securely to the ground may be required to keep fibrous organic mulch material from being removed. Jute netting is usually utilized to stabilize drainageways. When properly installed, it is difficult to remove and, because of its bulky and fibrous nature, it protects the soil surface and provides a good environment for seed germination.

Chemical stabilization. Chemical soil stabilizers are designed to coat and penetrate the soil surface and bind the soil particles together (fig. IV-23). They are used to protect bare soil slopes, not subject to traffic, from wind and water erosion during temporary establishment of a seedbed. Chemical stabilizers are used both in lieu of temporary mulch material and in conjunction

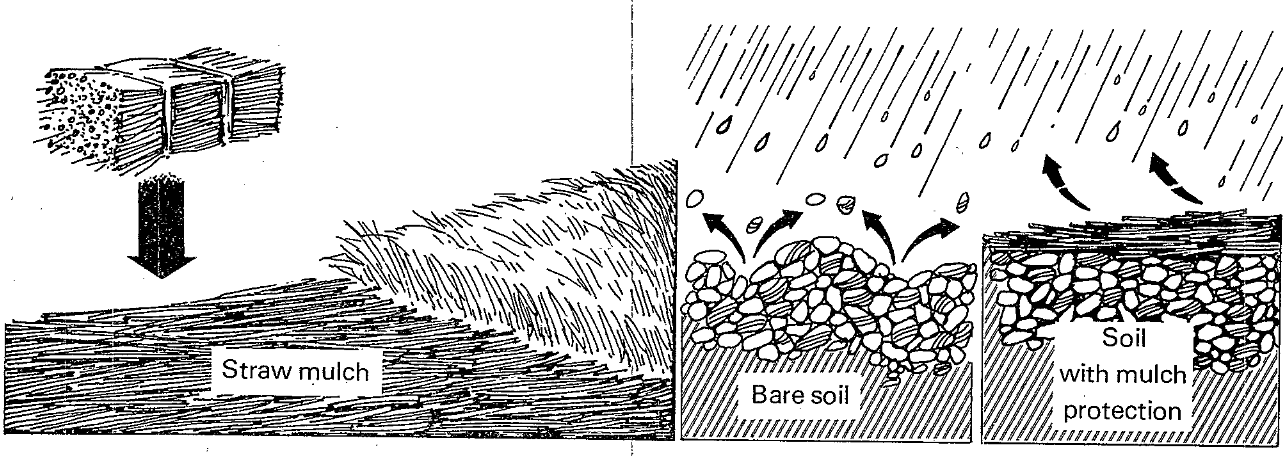

Figure IV-22. Straw mulch.

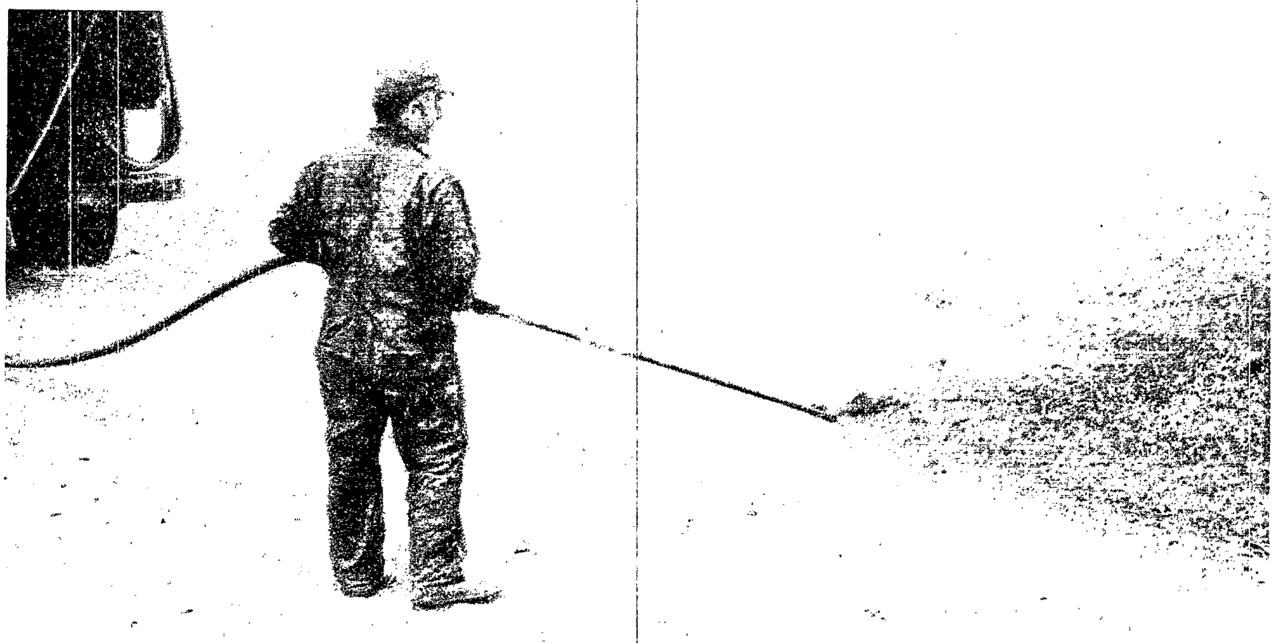

Figure IV-23. Chemical stabilizer being applied over straw mulch.

with the material to act as a mulch tack and soil binder.

Chemical stabilizers generally work best on dry, highly permeable spoil, or in-place soils subject to sheet flow rather than concentrated flow. It is recommended that chemical soil stabilizers be tested on small, representative plots of ground before selecting a mixture of chemicals and water and an application rate, or before deciding to use these chemicals extensively in stabilizing mine soils. As a general rule, chemical stabilizers do not provide protection for as long a period of time as straw, hay, and other organic mulches.

Section I, volume II, contains additional information on short-term stabilization measures and products.

Long-Term Measures. Long-term, nonvegetative soil stabilization is required when vegetation alone cannot withstand the erosional stresses imposed by surface runoff and when vegetation is not adaptable to the chemical, moisture, or traffic conditions occurring in the soil or on the surface to be stabilized. Areas at surface mines requiring such treatment include roadbeds, waterways, and toxic or excessively wet soil surfaces.

Long-term measures include nonstructural practices, like mulching, and structural practices, such as paving, channel lining, and grade control.

Mulching. Mulching practices involve the use of nonbiodegradable material, such as fiber glass and various plastics, to protect seedbeds during the critical germination and early plant development period, and to act as a reinforcement following establishment of the vegetative cover. These materials include nettings and loose, stringy products that, when applied to the seedbed, become securely enmeshed in the vegetation at the ground surface and in the rootmat. Light applications of crushed stone or gravel will perform a similar function.

Stone surfacing. To stabilize highly toxic surfaces, or excessively wet seepage areas on slopes, a heavy application of durable crushed stone, gravel, clinkers, or "red dog" is often warranted. The best cure for these problems, of course, is to dispose of the overburden and manage the drainage in a manner that prevents such problems from occurring.

Crushed stone, gravel, clinkers, and red dog also are used to surface roadways (fig. IV-24). In addition to securing the soil, such treatment increases the bearing capacity of the roadway, provides for continuous all-weather use, and decreases the likelihood of traffic damage and related accelerated soil erosion.

Channel stabilization. Channel stabilization is usually not as complex a problem at surface coal mines as it is at large, urban construction sites. For the most part, structural stabilization practices involve the use of stone riprap and other durable material to stabilize ditches and other manmade waterways. Where natural streams are severely affected by mining, either due to disturbance of the channel or increased surface runoff, sophisticated and costly structural measures are often required to protect the channel from erosion.

Channel stabilization structures are used to maintain channel alignment (i.e., prevent erosion of the sides of the channel) and/or maintain channel gradient (i.e., prevent scour of the channel bottom). Revetments and check dams are the structures most commonly used at mines to prevent channel erosion. Revetments are designed to shield the channel from the hydraulic and abrasive action of concentrated flow. Generally, these structures are built of stone riprap obtained from the mine site and placed in the bottom of the channel at critical locations to prevent down-cutting. Where the sides of the channel cannot be stabilized with vegetation alone, the stone is carried up the sides of the channel to form a complete channel lining. The stone riprap should be sandstone, limestone, or other durable rock of a size that cannot be removed by the runoff. Large voids between rock fragments should be clinked with smaller fragments to provide a dense cover. When heavy or sustained flows must be handled, a graded sand and stone filter, or filter cloth, should be placed under the structure, securely against the soil

Figure IV-24. Access road with aggregate surface.

surface to prevent the upward movement of soil particles due to hydraulic action. Wire baskets filled with stone (gabions), various concrete blocks, bags filled with a mixture of sand and cement, and nylon mattresses filled with a sand/cement grout (Fabriform®) are also used to construct revetments in waterways (fig. IV-25). These products and materials are generally only used to stabilize highly critical areas, such as natural streams or stream realignments. Where good riprap stone is not available at the mine site, cost considerations may warrant the use of certain material in ditches and other areas in place of stone riprap.

For environmental and esthetic reasons and to minimize maintenance requirements, vegetation should be used with structures whenever possible. Where sustained, heavy flow is not present, revetments constructed of loose stone riprap, or thin, stone gabions provide an environment for the growth of vegetation within the armored portion of the channel.

Revetments required to protect critical areas in stream channels, and occasionally subjected to heavy flow, should be designed by an engineer and be installed in accordance with construction specifications.

Unlike revetments, which can be used to protect the entire channel or its sides or bottom, check dams are designed to protect only the base, or bottom, of the channel from erosion. These structures are placed across the channel at intervals along the alignment to inhibit physically the moving water from eroding the bottom of the channel. They generally consist of a relatively narrow strip of stone riprap laid across the channel. Logs and lumber are also used to construct check dams. At surface mines, these structures are used to control erosion in ditches, and other constructed drainageways, having steep gradients or long grades.

Additional information on long-term nonvegetative measures can be found in sections I and II, volume II.

Areas To Be Stabilized

All areas that are in any way disturbed by the mining operations must be stabilized. Waterways that will have to handle increased flows

Figure IV-25. Stone gabion structure.

may also need to be stabilized. However, the major emphasis in stabilization must be placed on three critical areas that are particularly susceptible to erosion—roadways, fill slopes, and stream channels.

Roadways. Roadways are a major source of sediment at surface coal mines. Haul roads at contour mining operations are a particular problem since much of the drainage and runoff from the bench and other disturbed areas make their way to the haul road. Roadside ditches, safety berms, inlets, outlets, cut-and-fill areas, and the actual road surface are extremely susceptible to erosion.

Water-tolerant and erosion-resistant vegetation should be used for stabilizing roadside ditches. However, where high velocities are encountered, dumped or placed stone riprap will provide additional long-term protection. Culvert inlets and outlets also require a layer of stone riprap or other resistant, energy-dissipating material.

Safety berms present several problems. Stabilization with vegetation and, in some instances, other material is necessary to reduce soil losses. Roads should be pitched away from the berm, toward the cut slope, to avoid undercutting by water. The berm should be properly compacted, and, when concentrated water is handled, rock mulches should be used to provide temporary stabilization until a vegetative cover can be established.

Road surfaces should be stabilized by using nonvegetative material such as rock aggregate, clinkers, red dog, or other durable material that can slow down water and withstand truck traffic. This stabilization is also important for controlling dust on haul roads.

Slopes. Prompt and effective stabilization of cut-and-fill slopes is especially important in controlling soil erosion. Cut slopes greater than 2:1 (50 percent) place severe limitations on the ability of plant roots to hold and bind soil particles. As a rule of thumb, a 2:1 slope is assumed to be the maximum slope upon which vegetation can be established and maintained satisfactorily. However, maximum vegetative stability cannot be attained on slopes steeper than 33 percent (3:1). The maximum-slope rule should only be applied to ideal soil conditions where the soil is not highly erodible and has adequate moisture-holding capacity. In situations where vegetative measures, such as grasses and legumes, fail due to slope steepness, a blanket of crushed stone or other durable material will be required to stabilize the soil.

Fill material can be manipulated as previously discussed so that excessive slope lengths and steepness are avoided, thus improving the chances for soil-holding vegetation to become established. Fill slopes should remain accessible to maintenance equipment. Seeding of cut-and-fill slopes should follow closely behind the grading operations. Large boulders and rocks and debris can be located at the toe of the fill slopes to provide support and reinforcement. This will provide a more uniform slope, and make it less susceptible to voids where fills and gullies can form. Scalped material can be windrowed in front of the toe to act as a filter for sediment.

Stream Channels. Waterways downstream from surface mining operations are sometimes subjected to large increases in the volumes of surface runoff. These large volumes of surface runoff and the associated increases in velocity render the waterway highly susceptible to erosion.

Vegetative measures for stabilizing banks of stream channels involve the use of select grasses and legumes that are tolerant of wet conditions and resistant to high water velocities. Table IV-3 gives the maximum permissive velocities for various types of vegetative channel linings.

In certain places within waterways, vegetative practices alone are not enough to prevent erosion. Structural devices must be used to protect the waterway from scour or erosion.

Critical areas along streambeds that may need structural stabilization include the outside of bends where the flow impinges or impacts against the streambank, restrictions in the channel, junctions where tributaries enter the main channel, and places where the channel gradient is excessive (fig. IV-26).

Revetments are useful in areas where it is necessary to protect the streambanks. The material most commonly used for this purpose is stone riprap, which is durable, heavy, and flexible. Also, it generally is readily available at many mine sites. Gabions and revetment mattresses are also often used. In addition to these materials, MONOslabs™, poured concrete, concrete block, and sandbags filled with a sand-cement mixture are sometimes used. The use of these materials is discussed in volume II.

In some areas, it may be necessary to protect the streambed as well as the streambanks. Grade control structures are used for this purpose. These structures physically prevent the streambed from being eroded and slow the flow of water.

A grade control structure consists of durable material placed on the bottom of the channel. It can be a narrow strip of riprap stone placed across the channel, or it can be a complete lining of the channel (fig. IV-27). Materials used to construct revetments are also used to build grade control structures. Common uses of grade control structures include riprap energy dissipators placed at outfalls of stormdrains; riprap check dams placed at regular intervals along a waterway; and revetments of riprap, concrete, gabions, Fabriform®, or other material for lining streams and drainageways.

VEGETATIVE ESTABLISHMENT

The revegetation of mine spoils and other disturbed areas using, for the most part, soil-binding grasses and legumes, is one of the most important means of preventing excessive soil erosion at active mine sites. However, the effectiveness of vegetation in stabilizing the soil will be limited unless existing and future site conditions are adequately assessed in the selection of plant material and proper establishment practices are followed.

Plant Selection

Each plant species has its own growth characteristics that determine its value in stabilizing soil. Grasses and legumes are the most effective plant materials for controlling erosion in the early stages of reclamation. However, they are short-lived species and are generally planted in combination with trees and shrubs. Trees and shrubs are not very effective in controlling erosion in the early stages because of their initial slow development. But, during the middle and late stages of reclamation, as the grasses and legumes die off, the trees and shrubs form a protective canopy and provide a necessary build-up of surface organic material as a result of the leaf litter, which is excellent in controlling surface runoff and erosion. In addition, trees and shrubs are beneficial for screening, wildlife, and forestry purposes.

Grasses. Grasses are particularly well suited for stabilizing mine spoil and other exposed areas at a mine. They are highly adaptable to various site conditions and provide a quick, dense, and lasting ground cover. Furthermore, the dense, fibrous roots of grasses securely anchor the soil and allow surface water to infiltrate more rapidly. Grasses commonly used in stabilizing mine spoil include tall fescue, weeping lovegrass, and redtop. Other grass species and their characteristics are given in table IV-4.

Among grass species, a high degree of adaptability to various site conditions exists. Species are available for different exposure (sunlight, temperature, and wind) conditions, and for planting during the spring, summer, and fall. Some species are highly tolerant of wet soils, while others do well on dry, droughty soils.

Table IV-3.—*Maximum permissible velocities in channels lined with uniform stands of various grass covers, well maintained*[a]

Cover	Slope range	Maximum permissible velocity on:	
		Erosion-resistant soils	Easily eroded soils
	Percent	*ft/s*	*ft/s*
Bermudagrass	0-5	8.0	6.0
	5-10	7.0	5.0
	Over 10	6.0	4.0
Buffalograss Kentucky bluegrass Smooth brome Blue grama	0-5	7.0	5.0
	0-15	6.0	4.0
	Over 10	5.0	3.0
Grass mixture	[b]0-5	5.0	4.0
	[b]5-10	4.0	3.0
Lespedeza sericea Weeping lovegrass Yellow bluestem Kudzu Alfalfa Crabgrass	[c]0-5	3.5	2.5
Common lespedeza[d] Sudangrass[d]	[c]0-5	3.5	2.5

[a]Use velocities over 5 ft/s only where good covers and proper maintenance can be obtained.

[b]Do not use on slopes steeper than 10 percent.

[c]Use on slope steeper than 5 percent is not recommended.

[d]Annuals; used on mild slopes or as temporary protection until permanent covers are established.

Source: *Design Charts for Open-Channel Flow*, Hydraulic Design Series No. 3, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., Aug. 1961.

The ability of many grasses to spread themselves by surface and underground runners (stolons and rhizomes) is another important aspect. Given time and proper maintenance, these grasses are able to heal minor breaches in the ground cover resulting from erosion, plant disease, and other factors.

Legumes. Legumes are commonly used in surface mine areas in combination with various grasses. They are important because of their ability to take nitrogen from the air and store it in their roots. This stored nitrogen can be made available to non-nitrogen-fixing plants, such as grasses, and assist in their growth.


Figure IV-26. Stone riprap protecting bends in stream.


Figure IV-27. Riprap check dam (grade control structure) placed in a drainageway.

Table IV-4.–*Characteristics of commonly used grasses*[a] *for revegetation purposes*

Common name	Botanical name	Season			Site suitability				Growth habit[b]	pH range[c]	Use suitability			Remarks
		Cool	Warm	Dry (not droughty)	Well drained	Moderately well drained	Somewhat poorly drained	Poorly drained			Erodible areas	Waterways and channels	Agriculture[d]	
Bahiagrass	*Paspalum notatum*		X	X	X	X			P	4.5-7.5	X	X	X	Tall, extensive root system. Maintained at low cost once established. Able to withstand a large range of soil conditions. Scarify seed.
Barley	*Hordeum vulgare*	X			X	X			A	5.5-7.8	X		X	Cool season annual. Provides winter cover.
Bermuda grass	*Cynodon dactylon*		X	X	X	X	X		P	4.5-7.5	X	X	X	Does best at a pH of 5.5 and above. Grows best on well drained soils, but not on waterlogged or tight soils. Propagated vegetatively by planting runners or crowns.
Bluegrass, Canada	*Poa compressa*	X		X	X	X			P	4.5-7.5	X		X	Does well on acid, droughty, or soils too low in nutrients to support good stands of Kentucky bluegrass.
Bluegrass, Kentucky	*Poa pratensis*	X			X	X	X		P	5.5-7.0	X	X	X	Shallow rooted; best adapted to well-drained soils of limestone origin.
Bluestem, big	*Andropogon gerardi*		X		X	X	X		P	5.0-7.5	X		X	Strong, deep rooted, and short underground stems. Effective in controlling erosion.
Bluestem, little	*Andropogon scoparius*		X		X	X			P	6.0-8.0	X		X	Dense root system; grows in a clump to 3 feet tall. More drought tolerant than big bluestem. Good surface protection.
Bromegrass, field	*Bromus arvensis*	X			X	X	X		A	6.0-7.0	X		X	Good winter cover plant. Extensive fibrous root system. Rapid growth and easy to establish.
Bromegrass, smooth	*Bromus inermis*	X		X	X	X	X		P	5.5-8.0	X	X	X	Tall, sod forming, drought and heat tolerant. Cover seed lightly.
Buffalograss	*Buchloe dactyloides*		X			X	X		P	6.5-8.0	X		X	Drought tolerant. Withstands alkaline soils but not sandy ones. Will regenerate if overgrazed.
Canarygrass, reed	*Phalaris arundinacea*	X		X	X	X	X	X	P	5.0-7.5	X	X	X	Excellent for wet areas, ditches, waterways, gullies. Can emerge through 6 to 8 inches of sediment.
Deertongue	*Panicum clandestinum*		X	X	X	X	X	X	P	3.8-5.0	X	X		Very acid tolerant; drought resistant. Adapted to low fertility soils. Volunteers in many areas. Seed not available.
Fescue, creeping red	*Festuca rubra*	X		X	X	X	X		P	5.0-7.5	X	X	X	Grows in cold weather. Remains green during summer. Good seeder. Wide adaptation. Slow to establish.
Fescue, tall	*Festuca arundinacea*	X			X	X	X		P	5.0-8.0	X	X	X	Does well on acid and wet soils of sandstone and shale origin. Drought resistant. Ideal for lining channels. Good fall and winter pasture plant.
Grama, blue	*Bouteloua gracilis*		X	X	X	X	X		P	6.0-8.5	X			More drought resistant than sideoats grama. Sod forming. Extensive root system. Poor seed availability.
Grama, sideoats	*Bouteloua curtipendula*		X		X	X			P	6.0-7.5	X		X	Bunch forming; rarely forms a sod. May be replaced by blue grama in dry areas. Feed value about the same as big bluestem. Helps control wind erosion.
Indian grass	*Sorgastrum nutans*		X			X	X		P	5.5-7.5	X		X	Provides quick ground cover. Rhizomatous, tall. Seed available.
Lovegrass, sand	*Eragrostis trichodes*		X		X				P	6.0-7.5	X		X	A bunchgrass of medium height. Adaptable to sandy sites. Good for grazing. Fair seed availability.
Lovegrass weeping	*Eragrostis curvula*		X	X	X	X	X		P	4.5-8.0	X			Bunchgrass, rapid early growth. Grows well on infertile soils. Good root system. Low palatability. Short-lived in Northeast.

Table IV-4.—*Characteristics of commonly used grasses*[a] *for revegetation purposes—Continued*

Common name	Botanical name	Season			Site suitability				Growth habit[b]	pH range[c]	Use suitability			Remarks
		Cool	Warm	Dry (not droughty)	Well drained	Moderately well drained	Somewhat poorly drained	Poorly drained			Erodible areas	Waterways and channels	Agriculture[d]	
Millet, foxtail	*Setaria italica*		X	X	X	X			A	4.5-7.0	X		X	Requires warm weather during the growing season. Cannot tolerate drought. Good seedbed preparation important.
Oats	*Avena sativa*	X		X	X				A	5.5-7.0	X		X	Bunch forming. Winter cover. Requires nitrogen for good growth.
Oatgrass, tall	*Arrhenatherum elatius*	X		X	X				P	5.0-7.5	X		X	Short-lived perennial bunchgrass, matures early in the spring. Less heat tolerant than orchardgrass except in Northeast. Good on sandy and shallow shale sites.
Orchardgrass	*Dactylis glomerata*	X		X	X	X	X		P	5.0-7.5	X		X	Tall-growing bunchgrass. Matures early. Good fertilizer response. More summer growth than timothy or bromegrass.
Redtop	*Agrostis alba*	X		X	X	X	X	X	P	4.0-7.5	X	X	X	Tolerant of a wide range of soil fertility, pH, and moisture conditions. Can withstand drought; good for wet conditions. Spreads by rhizomes.
Rye, winter	*Secale cereale*	X		X	X	X			A	5.5-7.5	X		X	Winter hardy. Good root system. Survives on coarse, sandy spoil. Temporary cover.
Ryegrass, annual	*Lolium multiflorum*	X			X	X	X		A	5.5-7.5	X		X	Excellent for temporary cover. Can be established under dry and unfavorable conditions. Quick germination; rapid seedling growth.
Ryegrass, perennial	*Lolium perenne*	X			X	X	X		P	5.5-7.5	X		X	Short-lived perennial bunchgrass. More resistant than weeping love or tall oatgrass.
Sandreed, prairie	*Calamouilfa longifolia*		X	X	X				P	6.0-8.0	X			Tall, drought tolerant. Can be used on sandy sites. Rhizomatous. Seed availability poor.
Sudangrass	*Sorghum sudanense*		X	X	X	X	X		A	5.5-7.5	X		X	Summer annual for temporary cover. Drought tolerant. Good feed value. Cannot withstand cool, wet soils.
Switchgrass	*Panicum vergatum*		X		X	X	X		P	5.0-7.5	X	X	X	Withstands eroded, acid and low fertility soils. Kanlow and Blackwell varieties most often used. Rhizomatous. Seed available. Drainageways, terrace outlets.
Timothy	*Phleum pratense*	X			X	X	X	X	P	4.5-8.0	X		X	Stands are maintained perennially by vegetative reproduction. Shallow, fibrous root system. Usually sown in a mixture with alfalfa and clover.
Wheat, winter	*Triticum aestivum*	X		X	X	X	X		A	5.0-7.0	X		X	Requires nutrients. Poor growth in sandy and poorly drained soils. Use for temporary cover.
Wheatgrass, tall	*Agropyron elongatum*	X		X	X	X	X	X	P	6.0-8.0	X	X	X	Good for wet, alkaline areas. Tolerant of saline conditions. Sod forming. Easy to establish.
Wheatgrass, western	*Agropyron smithii*	X		X	X	X	X	X	P	4.5-7.0	X	X	X	Sod forming, spreads rapidly, slow germination. Valuable for erosion control. Drought resistant.

[a]Grasses should be planted in combination with legumes. Seeding rates, time, and varieties should be based on local recommendations.
[b]P = perennial; A = annual.
[c]Many species survive and grow at lower pH; however, optimum growth occurs within these ranges.
[d]Hay, pasture, green manure, winter cover, and nurse crops are primary agricultural uses.
Note.—Prepared in cooperation with Soil Conservation Service plant material specialists and State conservationists.

Legumes have a large taproot that extends deep into the soil and enhances both soil stabilization and infiltration (fig. IV-7). When legumes are planted, less nitrogen fertilizer is required to maintain the ground cover. Nitrogen is usually very deficient on most surface mine spoil and is needed to establish legumes. Before legumes are planted, the seed should be treated with the proper inoculant to insure the presence of nitrogen-fixing bacteria needed to carry out fixation. Inoculating bacteria for particular legumes are commercially available.

Legumes commonly used with grasses in stabilizing mine soils include sericea lespedeza, crownvetch, clovers, and birdsfoot trefoil. Other legumes that are commonly used for revegetation are given in table IV-5.

Shrubs. Various shrubs are available for planting on surface-mined areas. Although they are primarily useful as wildlife habitats and for esthetic purposes, some species have been developed that can help to stabilize the soil. Bristly locust can be applied directly with a hydroseeder. It provides good surface cover and is a rapid thicket former on acidic spoil. Another advantage in using locust is that it is a legume. Other commonly used shrubs include autumn olive and amur honeysuckle, in addition to those listed in table IV-6.

Trees. Trees have limited uses as soil stabilizers during early periods of growth. Their shallow, nonextensive root system, as well as their slow and upright growth habit, severely limits their effectiveness in stabilizing soil. Trees should be used in combination with grasses and legumes to provide long-term protective cover. The grasses and legumes provide the necessary protection in the early years while the trees develop their protective canopies and build up a stabilizing litter of dead leaves on the ground.

Once established, trees can provide an effective screen as well as a habitat for wildlife. Trees also represent a renewable, marketable natural resource.

Selection Criteria. In selecting plants for erosion control, the following criteria should be considered:

- Their ability to withstand the erosive and traffic stresses present at the area being stabilized
- Their adaptability to existing soil conditions (pH, moisture, texture, and fertility)
- Their adaptability to climatic condition (sunlight exposure, temperature, wind exposure, rainfall) found at the site
- Their resistance to insect damage and diseases
- Their adaptability to the postmining land use
- Their compatibility with other plants selected for use on the same area
- Their ability to propagate (either by seed or vegetatively) themselves
- Their maintenance requirements

To minimize the possibility of failure in establishing a plant cover and at the same time reduce postestablishment maintenance requirements, select plants that are adaptable to the natural conditions found at the site.

The characteristics of grasses, legumes, shrubs, and trees commonly used in revegetation of mine spoils and other denuded areas at mines are summarized in tables IV-4, IV-5, and IV-6.

Seedbed Preparation

Grasses and legumes used in revegetating mined areas are established by direct seeding on a properly prepared seedbed (fig. IV-28). Woody plants, such as shrubs and trees, are established by seedling. However, some species can be direct seeded. Whatever technique is used, most mine soils require ameliorative treatments before planting. It is recommended that the topsoil to be vegetated be analyzed to determine the proper lime and fertilizer requirements. Various problems and required treatments are as follows:

- Acidity (low pH): Lime and topsoiling material should be applied to increase the pH to 5.5 if possible.
- Low fertility: Fertilizers should be added to provide required plant nutrients as determined by the soil test.
- High surface temperatures: Black spoil materials should be covered to prevent high, seedling-killing temperatures.
- Excessive rockiness: Large rocks and boulders should be removed and buried deeply in the pit or used for riprap in waterways.
- Droughty soils: Use drought-tolerant plants, mulches, fine-grained topsoiling material, and organic additions.
- Topsoil: The surface or subsurface soil material most suitable for plant growth should be used. Selective stockpiling of material may be required.
- Wet soils: Provide good surface drainage and plant moisture-tolerant vegetation. Possibly use a rock blanket or long-term mulch material in combination with vegetation.
- Dense, poorly permeable soils: Loosen soil by scarification or tillage. For clayey soils, also add lime to loosen soil structure or cover with a more desirable soil.

Table IV-5.—*Characteristics of commonly used legumes*[a] *for revegetation purposes*

Common name	Scientific name	Season			Site suitability				Growth habit[b]	pH range[c]	Use suitability			Remarks
		Cool	Warm	Dry	Well drained	Moderately well drained	Somewhat poorly drained	Poorly drained			Erodible areas	Waterways and channels	Agriculture[d]	
Alfalfa	*Medicago sativa*	X		X	X	X			P	6.5-7.5	X		X	Requires high fertility and good drainage.
Clover, Alsike	*Trifolium hybridium*	X			X	X	X	X	P	5.0-7.5	X		X	Good for seeps and other wet areas. Dies after 2 years.
Clover, red	*Trifolium pratense*	X			X	X			P	6.0-7.0	X		X	Should be seeded in early spring.
Clover, white	*Trifolium repens*	X			X	X	X		P	6.0-7.0	X		X	Stand thickness decreases after several years.
Flatpea	*Lathyrus sylvestris*	X		X	X	X	X		P	5.0-6.0	X			Seed is toxic to grazing animals. Good cover.
Lespedeza, common	*Lespedeza striata*		X		X	X			A	5.0-6.0	X			Low-growing, wildlifelike seed. Kobe variety most often used. Acid tolerant.
Lespedeza, Korean	*Lespedeza stipulacea*		X	X	X	X	X		A	5.0-7.0	X			Less tolerant of acid soils than common lespedeza.
Lespedeza, sericea	*Lespedeza cuneata*		X	X	X	X	X		P	5.0-7.0	X	X		Woody, drought tolerant, seed should be scarified. Bunchlike growth.
Milkvetch, cicer	*Astragalus cicer*			X	X	X	X		P	5.0-6.0	X		X	Drought tolerant. Low growing. No major diseases. Hard seed coat.
Sweetclover, white	*Melilotus alba*	X		X	X	X			B	6.0-8.0	X		X	Requires high-pH spoil. Tall growing. Produces higher yields. Less reliable seed production.
Sweetclover, yellow	*Melilotus officinalis*	X		X	X	X			B	6.0-8.0	X		X	Requires high-pH spoil. Tall growing. Can be established better than white sweetclover in dry conditions.
Trefoil, birdsfoot	*Lotus corniculatus*	X		X	X	X	X		P	5.0-7.5	X		X	Survives at low pH. Inoculate with special bacteria. Plant with a grass.
Vetch, crown	*Coronilla varia*	X		X	X	X			P	5.5-7.5	X		X	Excellent for erosion control. Drought tolerant. Winter hardy.
Vetch, hairy	*Vicia villosa*	X		X	X	X			A	5.0-7.5	X		X	Adapted to light sandy soils as well as heavier ones. Used most often as a winter cover crop.

[a]Legumes should be inoculated. Use four times normal rate when hydroseeding.

[b]A = annual; B = biennial; P = perennial.

[c]Many species survive and grow at lower pH; however, optimum growth occurs within these ranges.

[d]Hay, pasture, green manure.

Note.—Prepared in cooperation with Soil Conservation Service plant material specialists and State conservationists.

Table IV-6.—*Commonly used trees and shrubs*

Common name	Scientific name	Remarks
Shrubs:		
Amur honeysuckle	*Lonicera maacki podocarpa*	Good for wildlife. Shows more vigor and adaptability as plants mature.
Bristly locust	*Robinia fertilis*	Extreme vigor. Thicket former. Good erosion control. Rizomatous, 5-7 ft tall. Excellent on flat areas and outslopes.
Autumn-olive	*Elaeagnus umbellata*	Nitrogen-fixing nonlegume. Good for wildlife. Excellent fruit crops. Wide adaptation. Up to 15 ft tall.
Bicolor lespedeza	*Lespedeza bicolor*	Can be established from planting and direct seeding. Ineffective as a ground cover for erosion control.
Indigo bush	*Amorpha fruticosa*	Has high survival on acid spoil. Leguminous. Not palatable to livestock. Thicket former. Slow spreader. 8-12 ft tall.
Japanese fleeceflower	*Polygonum cuspidatum*	Grows well on many sites, especially moist areas. Excellent leaf litter and canopy protection. pH range of 3.5 to 7.0.
Silky dogwood	*Cornus amomum*	Grows best on neutral spoil pH. Can withstand pH range of 4.5 to 7.0. Some value as wildlife food and cover plants. Poor surface protection.
Tatarian honeysuckle	*Lonicera tatarica siberica*	Upright shrub, forms clumps. Does well on well-drained soils. Up to 12 ft tall. Takes 2 years for good cover.
Trees, conifers:		
Virginia pine	*Pinus virginiana*	Tolerant of acid spoil. Use for esthetics and where other species will not survive. Slow development. Good for wildlife.
Pitch pine	*Pinus rigida*	Deep rooted and very acid tolerant. Can survive fire injury. Deer like small seedlings. Plant in bands or blocks.
Loblolly pine	*Pinus taeda*	Very promising species, rapid early growth. Marketable timber products. Can survive pH 4.0 to 7.5. Susceptible to ice and snow damage.
Scotch pine	*Pinus sylvestris*	Good for Christmas trees if managed properly. Can be planted on all slopes and tolerates pH of 4.0 to 7.5.
Shortleaf pine	*Pinus echinata*	Some insect problems. Will sprout freely if cut or fire killed when young. Good marketable timber.
White pine	*Pinus strobus*	May be used for Christmas trees. Has poor initial growth but improves with time. Plant in bands or blocks.
Austrian pine	*Pinus nigra*	Can be planted on all slopes. Plant in bands or blocks. When planted near black locust, deer cause browse damage.
Japanese larch	*Larix leptolepis*	Should be planted on unleveled and noncompacted spoil. Provides good litter.
Red pine	*Pinus resinosa*	Sawfly damage in some areas. Plant on all slopes. Light ground cover.
Rocky Mountain juniper	*Juniperus scopulorum*	Has shown good survival on Kansas spoil materials. Compact growth varieties have from silver to purple colors.
Eastern red cedar	*Juniperus virginiana*	Tall, narrow growth. Best on dry, sandy soils. Good with black locust. pH 5.0 to 8.0.
Mugho pine	*Pinus mugo mughus*	Survives on acid spoil. Develops slowly. Low growing. Good cover for wildlife.
Trees, hardwoods:		
Black locust	*Robinia pseudoacacia*	Can be direct seeded. Wide range of adaptation. Rapid growth; good leaf litter. Use mixed plantings. Dominant stem clones preferred.
Bur oak	*Quercus macrocarpa*	Better survival with seedling transplants than acorns. Light to heavy ground cover.
Cottonwood	*Populus deltoides*	A desirable species for large-scale planting. Good cover and rapid growth. Pure stands should be planted.
European black alder	*Alnus glutinosa*	Rapid growing. Wide adaptation. Nitrogen fixing, nonlegume. Can survive pH 3.5 to 7.5. Adapted to all slopes.
Green ash	*Fraxinus pennsylvanica*	Very promising species. Use on all slopes and graded banks with compact loams and clays. Plant in hardwood mixture.
Hybrid poplar	*Populus spp.*	Rapid growth. Good survival at low pH. Marketable timber after 20 years. Cannot withstand grass competition. Good for screening.
Red oak	*Quercus rubra*	Makes slow initial growth. Good survival, plant on upper and lower slopes only. Can grow from pH 4.0 to 7.5.
European white birch	*Betula pendulata*	Makes rapid growth on mine spoil. Poor leaf litter and surface coverage.
Sycamore	*Platanus occidentalis*	One of the most desirable species for planting. Poor ground cover. Volunteer trees grow faster than planted ones.

Preparation Practices. To obtain a rapid and successful growth of vegetation, the following practices should be followed:

- When required, topsoiling material should be spread to a depth of 15 to 30 cm (6 to 12 inches). The spoil surface should be roughened before the material is applied so that a sound bond can be formed.
- Where terrain permits, soil material should be worked by discing, harrowing, or other means to break up large clods and eliminate any surface crusting. Commercial rock pickers are effective in removing rock and debris, which often prevent good seedbed preparation. On steep slopes where equipment travel is limited and aerial seeding or hydroseeding is performed, the surface soil should be prepared with commercial pick chains, by dragging a cleated dozer track or other device along the slope, or by running a cleated dozer up and down the slope.
- Application rates for lime and fertilizers should be determined from soil tests. Where terrain permits, the lime should be worked into the soil to a depth of about 15 cm (6 inches) by discing or harrowing. Highly acidic soils (pH below 4.0) will require extra lime.
- Seeding should be performed as soon as possible after final grading or application of topsoiling material. Surface soil crusting resulting from delays in seeding can result in poor seed germination and loss of seed due to wind action and surface runoff.
- Mulches should be applied immediately after seeding to promote growth and provide temporary stabilization. Mulch crimping is an effective means of securing mulching material, especially on steep slopes and in areas where wind is a problem.

pH and Liming. The primary factor limiting plant growth on surface mine spoil is acidity, which is often expressed as pH.

The pH of a soil is a numerical measure of the acidity (sour) or alkalinity (sweet) of the soil (fig. IV-29). On a scale of 1.0 to 14.0, acid values range from 1.0 to 7.0 with 1.0 being the most acidic and 7.0 being neutral. Alkaline values range from 7.0 to 14.0, with 14.0 being the most alkaline.

The acidity of most surface mine spoil limits the number of plant species that can be planted. Some plants, such as weeping lovegrass, can be planted on spoil with a pH as low as 4.0. How ever, other species, such as K-31 tall fescue, require a pH of no lower than about 5.0 before good growth can be obtained. Legumes generally require a higher pH than grasses.

Lime is used to correct acidic soil conditions and enhance the availability of soil nutrients, such as phosphorus and magnesium. Some nu-

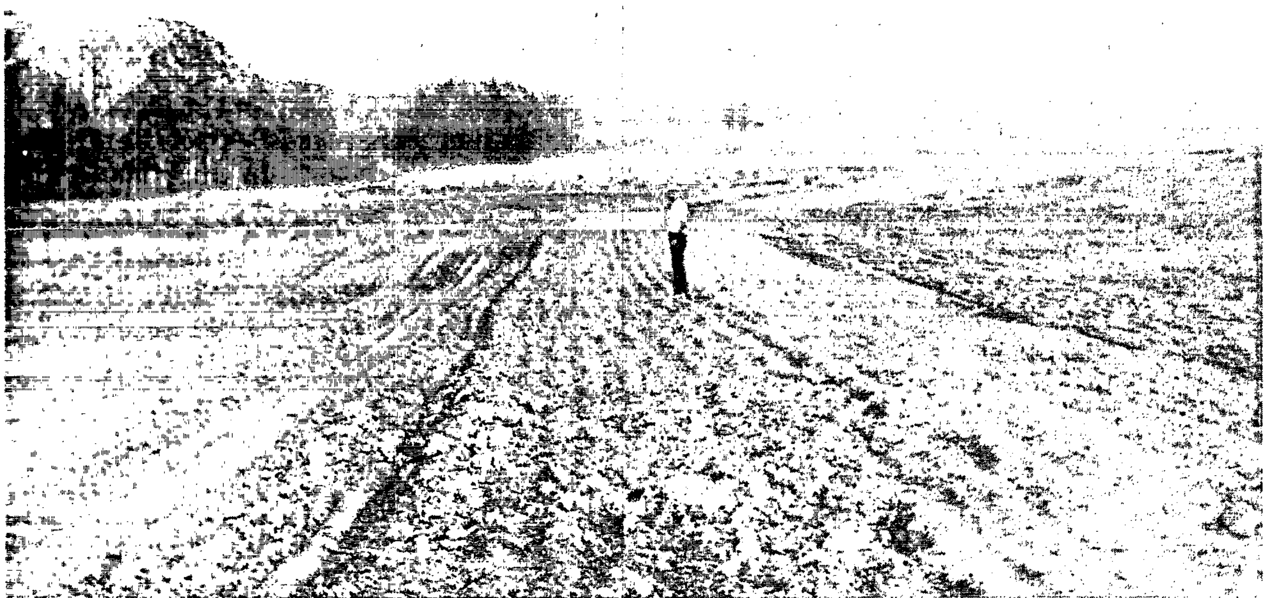

Figure IV-28. Well-prepared seedbed.

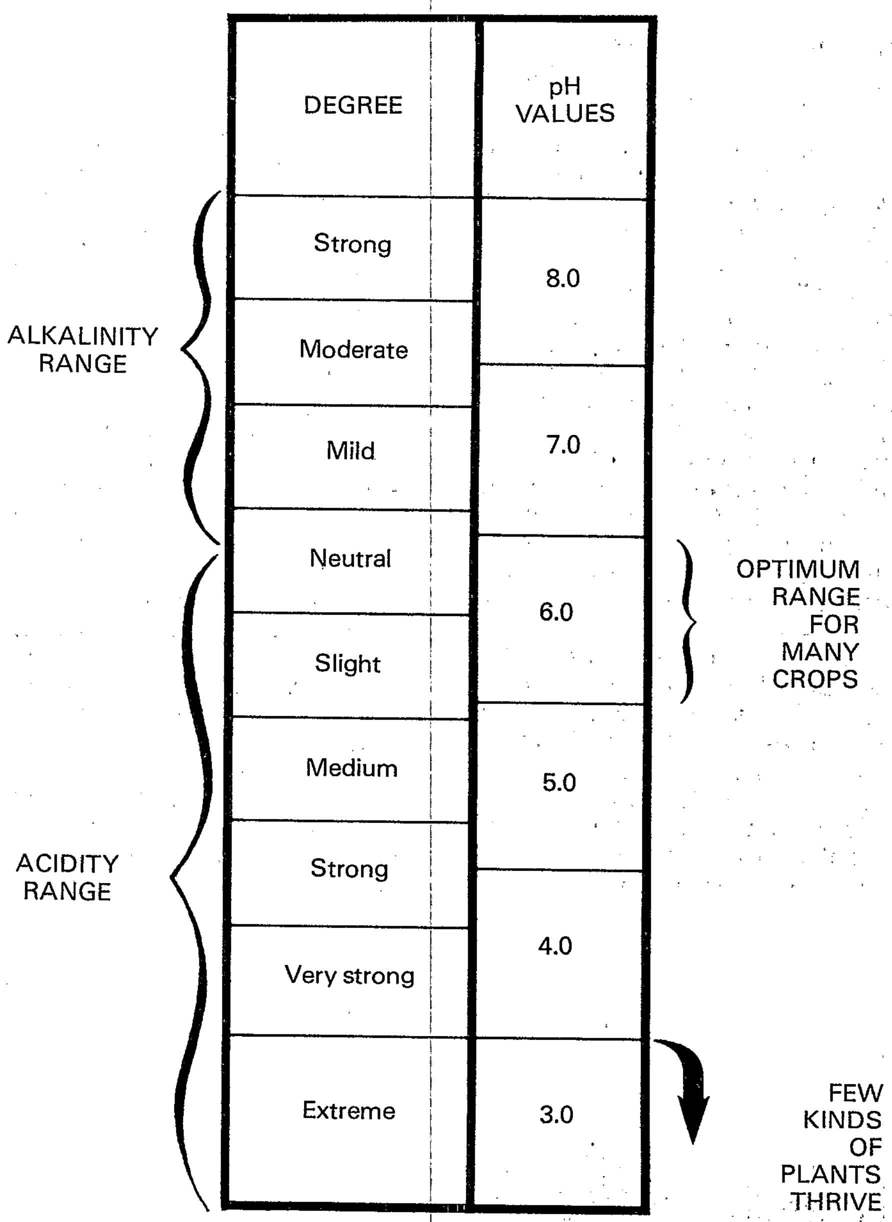

Figure IV-29. pH scale.

trients become available with increased pH, while other elements, which are toxic to plants at low pH levels, become unavailable. When liming acidic spoil, the rates applied should be based on soil tests. When samples are collected for laboratory analysis, subsoil (below 15 cm, or 6 inches, in depth) and surface soil (top 15 cm, or 6 inches) samples should be taken. This will insure that sufficient lime will be applied to counteract current and future acidity.

Table IV-7 contains the approximate liming rates required to increase the pH of various tested soils to 4.5 to 5.0, 5.0 to 5.5, and 5.5 to 6.0.[4] These figures should only be used as approximates. Soil samples should be taken and analyzed for accurate rates.

When purchasing and applying agricultural lime to spoil material, the following factors should be understood:

- Common agricultural limestone or ground limestone is the most common liming material for correcting spoil acidity. Limestone may consist mainly of calcium carbonate ($CaCO_3$), or it may contain both calcium carbonate and magnesium carbonate ($MgCO_3$). Limestone that contains about as much magnesium carbonate as calcium carbonate is

Table IV-7.—*Agricultural lime needed to increase surface mine spoil pH to specified level*[a,b]

Spoil pH test	Tons lime needed per acre to increase pH to		
	4.5 to 5.0	5.0 to 5.5	5.5 to 6.0
	Stabilization and erosion control	Medium forage production	High forage production
Less than 3.0 . .	6 to 8 or more	8 to 10 or more	10 to 12 or more
3.0 to 3.5	3 to 5 or more	5 to 7 or more	7 to 9 or more
3.5 to 4.0	2 to 3	3 to 5	5 to 7
4.0 to 4.5	1 to 2	2 to 3	3 to 5
5.0 to 4.5		1 to 2	1 to 3

[a]Rate per acre is based on lime having a neutralization value of 100 and affecting a 15-cm (6-inch) depth.
[b]These figures are only an approximate. Soil samples should be taken and analyzed for accurate rates.
Source: *Guidelines for Reclamation and Revegetation, Surface-Mineral Coal Areas in Southwest Virginia,* Virginia Polytechnic Institute and State University, Extension Division, Feb. 1973.

called dolomite. Limestone containing lesser proportions of magnesium carbonate is called calcitic or magnesian limestone. Other liming materials include quicklime, hydrated lime, chalk, marl, and fly ash. Rock phosphate is high in calcium and has some neutralizing effect on acidic spoil in addition to providing phosphorus.

- The total capacity of lime to correct acidity, or the neutralizing value, is measured by the calcium carbonate equivalent.
- The size of the particles of the liming material is usually the best guide to the rate at which soil acidity can be corrected. The smaller the particles are, the faster the lime can correct acidity. The coarser the lime particles, the less reactive the material.
- The ideal time for lime application is 6 months prior to seeding. When this is not possible, the finest ground limestone should be purchased and thoroughly mixed with the soil as far in advance of seeding as possible.
- Lime should be applied immediately after grading, regardless of season, and worked into the spoil to a depth of 15 cm (6 inches). On extremely acidic spoil, lime should be applied to a depth of 25 to 30 cm (8 to 12 inches). In this event, additional lime will be required.
- Lime can be applied by truck, tractor-drawn spreaders, and by hand broadcasting. On steep outslopes, lime can be applied by rear-mounted blowers attached to liming trucks.
- Maintenance liming may be required in the third or fourth season following the initial application, based on soil-testing recommendations.

Fertilizing. Most surface mine spoil is deficient in plant nutrients such as nitrogen, phosphorus, and sometimes potassium, which are needed for plant establishment and sustained growth. Prior to the use of any fertilizer, soil samples should be taken and analyzed by State or commercial soil-testing laboratories experienced in mining soils and spoils. Fertilizers should be selected based on the results and on the recommendations of the lab.

Fertilizers are labeled according to their nitrogen (N), phosphate (P_2O_5), and potash (K_2O) content. These values are given in percent or pounds per 100 pounds of fertilizer. This is called the fertilizer grade. For example, the grade 5-10-10 contains 5 percent N, 10 percent P_2O_5, and 10 percent K_2O. Likewise, an 0-20-20 fertilizer contains no N, 20 percent P_2O_5, and 20 percent K_2O.

When a soil test recommendation calls for 25 pounds of N, 50 pounds of P_2O_5, and 50 pounds of K_2O per acre, a fertilizer with a 1-2-2 ratio (twice as much P_2O_5 or K_2O as N) is needed. This ratio can be provided by using a 5-10-10-, 6-12-12-, 8-16-16-, or 10-20-20-grade fertilizer. If a 5-10-10 grade is chosen to supply 25 pounds of N, 50 pounds of P_2O_5, and 50 pounds of K_2O, the first number of the grade (5) is divided into the N recommendation (25) and the result multiplied by 100, as shown below, to arrive at the amount of fertilizer required per acre.

$$25/5 = 5 \times 100 = 500 \text{ lb/acre of 5-10-10 to supply 25 lb N, 50 lb } P_2O_5 \text{, and 50 lb } K_2O$$

Higher analysis, or "straight" fertilizers, contain only one of the nutrients. Examples are concentrated super phosphate, 0-46-0, and ammonium nitrate, 33.5-0-0. These high-analysis fertilizers can be combined to provide some advantages over the use of regular mixed fertilizers because:

- They are generally more economical than mixed fertilizers.
- There is less material to handle.
- Extra amounts of fertilizers are avoided.
- Seed damage due to unneeded potash (K_2O) is avoided. (This damage can occur with mixed fertilizers such as 10-10-10.)

In addition to commercial synthetic fertilizers, the organic materials listed in the following table have some fertilizing value and are available in some areas:[5]

Organic fertilizer	Pounds per ton		
	N	P_2O_5	K_2O
Cattle manure	10	5	10
Poultry manure	20	16	8

In some areas, sewage sludge and fly ash have been used for fertilizing spoil; however, technical assistance should be obtained before using the material. The U.S. Soil Conservation Service (SCS) is often a good source of information for local conditions.

Fertilizers should be applied at the time of seeding, when conditions will be favorable for germination. When seed is planted in sandy soil in late fall and remains dormant during the winter, fertilizer application should be postponed until early spring when the seed begins to germinate. Otherwise, fertilizers can leach out of the soil during the winter and make refertilization necessary. On the other hand, heavy clay soils that are wet in the spring can be fertilized in the late fall even though the seed will remain dormant until spring. Clay soil will hold the fertilizer and prevent it from leaching, especially if winter temperatures are low. Maintenance applications of fertilizers may be required in the third year or later on soil-testing recommendations. Methods of applying fertilizers include hand, hydroseeder, truck, and pull-type spreaders.

Planting. Methods of planting vegetation at surface mining sites vary depending on topography, type of vegetation, stoniness of soil surface, and equipment availability. Currently used methods of establishing vegetation and their specific suitability are:

- *Hydroseeders* are very useful for applying seed, fertilizer, and mulch to steep outslopes and other areas where equipment accessibility is limited (fig. IV-30).
- *Aircraft* are especially useful for broadcast seeding on large areas, inaccessible areas such as orphan mined lands, and during thawing and freezing periods.
- *Cyclone seeders* are well suited for broadcasting seed on benches and level areas. Germination can be increased by limiting equipment travel over seeded areas.
- *Grass or grain drills* are limited to rolling or level terrain that is relatively free of stones. The Rangeland drill is sturdier than conventional drills and provides better and longer performance on strip mine spoil.
- *Rear-mounted blowers* can be attached to lime trucks to spread both seed and fertilizer on steep outslopes and other inaccessible areas.
- *Hand planting* generally is used when trees and shrubs are planted. The method is time consuming and therefore costly.

Mulching. Mulching is required to protect the newly seeded area from soil erosion during and immediately following the germination period. In addition, mulching provides a better environment for germination and plant development by conserving soil moisture, moderating soil temperature, and, in the case of organic mulches, providing nutrients to the soil.

Recommended practices to be considered in the mulching of seedbeds are:

- Mulching material should be applied at the recommended rates (sec. II, vol. II). The material should be spread as evenly as possible over the entire site. A comparison of straw mulching rates and surface coverage is given in figure IV-31.
- Organic mulches, such as straw, hay, woodchips, and wood fiber, should be given preference over inorganic mulches, since they provide needed micro-organisms, seeds, organic matter, and nutrients to the soil.

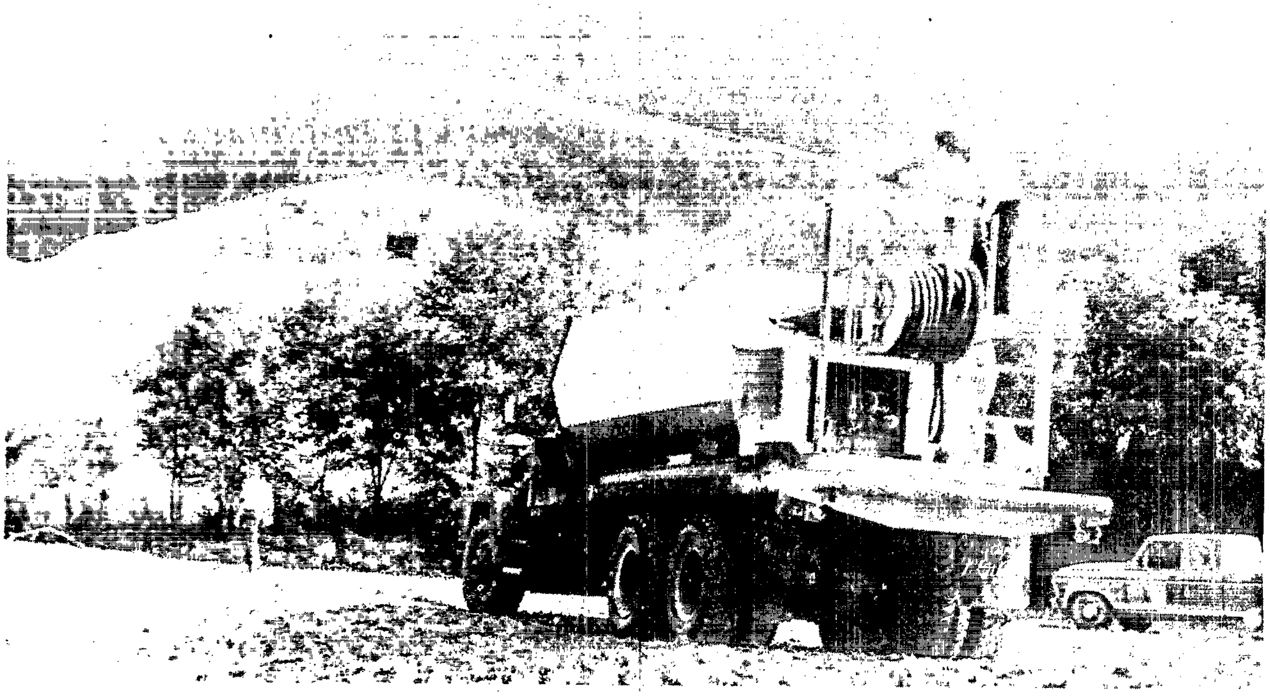

Figure IV-30. Hydroseeding a graded and properly roughened mined area.

- Straw and hay mulches should be tacked to prevent their removal by wind. Crimping is the preferred method of securing the mulch material. Asphalt and emulsified chemical tack materials are also suited for securing straw and hay mulch.
- Highly acidic spoil areas should be given a heavier mulch application. Fiber glass, stone, and other nonbiodegradable mulches will provide long-term stabilization of these problem areas.

Information Sources

In addition to assistance from State reclamation departments, various forms of assistance are available to coal mine operators and their representatives from local, State, and Federal agencies.

County agricultural extension agents can be contacted for information concerning soil sampling, soil testing, revegetation, and other matters related to agriculture. Local agents may be contacted through the offices of State extension service directors listed in section IV, volume II.

The SCS also has regional and county offices that can provide valuable assistance in planning revegetation and other erosion and sediment control efforts. Local SCS representatives may be contacted through the State conservationists' offices listed in section IV, volume II.

MAINTENANCE

Maintenance of erosion control practices is an extremely important requirement in achieving effective control. Roadways and water-handling structures require considerable maintenance attention during mining. Also, attention must be given to revegetated areas in order to insure that long-term soil stabilization is achieved.

Runoff Control Practices

All water-handling structures must be inspected after every major storm to be sure that no breaches have occurred. Sediment buildup in diversion structures, such as dikes and ditches, must also be checked. Outlet disposal areas require frequent inspection to insure that no erosion is occurring. Erosion damages require prompt repair to prevent further soil loss and to protect other areas of the site. Measures should also be taken to insure that similar damage does not occur in the future.

Sediment and other soil debris removed from ditches and other water-handling structures should be disposed of in the mine in a manner that will prevent the sediment from being carried back into the waterways at the mine.

Vegetative Stabilization Practices

When revegetating with grasses and legumes, top dressing with nitrogen, phosphorus, and potassium fertilizers is required on a periodic basis to keep vegetation healthy and provide long-term erosion control. Too often a stand of vegetation is allowed to deteriorate and become ineffective because it is nutritionally starved. Fertilizer will help keep a dense stand and provide for the growth of desirable plants. Soil samples should be taken from reclaimed areas and additional lime and fertilizer added as needed.

Areas where failures have been experienced in the establishment of vegetative protection

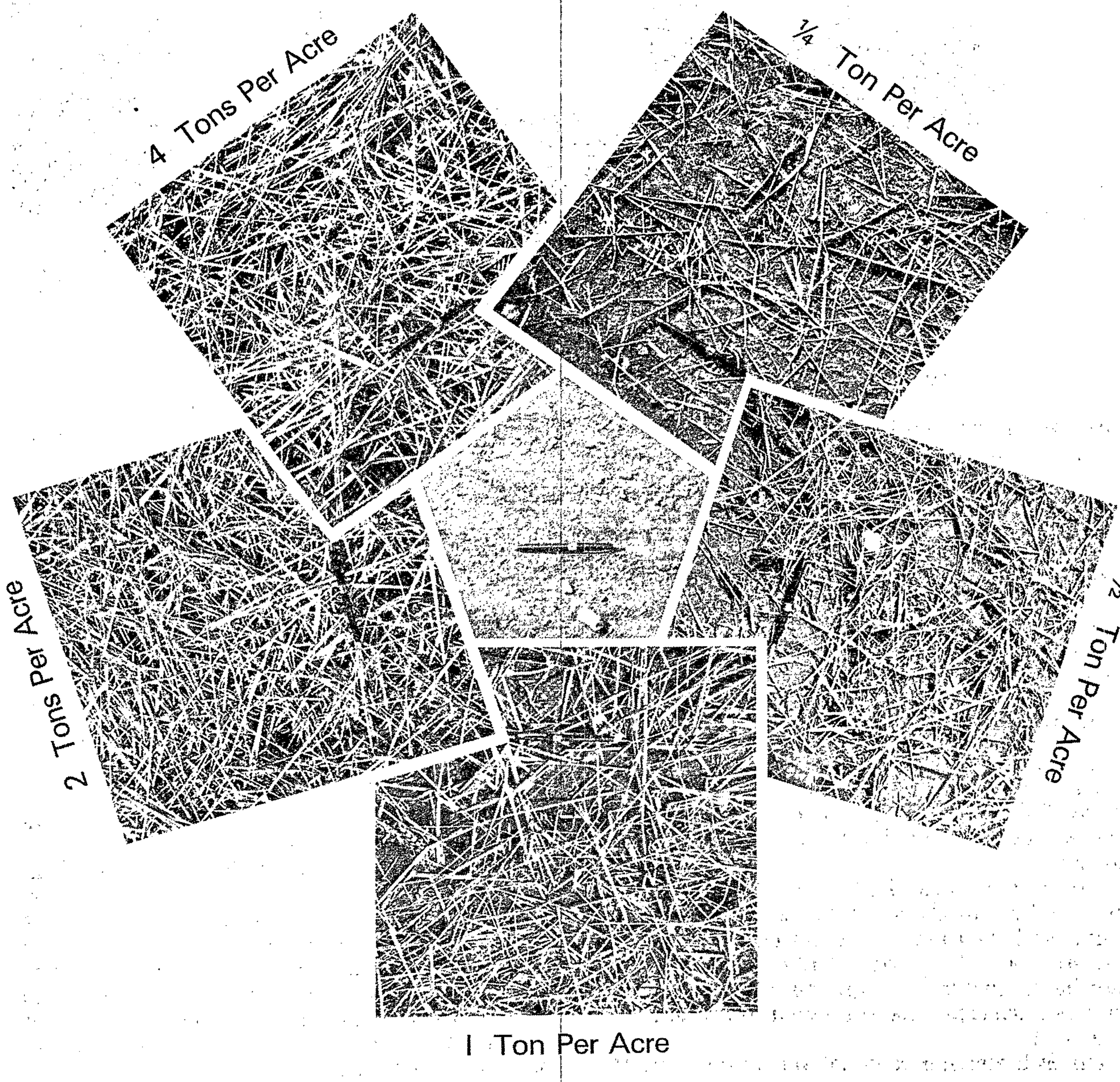

Figure IV-31. Comparison of straw-mulching rates and surface coverage.

must be promptly treated. If the failure is due to rilling or gully formation, temporary structural practices, such as flexible downdrains and section slope drains (sec. I, vol. II), can be utilized while arrangements for permanent control are made. The reestablishment of permanent vegetative cover should be the ultimate goal. However, changed site conditions may require the installation of some sort of permanent structural control, such as level spreaders or diversion (sec. I, vol. II). Any remedial treatment should be initiated as soon as possible in an effort to keep the area requiring maintenance work to a minimum. Timely maintenance will also reduce costs in the long run.

Nonvegetative Stabilization Practices

Roadbeds should be kept in good repair to prevent rutting and subsequent subbase saturation and erosion. The roadway needs to be graded periodically to maintain surface drainage and keep the surfacing material evenly distributed over the roadbed. The roadbed is usually maintained by grading smoothly with a blade. Shaping should be done in the spring after the road has lost its heavy moisture, but before it becomes hard and dry. Routine smoothing during the summer should be done after a rain has moistened the road but not made it slippery. In grading the road, considerable care must be taken to prevent soil from being pushed into the ditch, and to prevent damage to vegetation on the safety berm.

During dry periods, periodic watering of the roadway may be required to prevent the dust from damaging nearby vegetation and entering the ditch. Once in the ditch, the dust can be easily transported to lower lying natural waterways.

Channel stabilization structures, such as revetments, and check dams found in ditches, diversions, and streams must also be frequently inspected for damage. Repairs must be prompt to prevent further costly damage, and measures should be taken to prevent a reoccurrence of the problem.

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Section V
SEDIMENT CONTROL

Many coal-producing States prohibit the discharge of high concentrations of sediment into their streams. Surface coal mining involves massive earth-moving operations that subject large areas of unstabilized soil to accelerated erosion. Guidelines to reduce erosion have been presented in the preceding section. To supplement these erosion control practices, and to provide a secondary line of defense against any possible offsite sediment pollution, a number of sediment control practices can be used. The objective of these practices is to filter, or settle out, any waterborne sediment sufficiently to meet appropriate State or Federal effluent limitations. At the same time these structures delay and reduce peak flows in the streams, thereby reducing the potential for stream erosion.

SEDIMENT TRANSPORT AND DEPOSITION

Sediment is a product of erosion. The combined processes of soil detachment, dispersion, transportation, and, finally, deposition are referred to as sedimentation. The first line of defense against sedimentation is an effectively designed erosion control program. However, it must be stressed that even with the use of the most effective erosion control techniques, soil loss cannot be totally eliminated. The need for containment of sediment, therefore, is equally important. This section addresses those containment measures.

Surface runoff is the prime mover of detached soil particles. The sediment load transported by the runoff consists of wash load, suspended sediment load, and bed load. The wash load consists of very fine, or colloidal (silt- and clay-sized) particles, which settle very slowly even in still water. The suspended sediment is composed of inorganic soil particles (fine sand, silt, and clay) and organic particles carried and supported by the water itself. Bed load sediment refers to the coarser particles of soil, which move by rolling, sliding, or bouncing along the streambed. The capacity of the channel to transport material at any location decreases as the amount of sediment being carried increases, regardless of the type of transport taking place.

FACTORS INFLUENCING SEDIMENTATION

Sediment transportation and deposition is influenced by:

- The flow characteristics of the water
- The nature of the particles transported

Flow characteristics are determined by the velocity and turbulence of the moving water. As velocity and turbulence increase, the water is able to transport more sediment. Conversely, as velocity and turbulence decrease, the water has less potential for transporting sediment, and deposition of soil particles occurs.

The nature of the particles being transported refers to their size, shape, and density. Smaller and lighter particles, such as fine sand, silt, and clay, are more easily transported by water than coarser particles; the coarser and heavier particles are more easily deposited.

SEDIMENT CONTAINMENT STRATEGY

In developing a sediment containment strategy for a particular mine site, or a portion of that site, there are a few basic concepts that must be considered, if the greatest possible degree of control is to be achieved. First among these is the concept of "at-source" control. This means that every effort should be made to control the sediment at, or as near to, its source as possible (fig. V-1). It is too often the practice to attempt to control the sediment from the entire area being disturbed by building one or more large sediment basins offsite and in the major drainageways (fig. V-2). This approach requires that a much larger drainage area be controlled, as well as the construction, cleaning, and possibly, the postmining removal of larger structures. From a sediment control standpoint,

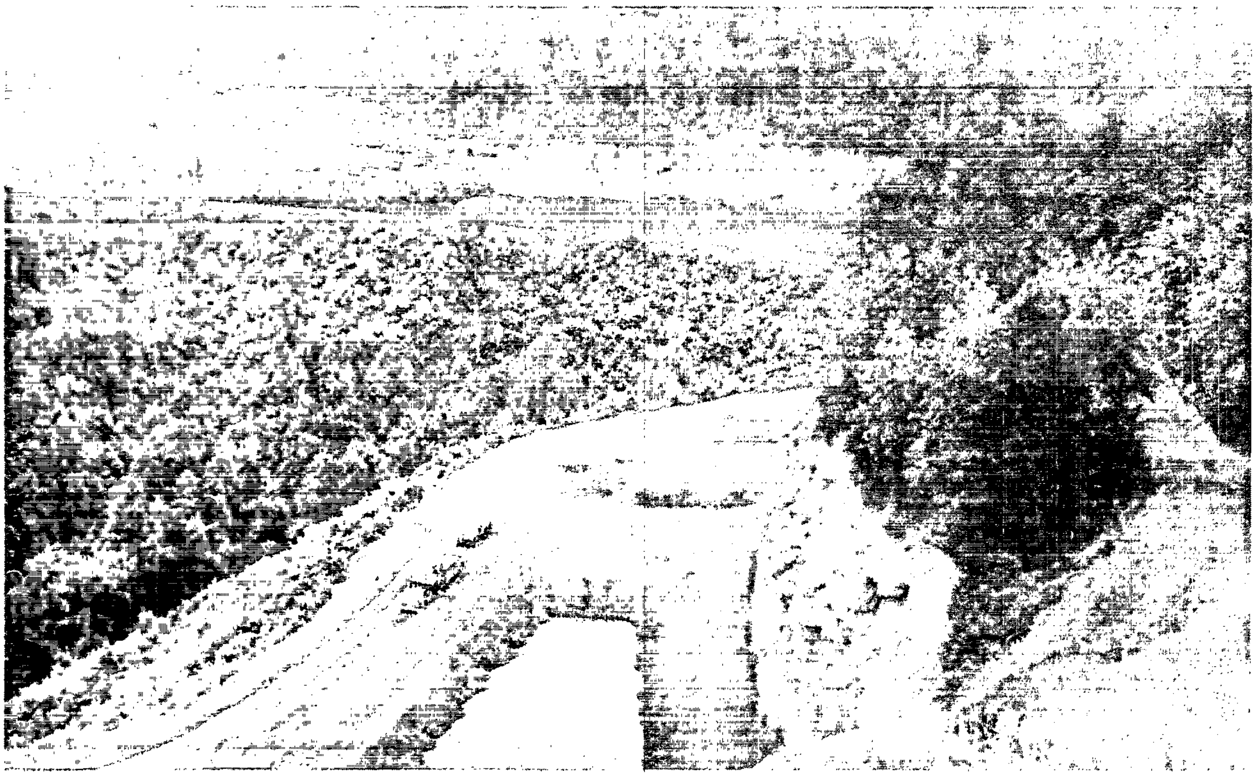

Figure V-1. Trapping sediment on the bench near its source.

Figure V-2. Perimeter sediment basin at a surface coal mine.

and for other environmental reasons, it is more desirable to segregate the sediment-laden waters from the rest of the surface flow.

Another important concept is identification and control of all major sources of sediment. The major sources of sediment from surface mine operations are generally access roads and spoil areas. As shown in table II-2, for an equal area of disturbance, sediment yield from haul roads can be twice the yield from spoil banks, and 30 times as high as the yield from the entire mine—a fact that is often ignored. A single basin is built in the stream valley to control the entire mine site. Portions of the haul road, however, often drain into different watersheds; consequently, some sediment goes completely uncontrolled. The sediment control plan should clearly identify all major sediment source areas at the mine, and show how the surface drainage from each area is to be controlled.

A third concept, upon which all sediment control practices are based, is runoff control. There can be very little control over the nature of the particles transported. It is usually feasible, however, to control the velocity of the water and the associated turbulence. A decrease in velocity and turbulence will reduce the ability of the water to transport sediment, and the sediment will settle out.

Reduction in slope steepness and/or length, roughening of slopes, spreading rather than concentrating flow, dissipating flow energy, and detaining flow are all means of slowing the flow of surface runoff and, thus, reducing its ability to transport detached soil particles (fig. V-3). Slowing also reduces the ability of the runoff to detach other soil particles.

TYPES OF CONTROL

Vegetative Buffers

Both natural and installed vegetative buffers are used to detain, absorb, and filter overland runoff, particularly sheet flow, and thus trap sediment.

Natural Vegetative Buffers. This practice involves the preservation and protection of a strip of natural vegetation downslope of the

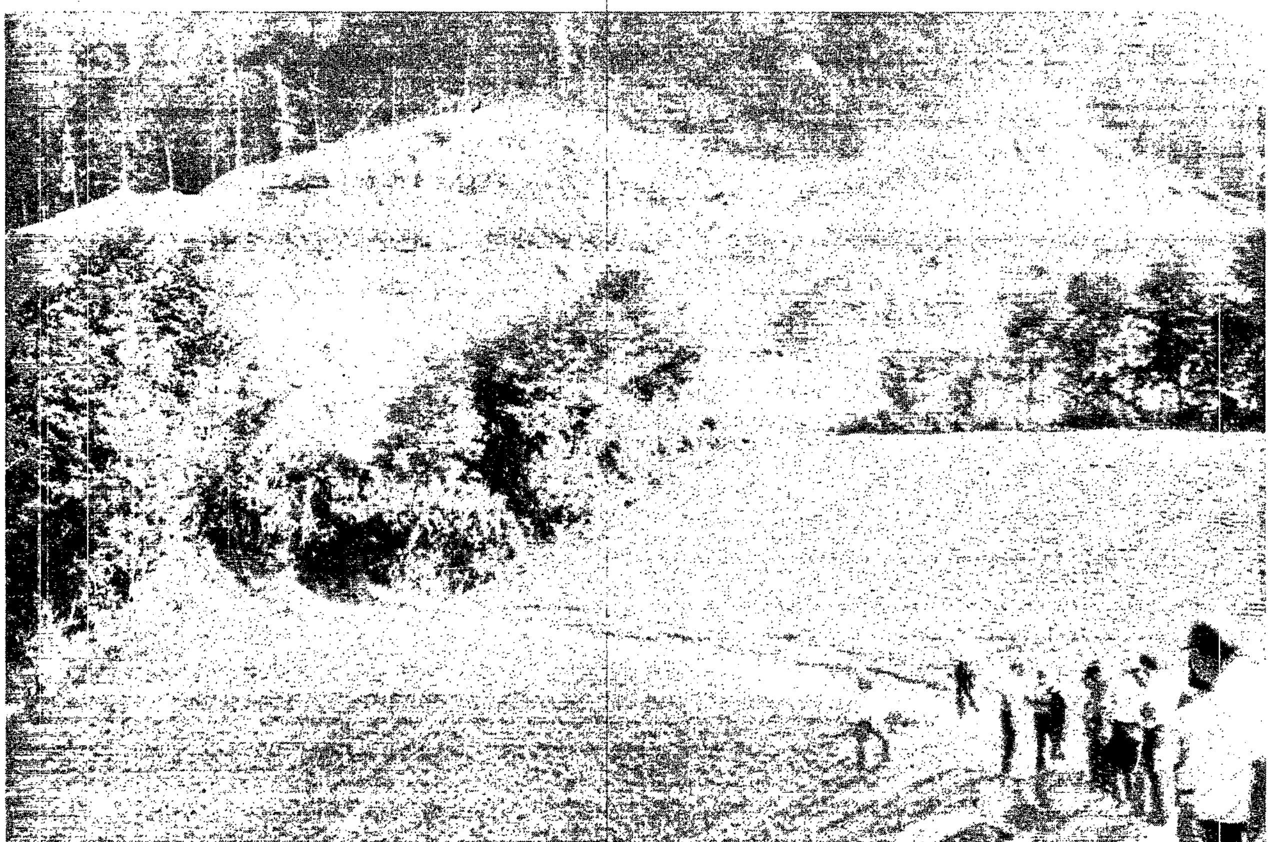

Figure V-3. Slope roughening and flattening to trap sediment near its source.

area disturbed by mining (fig. V-4). Where the ground slope is not too steep, a band of thick vegetation, whether grass or woody plants with accompanying ground litter, is an effective and economic means of trapping sediment washed from perimeter spoil slopes or haul road outslopes.

Installed Vegetative Buffers. Where the existing vegetation will not form a satisfactory buffer, or where an open drainageway is constructed, timely establishment of a vegetative buffer will help trap sediments (fig. V-5). Staging grading operations to provide a vegetated area between critical features, such as a drainageway, and higher elevated areas being reclaimed is the recommended procedure for installing a vegetative buffer. The surface of the buffer area should be roughened and planted to a quick-growing, robust grass. Flattening the slope in the buffer area will also help slow the runoff and trap sediment.

Sediment Traps

Sediment traps are small, temporary structures used at various points within, and at the

Figure V-4. Natural vegetative buffer below a haul road.

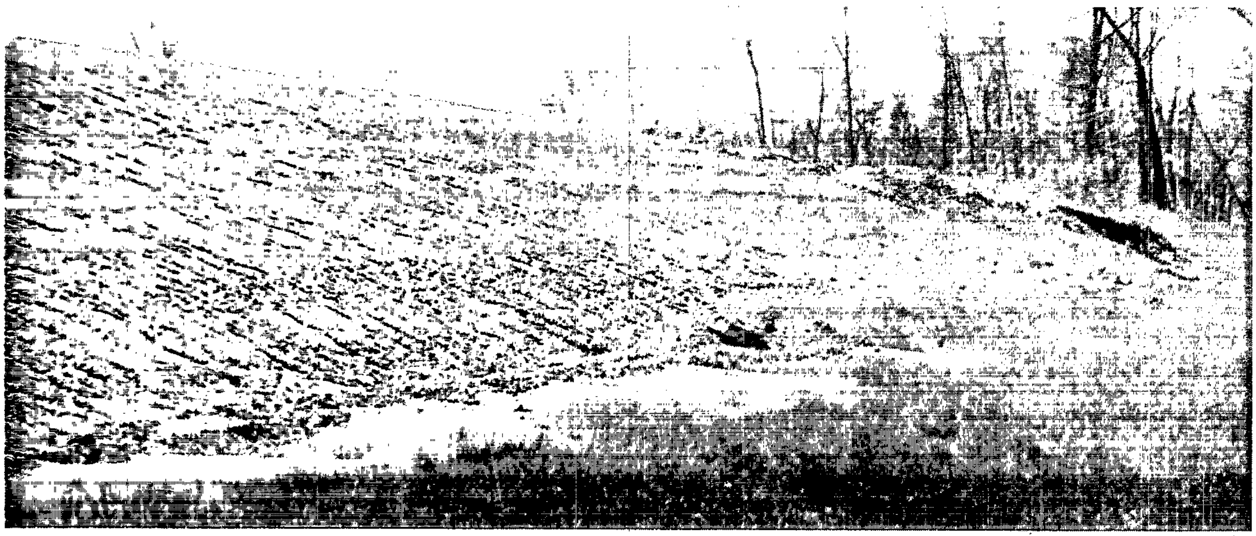

Figure V-5. Vegetative buffer strip below a spoil bank trapping sediment.

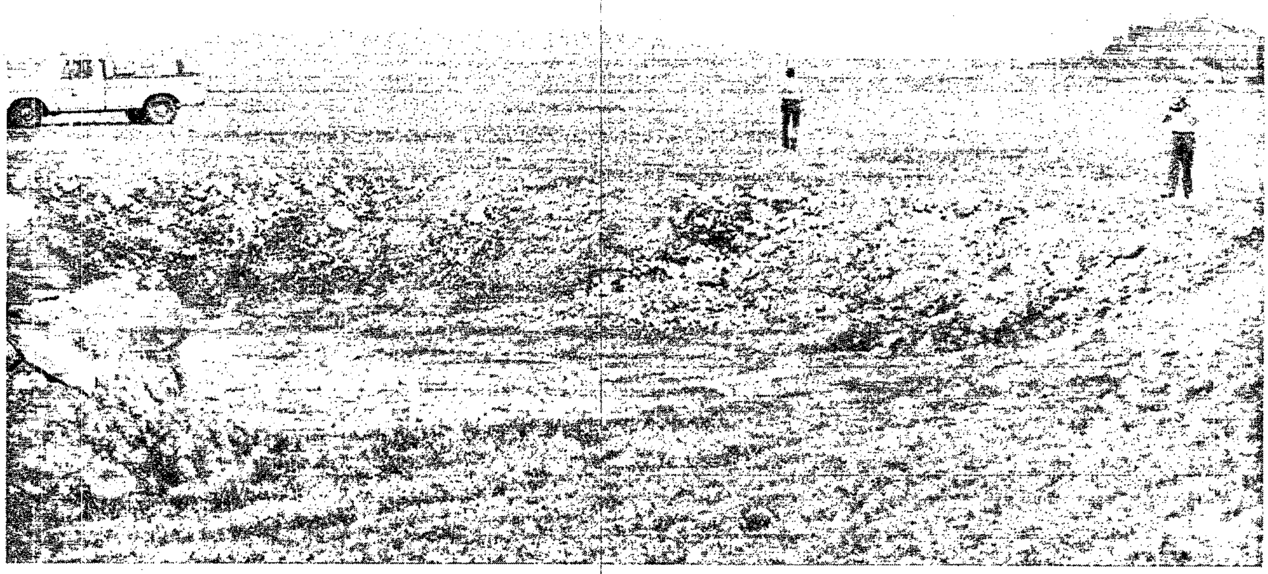

Figure V-6. Excavated trap on a construction site.

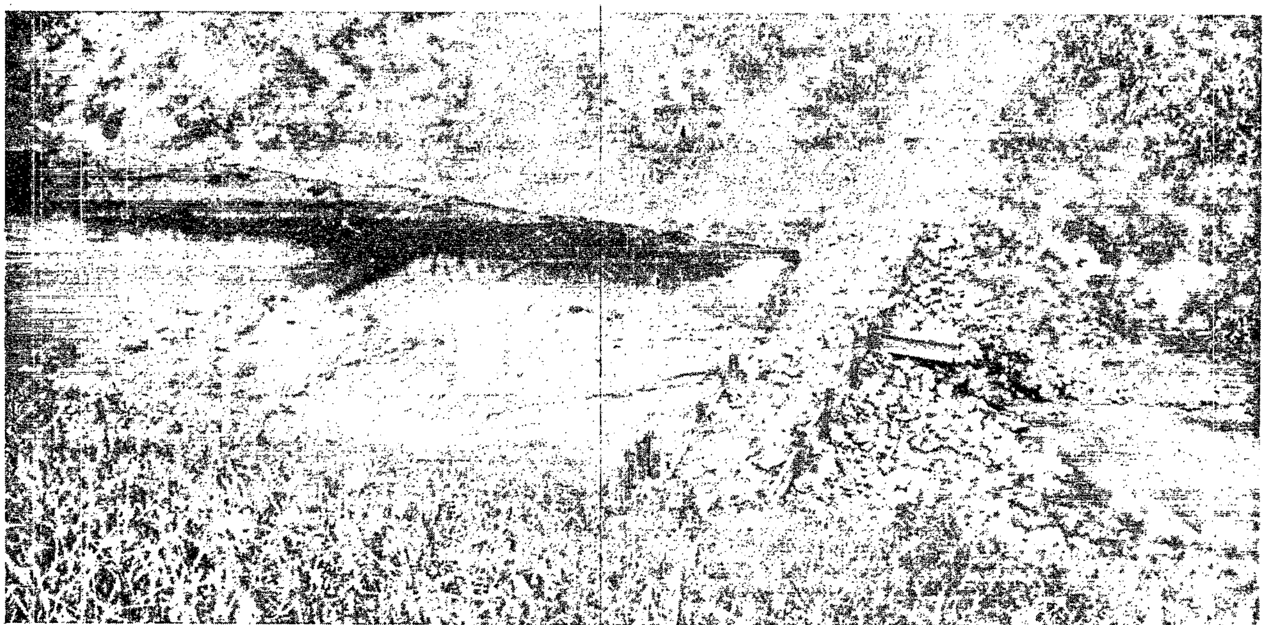

Figure V-7. Stone check dam trapping sediment.

periphery of, disturbed areas to detain runoff for a short period of time and trap heavier sediment particles (fig. V-6). Various types of sediment traps used include sandbags and straw bales, stone check dams, log-and-pole structures, excavated ditches, and small pits (fig. V-7). In fact, any sufficiently large depression in the surface will act as a trap. Depressions or undulations, particularly in the pit area, are recommended since they will detain the runoff and help to settle out some of the suspended sediment. See section I, volume II, for design and construction considerations.

Sandbags and Straw Bales. These devices are very easy and economical to construct. They need a limited amount of equipment for their construction, and therefore create less disturbance of the area in which they are constructed.

Sandbag-barrier sediment traps are constructed of bags filled with sand or crushed rock that are stacked in an interlocking manner (fig. V-8). Straw bale sediment traps are constructed of bales of hay or straw stacked as shown in figure V-9. Tying the bales with wire and staking them to the ground provides additional stability. Undercutting is the major cause of failure of these barriers. This can be prevented by setting the sandbags or straw bales 4 to 6 inches in a trench and compacting excavated soil along the upstream side.

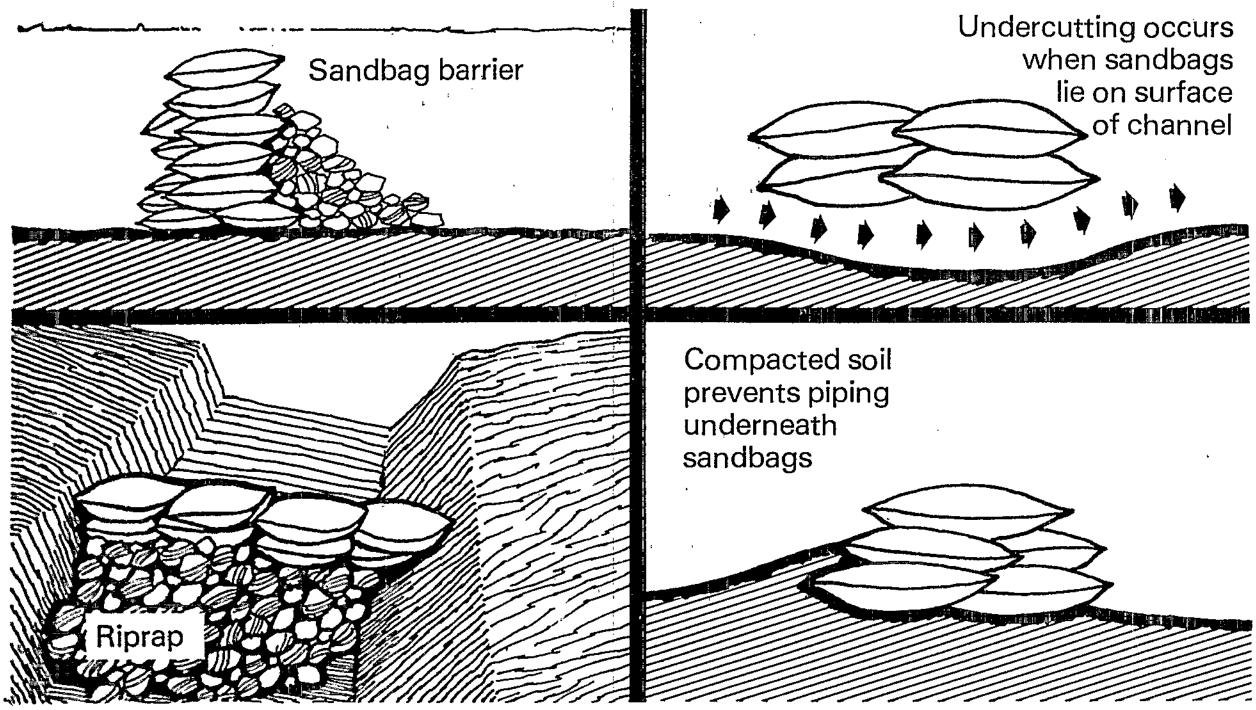

Figure V-8. Sandbag barrier.

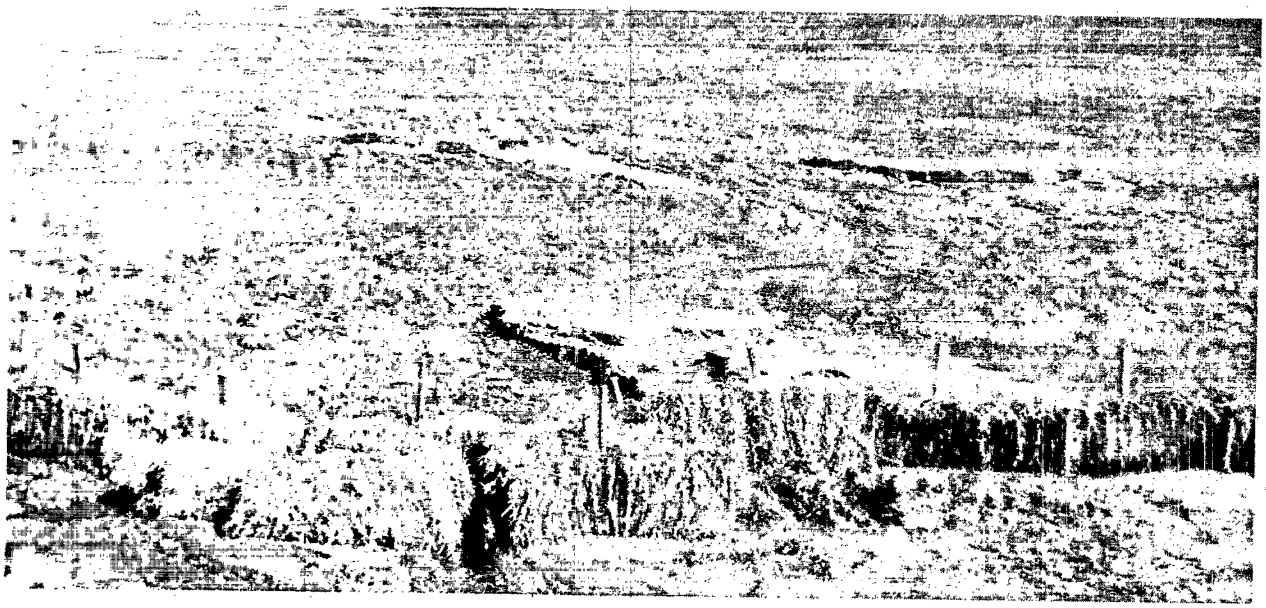

Figure V-9. Straw bale barrier.

Log-and-Pole Structures. A drawing of a log-and-pole structure is shown in figure V-10. These structures are built across waterways. The structure is built from the timber that is generally available at the site. Log-and-pole structures serve two purposes. First, they retard the flow of runoff and catch some of the sediment load. Second, they delay and reduce the peak flow in the stream, thereby reducing the potential for stream erosion. The effectiveness of these structures can be increased further by building several structures at regular intervals along the drainageway.

Sediment Basins

State-of-the-Art. Sediment basins are the most effective structures for trapping sediment. They are generally used in large earth-moving operations where heavy concentrations of both runoff and sediment are anticipated (figs. V-11 and V-12). The conventional method of controlling sediment that reaches the periphery of the mining operations is through the construction of a sediment retention basin at a point that intercepts the surface runoff before it leaves the mining site. There are two types of sediment ponds: the dry basin and the wet basin. The dry basin is generally used to trap sediment in an offstream location, and, therefore, is preferable. The wet basin is used when it becomes necessary to dam permanent streams in order to trap sediment.

Design standards and construction criteria for sediment basins vary from State to State, although most State standards are adapted from those developed by the Soil Conservation Service (SCS). To this date, only two States in the region covered in this manual have actually modified the basin design to fit the surface mining industry.[1,2] Under the SCS approach, sediment basins are usually not designed to achieve any set effluent water quality criterion or to remove any given percentage of the sediment in the inflow. Rather, the size of the basin is usually determined by utilizing a rule of thumb on the volume of the basin required based on the area of land disturbed. For example, the State of West Virginia, based on studies by the U.S. Forest Service and SCS, requires that the sediment basin pool have a minimum capacity to store 381 cubic meters per hectare (0.125 acre-feet per acre) of disturbed area in the drainage area.[1]

The SCS sediment basin design approach does not provide the designer with enough information to insure that State and Federal water quality criteria are met. A recent study of the effectiveness of sedimentation basins designed under this method revealed that during

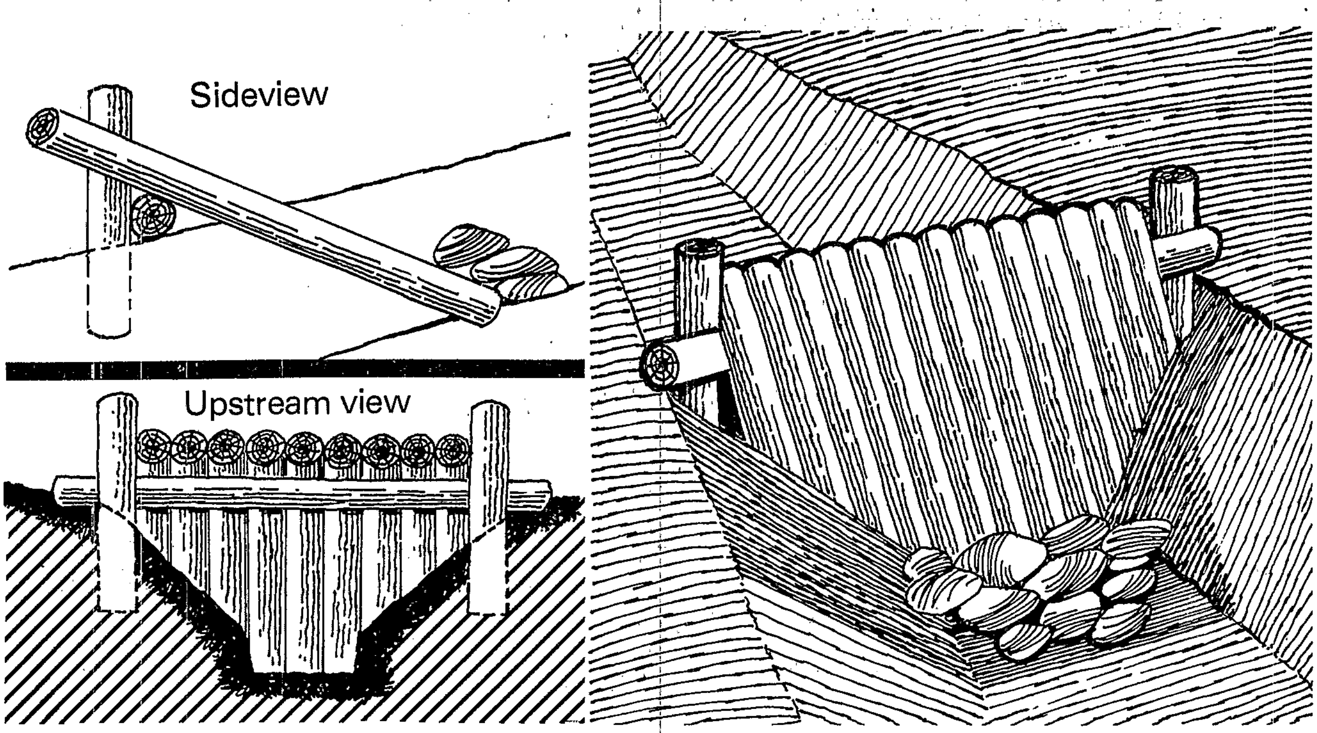

Figure V-10. Log-and-pole structure.

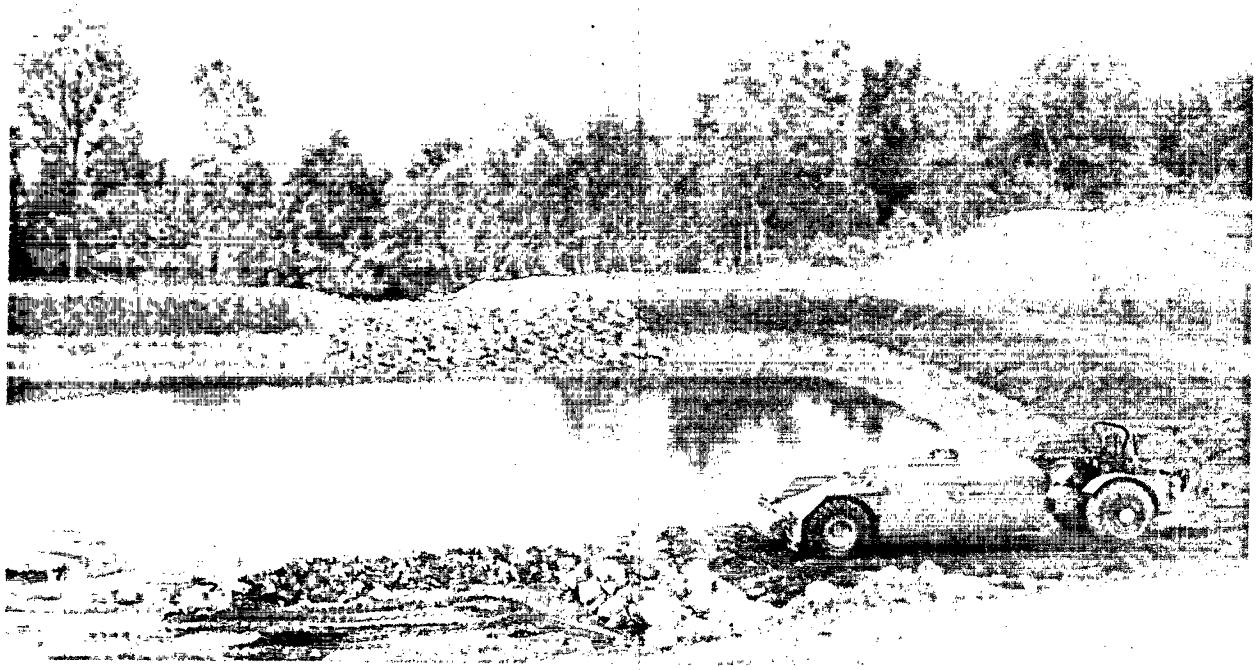

Figure V-11. Sediment basin.

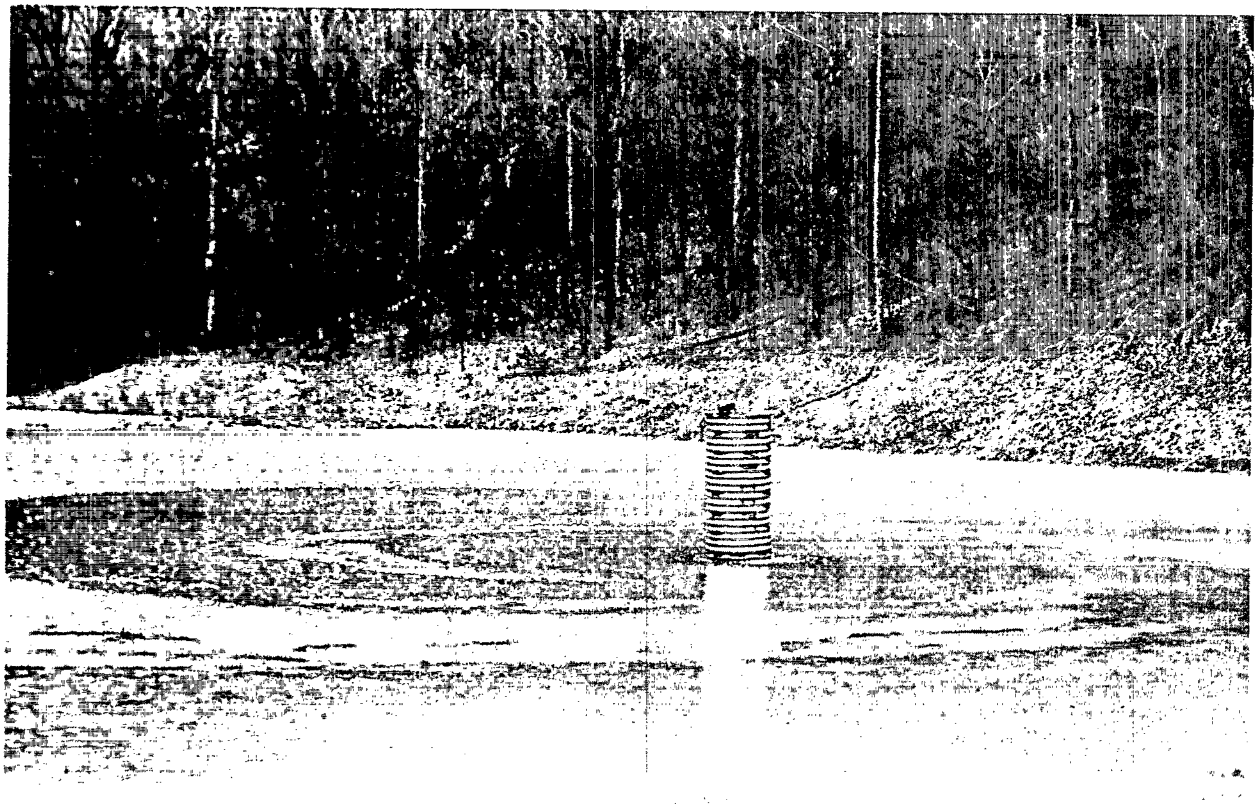

Figure V-12. Sediment basin functioning during a storm.

a storm the majority of these basins do not meet the proposed Federal criteria (table V-1).[3] Clearly a more rigorous and complete design procedure is needed. An alternative approach derived from the design process for settling tanks used in wastewater treatment facilities is provided.

Design consideration. Designing a sediment pond based on the removal of a certain size particle or percentage of suspended sediment requires more design data than the SCS approach. Many of the variables that need to be quantified for input to the design are not normally measured during the preliminary design or site investigations. However, these data can be obtained easily during the site exploration without much additional effort. The following factors must be known or assumed before an analysis can be made:[4]

- Design outflow rate (design stormflow)
- Anticipated grain-size distribution of the incoming sediment
- Expected suspended solids concentration in the inflow
- Specific gravity of the incoming solids
- Anticipated pond water temperature

Solids removal. The sediment basin can be designed to achieve a certain percentage removal of the suspended material or to settle out a minimum-size particle. These two parameters are plotted against each other on a grain-size distribution curve. Or, the basin can be sized to meet a given effluent solids concentration. These parameters are related by the following formula:

$$R\,(\%\text{ solids removed}) = \left\{1 - \frac{\dfrac{10^6}{c_1} - 1}{\dfrac{10^6}{c_2} - 1}\right\}100$$

where c_1 = solids concentration of influent, mg/l
c_2 = solids concentration of effluent, mg/l

This formula, which was originally derived from a simple mass balance for a conventional dredged-material-containment basin, is useful in evaluating the efficiency of the sediment basin.[4]

Table V-1.—*Results of pond sampling during rainfall conditions*

Pond number	Flow average/range (m^3/s)	Computed detention time (h)	Sampling period (h)	Number of samples	Average suspended solids concentration (mg/l)		Actual removal efficiency (percent)	Theoretical removal efficiency (percent)
					Influent	Effluent		
1	0.021	31.9	2.0	8	474	196	58.8	95
2	.028	—	2.0	8	239	17	92.8	88
3	.149	7.8	4.0	8	21,970	11,539	48.0	83
4	.133	4.4	4.0	16	9,643	6,198	36.4	84
5	.060	5.2	5.0	9	668	275	58.8	91
6	.042	325.0	26.0	8	868	35	95.9	99
7	.012-.093	20.8-2.7	16.0	9	765	66	91.3	83-67
8	.013	184.4	5.5	8	363	28	92.3	97
9	.056-.110	5.7	7.0	10	412	193	53.1	99

Source: D. V. Kathuria, M. A. Nawrocki, and B. C. Becker, *Effectiveness of Surface Mine Sedimentation Ponds,* prepared by Hittman Associates, Columbia, Md., for the U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio, Contract No. 68-03-2139.

The removal of solids by settling is basically a function of the overflow rate and the surface area of the basin. Depth of the basin and detention time are not primary design parameters, but they can affect the design and thus are secondary considerations. An initial approximation of the solids removal capabilities of a conventional basin can be made by assuming theoretically ideal settling conditions. For the theoretically ideal case, the size of the particles that will be retained will be determined by the overflow velocity and the critical settling velocity of the particles. The basic ideal relationship can be expressed in general terms below:[4]

$$\text{Required settling area} = \frac{\text{Overflow rate}}{\text{Critical settling velocity of the smallest particle to be retained}}$$

In the design of sediment ponds to settle a certain size particle, the ratio of the pond outflow to the surface area of the pond, Qo/A, is termed the overflow velocity Vo. Thus:

$$Vo = Qo/A$$

Based on the above relationship, it can be shown that if the critical settling velocity of any size particle is greater than the overflow velocity, that particle and all larger than it will settle out. Increasing the area of the pond, therefore, would decrease the overflow velocity. This means that a smaller particle size could be settled out.

Factors affecting ideal settling. In any sediment pond, it is unlikely that purely ideal settling conditions will be met. Factors that disturb the smooth settling and thus alter the pond area required as calculated using ideal settling theory include:

- Short circuiting
- Bottom scour
- Turbulence
- Nonuniform deposition of materials
- Entrance and exit effects
- Shape of the suspended particles
- Specific gravity and velocity of the suspending liquid

In most cases, the effects of the above factors would be to increase the pond surface area required over that calculated by ideal settling theory. In usual design practice the surface area calculated by ideal settling theory is multiplied by a factor of 1.2 to account for nonideal settling factors.[4]

A complete description of the design procedure and a detailed design example are provided in section I of volume II in the design and construction specifications for sediment basins.

Methods for improving pond efficiency. A number of innovative techniques have recently been developed that can help increase the pond efficiency.[5]

- Baffles can be located within the pond to increase the detention time and also, if properly placed, provide for utilization of the full area of the pond.
- Partitioning the pond into a number of chambers and then introducing and overflowing water from particular chambers along the entire width of the sediment pond can also improve its performance.
- Dye tests on experimental sediment ponds have shown that maximum efficiency can be expected from a sediment pond when the length-to-width ratio is maintained at about 5 to 1.
- Construction of an energy dissipator at the pond entrance can produce a reduction in the inflow velocity and consequent deposition of sediment before it reaches the pond.
- Modifying the inflow to the sediment basin so that the flow enters along as much of the entire width of the basin as possible is another flow modification technique that has proved effective.
- Wrapping a plastic filter cloth around a standard perforated riser can increase the retention of fine-grained material. However, the filter cloth will eventually plug with the fine-grained sediment.
- A siphon arrangement in a nonperforated riser pipe is also effective in improving the sediment pond efficiency.
- Use of a very wide overflow wier instead of a standard riser pipe reduces the outflow velocity and thus increases the removal efficiency of the pond.
- Two or more ponds used in series instead of one larger basin covering the same area have been shown to increase the removal efficiency. The multiple-basin concept equates to the use of a compartmentalized, larger sediment basin. Thus, higher removal efficiencies can be expected from both multiple sediment basins and a compartmentalized, larger basin.

Chemical Treatment. Generally, the surface runoff from the mining area is pumped, or diverted, into settling basins where natural gravitational settling is used to remove the suspended solids. The removal efficiency of suspended solids depends on the surface area of the basin and on the detention time. If the inflow of the settling basin has a high percentage of fine-grained (silt and clay) sediments, there may not be adequate land area available to construct a settling basin of the size required to obtain the desired water quality. Since fine silts and clays carry a negative electric charge, they repel each other, and stay in suspension for long periods of time, thereby producing a turbid effluent. In these cases, chemical treatment is necessary to affect the negatively charged colloidal particles, causing them to become attracted to each other and form larger masses of particles that settle out.

Types of Coagulants. The addition of coagulants causes fine-grained particles to agglomerate, and thereby exhibit the settling characteristics of coarser sized particles. The chemical coagulants normally used are classified into the following three types:

- Metal salts
  - — aluminum sulfate
  - — ferrous sulfate
  - — ferric chloride
- Metal hydroxides
  - — aluminum hydroxide
  - — calcium hydroxide
- Synthetic polymers or polyectrolytes
  - — anionic
  - — cationic
  - — nonionic

Selection of the type of coagulant and required dosage is an important factor in the design of a chemical treatment system, and depends upon the characteristics of the specific material to be removed. There is no accurate theoretical method or rule for selection of a coagulant and its dosage. However, a rough estimate of the amount of coagulant can be made by a standard jar test, or by measurement of the suspended particles. The optimum dosage for best results will be adjusted in the field.

MAINTENANCE

All sediment containment measures require adequate and timely maintenance throughout their design lifespan to perform efficiently (fig. V-13). If they are built in an area where accessibility is poor, they are often ignored and forgotten. They should be located in an area where they are readily seen, and adequate accessibility should be provided for the maintenance equipment to perform emergency and routine

Figure V-13. Basin inspection.

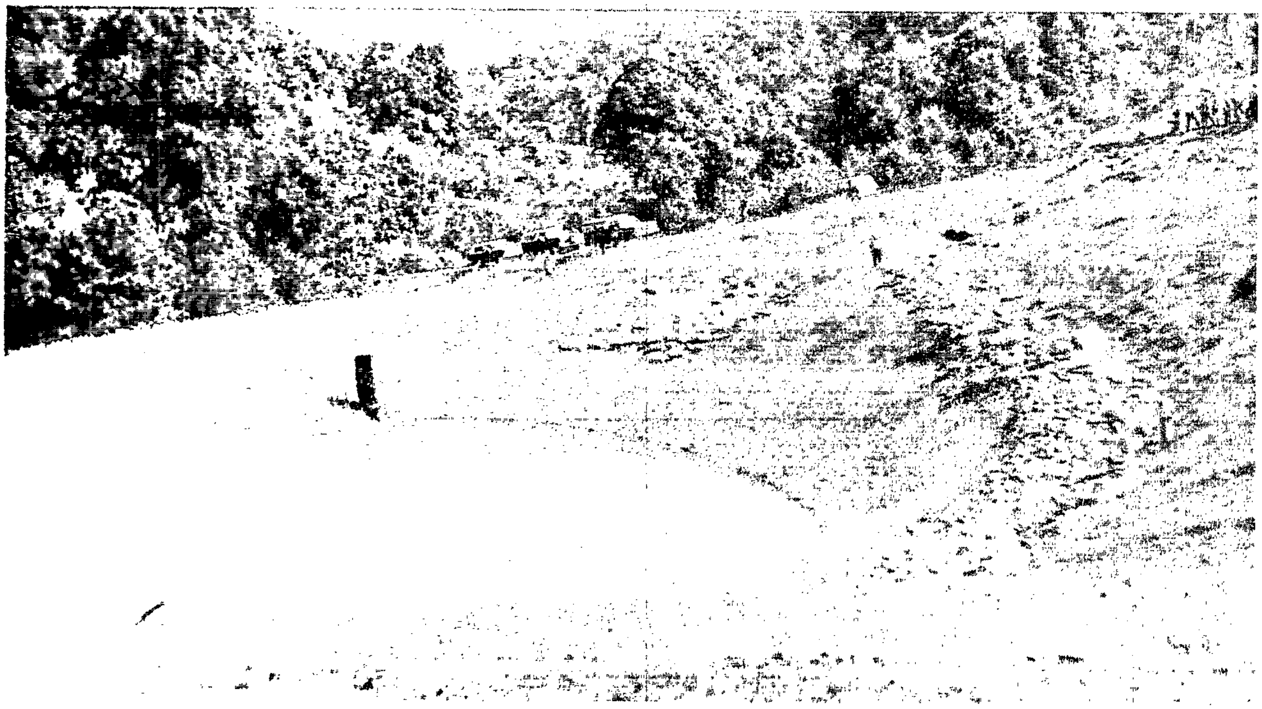

Figure V-14. Well-built and -maintained basin.

repairs. Responsibility for maintenance must be formally assigned to an individual who is knowledgeable of maintenance requirements and also has access to equipment and materials required for this purpose (fig. V-14).

All sediment containment structures require inspection after high-intensity or major rainstorms. Corrective decisions made onsite at this time can reduce sediment damages and operating costs in the long run. Most of the at-source sediment control measures cannot survive if they are subjected to foot or vehicle traffic. In areas where the measures are installed, the prohibition of traffic must be maintained.

Sediment Removal

The most important maintenance problem associated with sediment containment basins is the removal of accumulated sediment. Research has shown that the highest sediment yields are usually observed during the first 6-month period after mining. Filling of sediments in the basin reduces its capacity to retain runoff long enough for sediment to be deposited before it is carried downstream. Many States have established criteria for sediment removal from the basin. A rule of thumb that can be used is to clean out a basin when it has reached 50 percent of its sediment storage capacity, or 6 months after the mining operation was started, whichever comes first. In the design for storage capacity of a sediment basin, provisions should be made to accumulate enough sediment to permit the pond to function for a reasonable period between cleanings.

For small sediment traps used near the mining activity, cleaning is generally best accomplished by dragline and truck transport, since this equipment is readily available (fig. V-15). Removed material can be stockpiled directly on the banks, and allowed to dewater before being hauled away, or it can be buried in the mine pit.

For large containment basins that cannot be cleaned by draglines operating from the banks, the cleaning becomes more difficult. In such cases, the services of professionals experienced in the handling and disposition of sediment should be retained.

Sediment Disposal

Sediment disposal is an integral part of the sediment removal program from a containment basin. Indiscriminate piling or dumping of removed material is more likely to allow sediment to reenter the surface drainage system during successive storms, and thus become a pollutant again. The sediment removal operation must also consider the stable disposition of the material removed from the basin. Where disposal of a small quantity of sediment is involved, it can be disposed of behind a protective berm or grass filter strip, or buried in the mine pit. For larger quantities of sediment, special provisions should be made either to bury it in an area designated for this purpose, or to stockpile, dewater, and vegetate it properly.

POSTMINING CONSIDERATIONS

Sediment containment structures should be designed to be temporary structures for trapping sediments generated from exposed areas during surface mining operations. Once the mining is completed, and all disturbed areas are well stabilized, all sediment control structures, as well as the accumulated sediment, should be abandoned and/or disposed of in a proper manner. If proper attention or consideration is not given to postmining aspects in this area, control structures as well as the accumulated sediment may in time be carried into the streams and natural waterways during major storms. By thus becoming part of the pollution problem, the very purpose of their use in the first place would be defeated. It is, therefore, extremely important that the disposal and dismantling of all temporary control devices be performed before all mining equipment is demobilized from the mining area.

Disposal of Accumulated Sediments

Proper handling, disposal, or abandoning procedures for trapped sediment should be contained in the original plans and specifications for surface mine development. In the event that the accumulated sediment is to be left in place, it should be covered, topsoiled, and vegetated, or stabilized by mechanical means, to prevent it from sliding or eroding back into the stream. If the accumulated sediment is to be disposed of in a predetermined area within the mine property, it should be spread in layers, dewatered, covered with earth, and stabilized by vegetation or mechanical means (fig. V-16). The depth of the layer will depend on the grain size of the material being handled.

Dismantling of Earth Embankments

If the earth embankment is built across a natural drainageway, the embankment and all

Figure V-15. Backhoe loading sediment into a truck for transport to a disposal area.

accumulated sediment should be removed and disposed of in a predetermined area within the mine property. The natural stream should be returned to its original profile and cross section. The side slopes and bottom of the stream should be riprapped to prevent future erosion.

If the embankment is built adjacent to the natural waterway, it may be left in place by diverting the entrance channel to the natural waterways, thus preventing any future surface runoff from entering the impoundment.

Excavated Ponds

Offchannel dugout ponds, which are usually built by excavating a pit in the ground, should be backfilled, preferably with the material constituting the embankment around them. The backfilled material should be properly compacted. All areas disturbed as a result of this operation should be stabilized with vegetation.

If it is anticipated that the pond could serve some useful purpose, it may be left in place. However, precautions must be taken that no surface runoff enters the pond and that the outflow channel from the pond is protected against erosion.

The ponds that are built by excavating the streambed to store sediment should be backfilled so that the stream is brought back to its original profile and cross section. The side slopes and bottom of the channel should be stabilized by mechanical and/or vegetative means.

REFERENCES

[1]*West Virginia Drainage Handbook for Surface Mining*, prepared by Division of Planning and Development and Division of Reclamation, Department of Natural Resources, in cooperation with Soil Conservation Service, U.S. Department of Agriculture.

[2]*Engineer's Handbook on Strip Mining in Eastern Kentucky*, Department for Natural Resources and Environmental Protection, Commonwealth of Kentucky.

[4]C. W. Mallory and M. A. Nawrocki, *Containment Area Facility Concepts for Dredged Material Separation, Drying, and Rehandling*, prepared by Hittman Associates, Columbia, Md., for the Environmental Effects Laboratory, U.S. Army Engineer Waterways Experiment Station, Contract No. DACW 39-73-C-0136, Oct. 1974.

[5]M. A. Nawrocki and J. M. Pietrzak, "Methods to Control Fine-Grained Sediments Resulting From Construction Activity," Draft Report HIT-648, prepared under EPA Contract No. 68-01-3260, June 1976.

[3]D. V. Kathuria, M. A. Nawrocki, and B. C. Becker, *Effectiveness of Surface Mine Sedimentation Ponds,* prepared by Hittman Associates, Columbia, Md., for the U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio, Contract No. 68-03-2139.

Figure V-16. Diked sediment disposal area on relatively flat ground.

Section VI

CONTROL PLAN

The erosion and sediment control plan is the blueprint that will enable the operator to mine the coal without choking adjacent streams with sediment. The control plan is an important part of the overall mining and reclamation plan, and should consist of a comprehensive, explicit set of instructions for controlling erosion and sediment during and after active mining. This section discusses the legal and technical considerations, the makeup of the control plan, the information required to prepare the plan, as well as the procedure for preparing the plan.

Preparation of an erosion and sediment control plan consists of five basic steps:

- Identification of legal and technical requirements
- Collection and evaluation of site information
- Development of a control strategy
- An interdisciplinary field review of the feasibility of the preliminary sketch plan
- Revision and finalization of the control plan

LEGAL AND TECHNICAL REQUIREMENTS

Prior to undertaking the preparation of an erosion and sediment control plan, the surface mine operator, or his engineer, must become knowledgeable of both the legal and technical requirements of the State in which the operation will be located. Legal considerations include laws, regulations, and design criteria at both the State and Federal levels. These legal requirements vary considerably from State to State. A summary of reclamation requirements, both legal and technical, in the States covered by the manual is provided in section IV, volume II, which also includes a listing of the designated reclamation agency (agencies) in each State that can provide the operator with the necessary information.

The reclamation requirements usually addressed in the State regulations include mine drainage restrictions, highwall restrictions, topsoiling requirements, revegetation standards, and grading requirements. Some States also stipulate acceptable effluent standards for surface coal mining operations. Table VI-1 compares the Federal effluent standards for the surface coal mining industry with the standards set by three Appalachian States. It has not yet been definitively established that sedimentation basins can reliably meet these effluent standards, particularly in areas that have soils with high percentages of silt and clays. In such cases chemical treatment becomes necessary and cost of control increases considerably.

The erosion and sediment control plan is itself only one part of the overall mining and reclamation plan. The overall plan is made up of a combination of narrative description, construction plans and drawings, details, and specifications. Table VI-2 provides a complete checklist of the recommended erosion and sediment control plan components. Depending on individual State preferences, this information may be mixed into the reclamation portion of the overall plan, or totally or partially segregated under the heading of "erosion and sediment control."

EVALUATION OF SITE INFORMATION

Conducting a thorough site evaluation prior to developing a mining plan is an important prerequisite to achieving cost-effective sediment control. In addition to investigating the nature and extent of the coal resources, the site evaluation must involve a complete investigation of features directly and indirectly influencing soil loss and the potential for offsite damage. Influential features include topography, geology, soil, climate, hydrology, vegetation, and land use.

The site evaluation should be performed by individuals, or a team of individuals, experienced in the selection, design, and layout of both surface mining operations, and erosion and sediment control. The evaluation team should be knowledgeable of earth and vegetative sciences and capable of identifying the critical physical features affecting erosion and sediment control.

The evaluation usually comprises a combination of published information surveys, surface and subsurface investigations, and laboratory analyses.

Sections IV and V of this manual contain information on the relationship of various site features to sedimentation processes and the use of control practices.

Published Information

Topographic maps, soil maps and surveys, vegetative maps, geologic maps and reports, and aerial photographs can be obtained, often free of charge, from various State and Federal agencies and institutions. Table VI-3 shows sources of such published information. To the experienced and trained individual these documents provide a valuable source of information on physical features that relate to erosion and sediment control.

Local land use and zoning maps should also be consulted. These maps will provide information on current and projected land uses in the vicinity of the mine site, and will help in determining postmining land uses.

Surface Investigation

The primary purpose of the surface investigation is to identify, prior to preparation of the overall mining and reclamation plan, surface features having a major influence on soil loss and potential offsite damage from sediment. This work involves both a survey of available souces of published and, when available, unpublished information, and a thorough field investigation of the site and surrounding areas. The results of this investigation, along with the findings from the subsurface investigation, are needed to identify mining practices that will minimize sediment damages and formulate a cost-effective erosion and sediment control plan.

Surface features requiring investigation include surface soils, drainageways, vegetation, and topography.

The presence of highly erodible surface soils is a critical physical feature. This is especially true if these soils occur on moderate to steep slopes. Soil erodibility should be considered when locating access roads and other offsite facilities, and in formulating plans for clearing, grubbing, and scalping operations. The location and characteristics of streams and other natural drainageways deserve very careful examination during the surface investigation. Not only are they the recipients of sediment from the mine site and access roads and transporters of sediment to areas farther downstream, but also they themselves can contribute to the sediment load through channel erosion. Increased surface run-

Table VI-1.—*Effluent standards for the surface mining industry*

State	Turbidity or suspended solids	pH	Total iron	Alkalinity
			mg/l	
Federal	30-100 mg/l	6.0-9.0	4.0-7.0	Greater than acidity
Kentucky	150 Jtu[a]	6.0-9.0	7.0 or less	Greater than acidity
Pennsylvania	([b])	6.0-9.0	7.0 or less	—
West Virginia	100 Jtu or less[c]	5.5-9.0	10 or less	—

[a]The discharge shall contain no settleable matter, nor shall it contain suspended matter in excess of 150 Jackson turbidity units (Jtu), except during a precipitation event, which the operator must show to have occurred, in which case 1,000 Jtu may not be exceeded.

[b]No silt, coal mine solids, rock debris, dirt, and clay shall be washed, conveyed, or otherwise deposited to the waters of the Commonwealth.

[c]Turbidity—not more than 1,000 Jtu 4 hours following a major precipitation event and not more than 200 Jtu after 24 hours (major precipitation event = 1/2 inch of rainfall in 30 minutes).

Source: D. V. Kathuria, M. A. Nawrocki, and B. C. Becker, *Effectiveness of Surface Mine Sedimentation Ponds,* prepared by Hittman Associates, Columbia, Md., for the U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio.

Table VI-2.—*Information checklist for an erosion and sediment control plan*

Background information:

1. General:

    Location of project
    Extent of area to be affected
    Type of mining operation
    Evidence of compliance with State's legal requirements

2. Site inventory:

    Topography
    Geologic analysis
    Soil analysis
    Climatic analysis
    Hydrologic analysis
    Vegetative analysis
    Land use analysis

Schedule of activities:

Site preparation:

1. Access roads:

    Plan view (location)
    Typical cross section
    Profiles
    Maintenance requirements and schedule

2. Drainage and sediment control structures:

    Plan view (location)
    Typical cross sections
    Details (where needed)
    Design computations (where needed)
    Maintenance requirements and schedule

3. Clearing and grubbing:

    Plan views of limits of areas to be cleared
    Description of procedure
    Machinery to be used
    Method of disposing of timber, brush, and waste materials
    Identification of critical areas requiring temporary stabilization

Mining operations:

1. Scalping:

    Method of scalping topsoil material
    Equipment to be used
    Plan view of topsoil storage areas
    Temporary vegetative stabilization of stockpile areas

Schedule of activities—*continued:*

Mining operations—*continued:*

2. Overburden handling:

    Method of overburden handling
    Handling of first cut
    Plan view of overburden storage areas
    Stormwater handling in overburden storage areas
    Temporary stabilization measures
    Permanent stabilization measures

Reclamation operations:

1. Handling of toxic material:

    Method of handling toxic material
    Equipment to be used

2. Spoil rehandling and grading:

    Typical cross section of regrading
    Equipment to be used
    Method of spreading topsoil or upper horizon material on the regraded area, including approximate thickness of the final surfacing material
    Method of drainage control for the final regraded area

3. Revegetation:

    Method to be used
    Surface preparation
    Type of vegetation
    Fertilizer application (method and rate)
    Seasonal revegetation schedule and rate
    Mulch application (method and rate)
    Maintenance requirements and schedule

4. Mine abandonment:

    Method for disposal and stabilization of drainage structures not covered above, particularly sediment basins
    Method for stabilization and/or abandonment of haul road
    Assignment of responsibility for any permanent structures left behind
    Maintenance program and schedule for any permanent structures left behind

Table VI-3.—*Published information aids*

Informational aid	Where obtained	Information available
Aerial photographs to LANDSAT imagery	*East of the Mississippi River:* U.S. Geological Survey, Distribution Center, 1200 South Eads St., Arlington, Va. 22202 *West of the Mississippi River:* U.S. Geological Survey, Federal Center Bldg. 41, Denver, Colo. 80225 Local air services U.S. Soil Conservation Service (SCS) U.S. Forest Service Agricultural Stabilization and Conservation Service NASA EROS Data Center, Sioux Falls, S.Dak.	1. Drainage networks 2. Land forms 3. Extent of colluvium, alluvium, and other 4. Vegetative patterns (infrared) 5. Fracturing and jointing patterns 6. Slope gradients 7. Location of mass movements 8. Land cover characteristics
Topographic maps	Same as aerial photographs	1. Benchmarks 2. Slope gradients 3. Location of roads, buildings, and nearest towns 4. Drainage basins 5. Relief 6. Stream systems
Soil surveys.	U.S. Soil Conservation Service, Independence Ave. between 12th and 14th Sts., S.W., Washington, D.C. Local Soil Conservation Service office See section IV, volume II, for complete list of counties with surveys.	1. Types of soils 2. Extent of various soils 3. Engineering properties of soils 4. Land use potentials for various soils 5. Erodibility of soils 6. Aerial photographs 7. General textural characteristics of the soils
Vegetative maps.	U.S. Department of Agriculture, Independence Ave. between 12th and 14th Sts., S.W., Washington, D.C. U.S. Forest Service State forestry division State agriculture division Local universities Infrared and other aerial photographs	1. Types and extent of vegetative cover 2. Density of cover
Geologic maps and reports . . .	Universities U.S. Geological Survey State geological survey	1. Kinds of strata 2. Location of geologic hazards a. Faults b. High-water tables 3. Strikes and dips of various strata 4. Geologic trends in the area 5. Topographic features and their relationship to the geology

off resulting from both mining and construction and sedimentation of the channel is a factor contributing to channel degradation. The gradient, alignment configuration, and the nature of the material lining the channel determine the susceptibility of the stream to erosion and its ability to transport sediment. Stream biology and recreational, industrial, and municipal uses are major considerations in determining the level of sensitivity to sediment pollution.

Streams and other drainageways intercepted by the mining operations and access roads will require very special attention, both during and following mining, if costly offsite damages are to be avoided.

Natural ground slope and vegetative cover will also have a major bearing on the potential for offsite damage. Fairly flat, well-vegetated buffer areas found below a mine site or access road are a major deterrent to the movement of sediment into waterways. On steeply sloping terrain where a good buffer area is not present, very careful consideration must be given to handling of sediment-laden runoff.

Water quality should also be studied during the surface investigations. If initial investigations indicate the suspended solids concentration is high due to natural causes or other land disturbances in upper portions of the watershed, it would be advisable to monitor the site and, thereby, more accurately establish the baseline conditions.

Potential roadway alignments, head-of-hollow fill areas, and other outslope spoil disposal areas require careful examination to locate possible landslide areas. Such areas include slopes containing ground water seeps, unstable soil, or bedrock material.

Subsurface Investigation

The subsurface investigation should not be limited to the identification of those geological features, soil, and overburden properties which relate to mining and geotechnical engineering and acid mine drainage. It should also be utilized to determine those chemical and physical properties of the overburden (both soil and bedrock) which influence erodibility and capability to sustain a long-term vegetative cover.

Erodibility factors to be examined include texture and permeability of soil material, weathering characteristics of fragmented bedrock materials, and clay mineralogy (sec. IV). This information will help in identifying suitable topsoiling material, grading (slope length and steepness) requirements, and the sophistication of perimeter sediment control practices.

From the standpoint of revegetation, the identification of suitable topsoiling material is extremely important. This will require an evaluation of surface soils to determine their suitability for salvage and use as topsoiling material, and a study of other overburden material, including shales and other bedrock materials, to determine whether or not they are more suitable for use as topsoiling material (fig. VI-1). Important parameters to be studied when evaluating overburden materials for use as topsoiling material are texture, pH, and nutrient level. Organic content and weed seed content are also looked at when evaluating surface soils.

Texture (i.e., size and gradation of soil particles) and organic content will determine the ability of a soil to absorb surface water and to retain water for use by vegetation. This latter characteristic is referred to as moisture-holding capacity. When evaluating textural properties of bedrock materials, fragmentation (i.e., size of rock particles after blasting) and weathering characteristics must also be considered.

Problems related to pH are common and must always be investigated. Excessively acidic soils will require periodic applications of crushed or pulverized limestone or dolomitic limestone in order to maintain a good vegetative cover. If the pH problem is not too severe, the use of vegetation with acid-tolerant characteristics may be in order. The major elements that affect the nutrient level of the soil are nitrogen, potassium, and phosphorus. Soils (spoils) deficient in these nutrients will require periodic applications of fertilizers selected on the basis of soil tests.

Clay mineralogy is also an important factor to be examined when evaluating possible topsoiling material. The presence of large quantities of highly expansive or "fat" clays, such as bentonite or montmorillonite, in a soil will decrease its permeability significantly, thus reducing infiltration and, ultimately, the ability of the soil to support vegetation.

Overburden samples for conducting various tests can be obtained while drilling to evaluate the coal deposits (fig. VI-2). However, additional coring may be required to get unblended samples of the overburden material. Surface soil samples can be easily obtained using hand-sampling techniques. Where deep soils exist, test pits may be required to gather visual information and collect good samples for testing.

Further guidance in performing subsurface investigations, conducting various tests, and in evaluating results can be obtained from the Soil Conservation Service (SCS) district or State office, and from the State geological survey. State offices of these agencies are listed in section IV, volume II.

Figure VI-1. Gathering topsoil sample.

Climatic Data

The gathering and assessment of climatic data are also important in the preparation of an erosion and sediment control plan. Important climatic factors to be investigated include rainfall frequency, duration, and intensity and temperature, sunlight, and radiation.

The following functions require a knowledge of climatic factors:

- Design of drainage systems for access roads: When designing a drainage system, information must be obtained on expected frequencies, intensities, and durations of severe storms (usually a 10- to 25-year frequency). Culverts, ditches, and other structural control features must be sized to handle the anticipated storm runoff.
- Location and sizing of stormwater and sediment detention facilities: Whereas the other elements of the drainage system are designed to handle a peak flow rate for a selected design storm, sediment basins and traps are designed to store a certain volume of runoff water. This design requires a knowledge of rainfall parameters.
- The scheduling of construction, mining, and reclamation operations: These operations

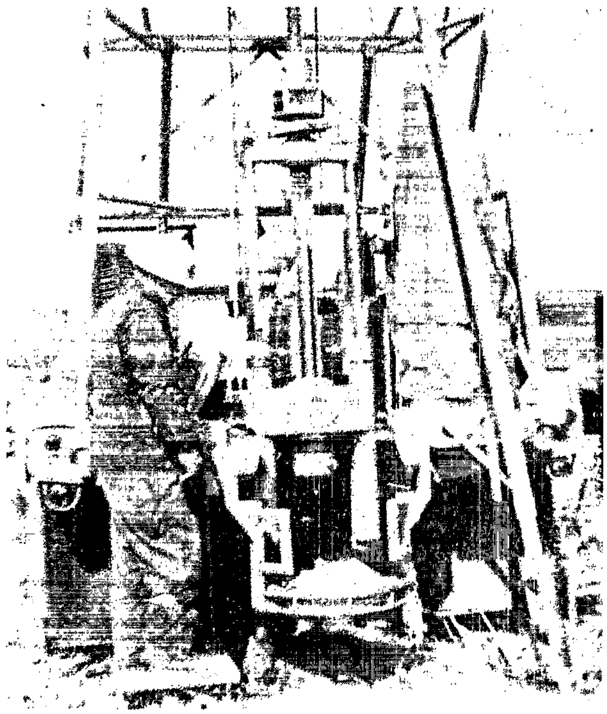

Figure VI-2. Core drilling to gather information on overburden and coal.

should be scheduled to minimize the area of soil exposed during periods of heavy and high-intensity rainfall. Information concerning average precipitation and rainfall intensity for various months is required to schedule such activities properly.

- Selection of plant materials and timing of revegetation: Climatic variables such as temperature, radiation, evapotranspiration, precipitation, and soil moisture storage have a direct bearing on seed selection and plant development. Through consultation with State reclamation personnel, SCS, and departments of forestry and agronomy in State universities, a seeding plan and planting schedule should be selected that will be conducive to rapid and sustained plant growth.

Information concerning the climatic variables is obtainable from local airports and the U.S. Weather Service. Rainfall intensity, duration, and frequency curves and maps are usually available from these sources.

CONTROL STRATEGY

The development of a sound erosion and sediment control strategy tailored to the mine site and affected offsite areas is the third step in preparing an erosion and sediment control plan.

The control rationale presented in section III outlined the basic principles to be followed in developing a control strategy. That basic philosophy must be applied in the development of a site-specific control strategy, particularly with respect to the selection of the mining operations and control measures.

Mining Operations

The development of a control strategy begins with the selection of mining practices to be used at the site and the identification of areas to be disturbed during mining (fig. VI-3). The mining practices selected are based on site conditions as defined in the site evaluation, legal constraints such as State and Federal regulations,

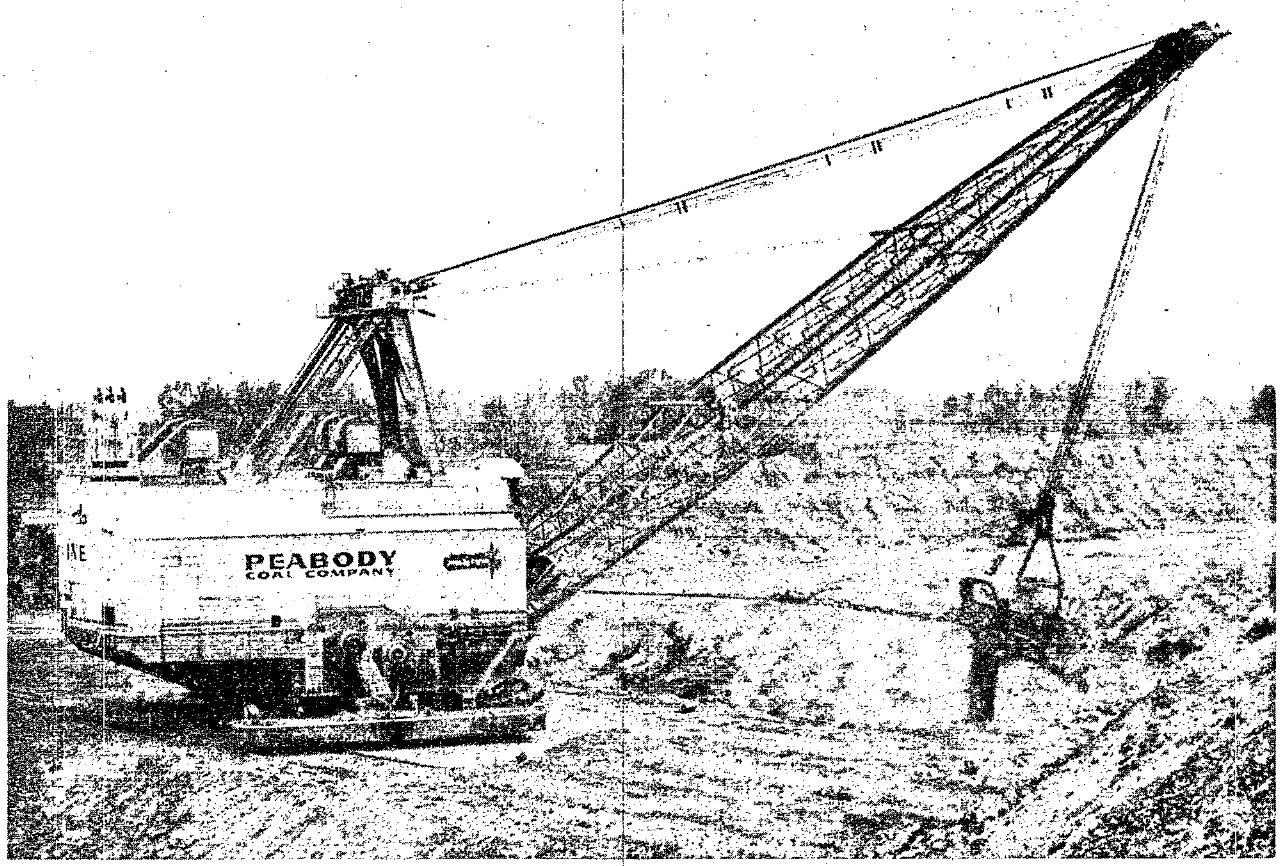

Figure VI-3. Area mining in the Midwest.

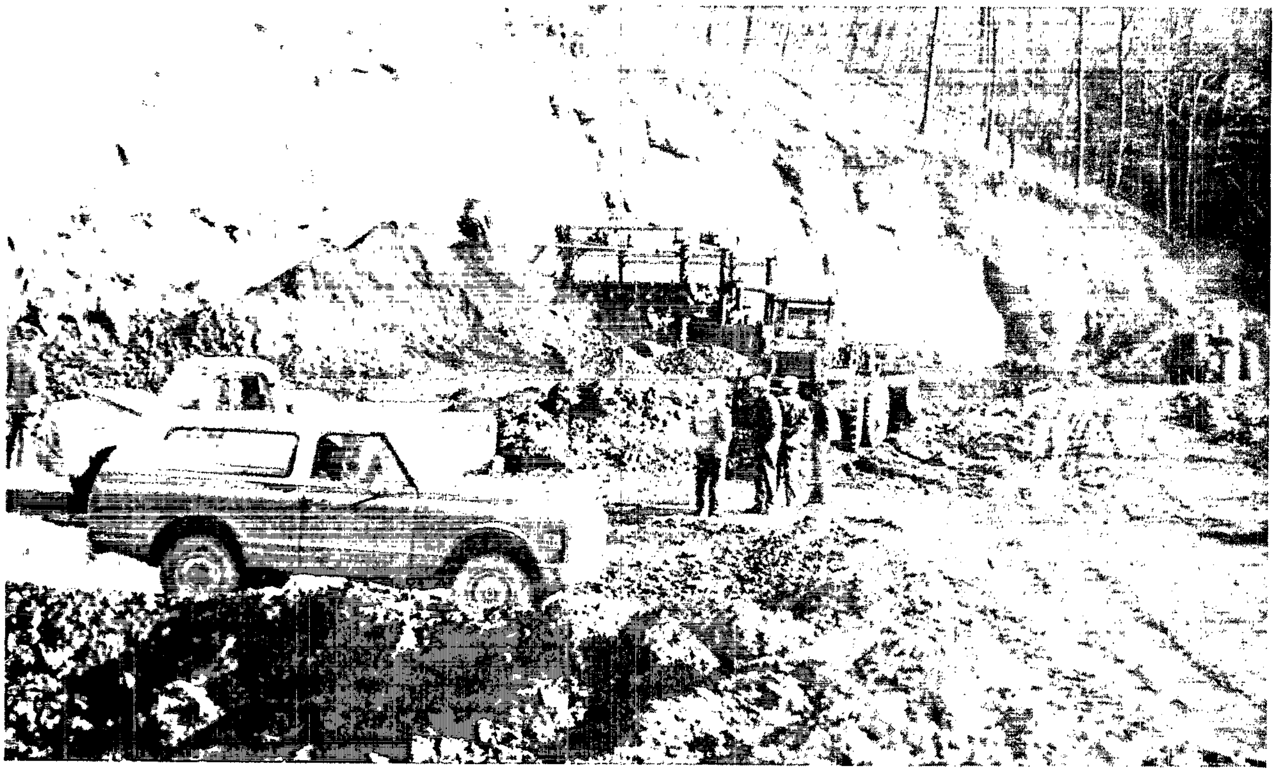

Figure VI-4. Haulback contour mining in Appalachia.

and an array of other factors, most of which relate to economics. The overall economic analysis is, of course, influenced by the cost of various environmental controls, including erosion and sediment control.

A summary of the basic environmental advantages and disadvantages of various mining methods has been described by Hill and Grim in *Environmental Protection in Surface Mining of Coal.*[1] From that summary one can ascertain that certain mining methods such as the block cut method, mountain top removal, and area mining generally have, from the standpoint of soil loss potential, an advantage over other methods because less land is usually disturbed. It has been demonstrated[2] that, when mining on a steep slope, erosion and sedimentation are directly proportional to the amount of land disturbed.

To reduce the opportunity for offsite sediment damage, the operations should be designed to limit the amount of land disturbed by retaining as much as possible of the spoil on the site and minimizing outslope disposal (fig. VI-4). Spoil placement, disposition, and stabilization should be well documented in the control plan.

After the mining method has been selected, a complete schedule of mining operations can be developed. A schedule of activities is necessary in order to be able to stage the operations properly so that both the area and time (i.e., duration and season) of exposure can be minimized. Although time is not as tangible as labor, materials, or equipment, it still remains a critical element in erosion and sediment control.

Sediment production can be decreased by reducing the size of the area that is disturbed at any given time and the length of time during which any area is left exposed. These two basic facts call for a control strategy that involves staging of activities to reduce both the area and time of exposure.

The location of areas to be mined, access roads, and other offsite facilities must also be defined in this stage of the development of a control strategy. The boundary of the property to be mined and the location of roadways and other facilities should be influenced by the results of the site investigation. This is especially important when selecting roadway alignments and outslope spoil disposal areas.

Multiple uses of access roads is often forgotten in the planning stage. Roads can frequently be used before mining for logging, and after mining for access to the mine area for fire protection, housing developments, hunting, or other uses. Well-built roads result in faster haulage time and cost less to maintain.

Control Measures

Once the mining techniques and the boundary of the property to be mined are known and the location of access roads and other offsite facilities is established, individual erosion and sediment control measures can be identified, sited, and scheduled.

Sections III, IV, and V of this manual provide information on control rationale and the use of various control practices. Section I, volume II, contains more detailed information on selected control practices. This information should be consulted when identifying various erosion and sediment control measures to be used at a specific site.

The control strategy must include a combination of perimeter and internal erosion and sediment control practices (fig. VI-5). Drainage upslope of the disturbed areas must be diverted properly around or through the disturbed area, and both internal and perimeter control practices must be deployed to reduce the amount of sediment leaving the mine site and access roads and entering waterways.

Scheduling of control measures is also a very important consideration. Prior to clearing, construction of access roads, or the initiation of any other earth-disturbing activities, perimeter control measures, such as diversion structures, sediment traps, and basins, must be installed (fig. VI-6). In highly inaccessible areas, some variance from this general rule will be required in order to gain access to the site for equipment needed to construct control measures.

Onsite erosion control and sediment containment practices should also be implemented in a timely manner and should be performed concurrently with excavation and grading activities.

Revegetation practices require close scheduling. Seasonal considerations, in particular, are very important in the successful establishment of vegetation. Seedbed preparation should be scheduled to coincide as closely as possible with completion of final grading. Extensive delays may, in some instances, necessitate the use of short-term stabilization practices, such as chemical stabilization, vegetation, or mulching.

In the identification of control practices, maintenance considerations must not be overlooked. Lack of maintenance is a major factor in the failure of many control programs. The operator must be constantly on the lookout for

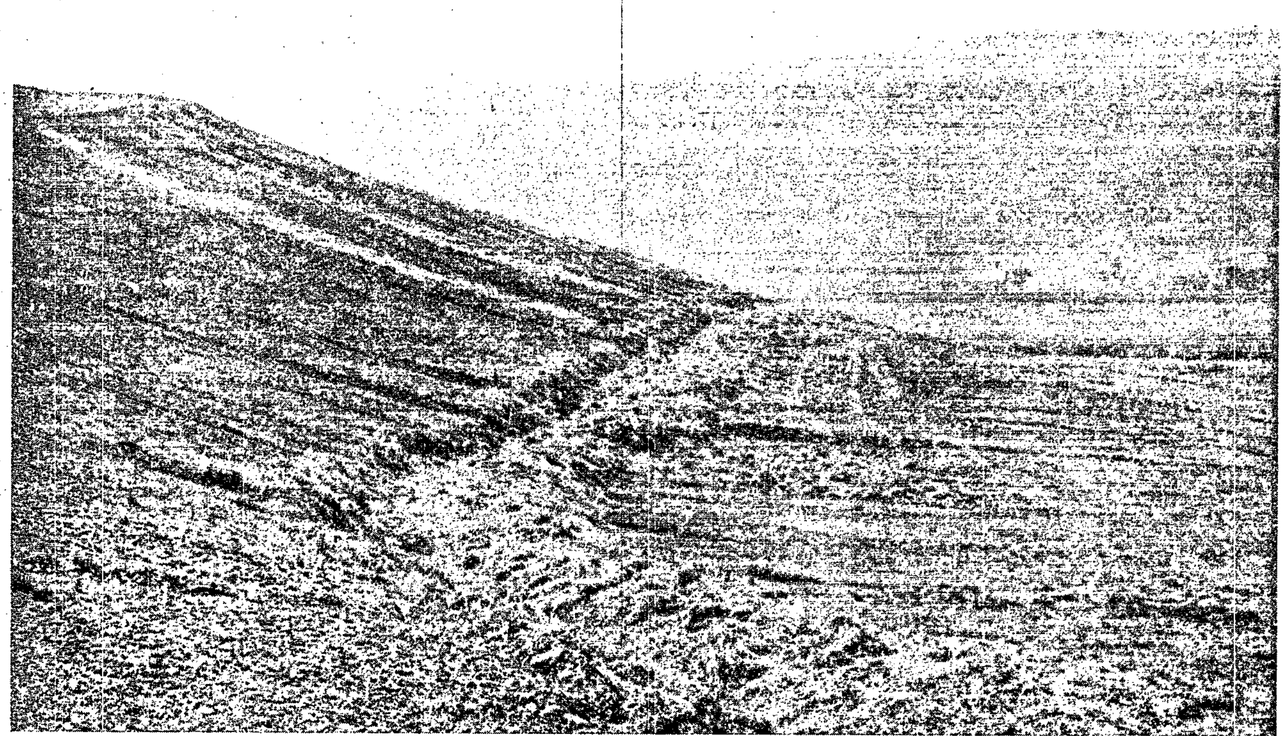

Figure VI-5. Contour furrows and diversion swale controlling erosion and protecting lower lying waterway.

Figure VI-6. Diversion ditch along perimeter of disturbed area.

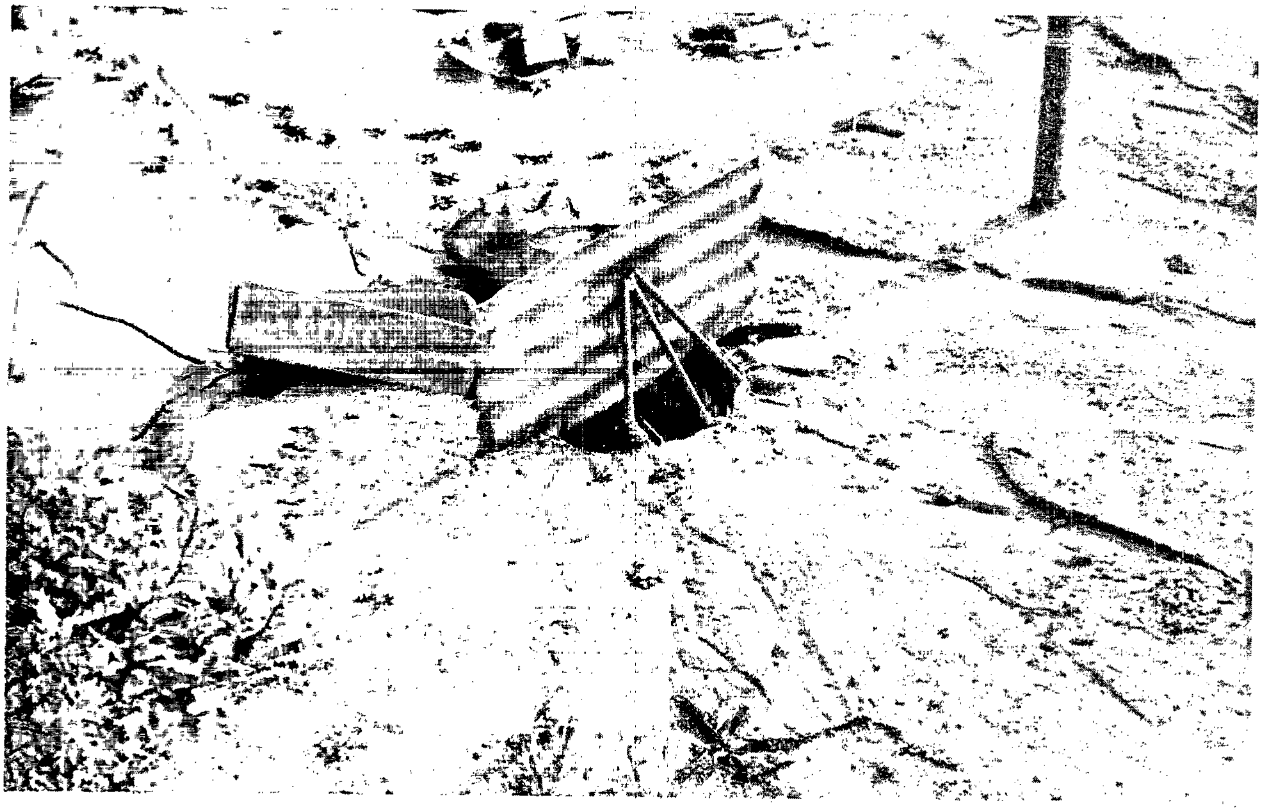

Figure VI-7. Sediment basin badly in need of cleaning.

erosion and sedimentation problems and must take prompt and effective action to correct identified problems. Particular attention should be given to inspecting and maintaining water-handling structures such as diversion, downdrain, and channel stabilization structures and sediment traps and basins (fig. VI-7). Breaches in stabilization and diversion structures and the accumulation of excessive amounts of sediment in containment structures should be anticipated, and procedures should be identified to correct such problems.

The access and haul roads, in particular, require a thorough maintenance program to maintain a desirable operating quality and to control erosion. Stabilization measures, as described in section IV, should apply to the roadbase, drainage appurtenances, and cut-and-fill slopes. Frequent inspections of these elements should be made to insure their functional integrity.

Considerable attention must also be given to inspecting and maintaining vegetative practices. Vegetation is a living material and requires oxygen, moisture, and nutrients to survive. Periodic applications of various soil amendments, such as lime and fertilizers, will be required to establish a ground cover that will provide long-term protection against soil erosion. Maintenance requirements can be minimized by selecting plant materials that are suited to natural site conditions and postmining land use.

The erosion and sediment control plan should clearly define both scheduling and maintenance requirements. For vegetative practices, it should also specify the following:

- Planting location
- Species to be used and application rates
- Methods of planting or seeding
- Seedbed preparation procedures
- Liming, fertilization, and mulching requirements, including types of material to be used and application rates
- Planting schedule

EVALUATION OF PRELIMINARY SKETCH PLAN

After the required legal and technical information has been collected and analyzed, and a control strategy has been formulated, a preliminary sketch plan is prepared. This sketch plan shows the approximate location of prospective access roads, mining areas, and control structures, and defines procedures to minimize erosion and control damage. The sketch plan provides the operator, or his engineer, with a working document that can be taken to the field to evaluate the feasibility of the plan.

After the preliminary plan has been prepared, the operator, or his engineer, should contact all the appropriate Federal, State, and local government agency representatives, and schedule an interdisciplinary field conference at the proposed site. Appropriate or responsible government agencies vary from State to State; however, representatives from agencies such as the State division of reclamation, SCS, the department of natural resources, the U.S. Geological Survey, and the U.S. Forest Service are generally included. In addition, any applicable local or regional governmental agency should be included. In some cases representatives of local citizen groups, such as the League of Women Voters, are invited to attend this conference. A listing of the respective agencies in each State is provided in section IV, volume II.

A conference of this type provides the following benefits:

- It provides a unique opportunity for an interdisciplinary evaluation of the proposed mining project by a highly skilled group of professionals
- The inclusion of the responsible government agencies in the formulation of the control plan means that delays usually encountered in obtaining final plan approval will be reduced.
- This interdisciplinary approach will balance the influence of the various individual disciplines and minimize oversights that could develop into serious problems at a later date.
- The conference will provide the beginning of a cooperative effort to mine the mineral resource while protecting the environment.

REVISION AND FINALIZATION OF THE PLAN

Suggestions or revisions resulting from the field conference are then incorporated with the preliminary plan and used to prepare a detailed final plan in accordance with the checklist provided in table VI-2. This final plan is then submitted to the responsible government agency for approval. The plan will either be approved and a permit issued, or it will be returned for corrections or revisions. In the latter case, the corrections or revisions will be made to the final plan and the plan will then be resubmitted for approval. A representative erosion and sediment control plan is presented in section III, volume II.

REFERENCES

[1]Elmore C. Grim, and R. D. Hill, *Environmental Protection in Surface Mining of Coal,* Environmental Protection Technology Series, EPA-670/2-74-093, Oct. 1974.

[2]*Design of Surface Mining Systems in Eastern Kentucky*, vol. II, Report ARC-71-66-71, prepared by Mathematica, Inc., and Ford, Bacon and Davis, Lexington, Ky., for the Appalachian Regional Commission, 1974.

Section VII
IMPLEMENTATION

Issuance of a mining permit signifies that the mining plan is an acceptable operational program designed to maximize productivity and minimize environmental damage. However, mine productivity and environmental protection are not assured by the design of the plan, but by its successful implementation. It is well recognized that a key to success in nearly all aspects of surface mining is onsite supervision and inspection. Just as supervision and inspection are required for the efficient removal of coal, these functions must also be applied to achieve effective sediment control. This on-the-ground phase of erosion and sediment control is the responsibility of two field specialists—the mine operator, or foreman, and the State surface mine inspector.

INSPECTION RESPONSIBILITIES

To assure that the mining operation is conducted in accordance with the control plan, the operator and the inspector must function as a team (fig. VII-1). Their success depends on how well each of them performs their duties, how well they work together, and the thoroughness of their field investigations. Section VII provides descriptions of the individual responsibilities of the operator and the inspector, and presents some guidelines for field inspection.

Figure VII-1. Operator-inspector team.

The Operator's Responsibilities

The man responsible for the day-to-day operation of the mine, the operator, has possibly the most important role in coal surface mining. In addition to mining coal efficiently and rapidly, he has the equally important jobs of following the approved mining plan, scheduling the operation so that everything is kept current, meeting production schedules, and talking with the inspector and other State officials.

The operator's performance will determine the success or failure of the mining operation. Mine-closing orders or noncompliance citations often result when the operator fails to carry out the mining operation as specified in the approved plan, or when unforeseen problems or failures develop, and are not corrected.

The Virginia Surface Mining and Reclamation Association, drawing from its experience with mine operators and the general public, has provided its surface mine operators with a list of do's and don'ts. This list has been adapted for general use and is presented below.

DO—Buy an inexpensive camera, a soil-testing kit, and a water-testing kit. Photograph and test the area *before*, *during*, and *after* mining. Prepare and maintain a logbook on each operation, being careful to note specific facts such as soil and water pH and silt levels. Sign and date each entry. Such a log can be extremely useful should questions arise regarding the specific effects of the operation on the area being mined.

DO—Be sure that water impounded on the bench is released gradually (i.e., pumped or siphoned), and that provisions are made to prevent erosion and siltation of streams.

DO—Keep your (haul and/or access) roads in good repair and properly ditched. A few hours each week spent on this work can save days of costly effort later.

DO—Listen to complaints about your operation *even if the complaining party appears unreasonable*. Try to find out what is really wanted. If you cannot satisfy his entire request, a compromise can usually be worked out. If a difficult situation arises regarding a complaint, seek assistance in working out a fair settlement.

DO—Advise nearby residents of planned blasting so they will know what to expect. If elderly or ill persons are nearby, offer them transportation to and from a friend's or relative's home away from the area during the shot. This is the fair and courteous thing to do.

DO—Keep regrading current. It is hard to catch up once you get behind.

DO—Obtain designated State or Federal agency approval of regraded areas *before* applying seed and fertilizer. Otherwise, some expensive reworking could be required.

DO—Order only certified seed and fertilizer, far enough in advance to insure delivery before needed. This will assure that all arrangements are made in time to prevent expensive delays. Have a storage area available if materials must be stored before delivery to the job.

DO—Be extra careful when working near homes or public roads. *Plan* the job carefully, *work* the job responsibly, and *reclaim* the job better than the law requires. Even though your work might be perfectly acceptable, you and the industry will be criticized if the job *looks* bad.

DO—Perform touchup work on seeding and fertilizing as soon as rough spots are apparent. The sooner the work is satisfactory, the sooner you will be released from your obligations.

DO—Publicize especially good reclamation work. Make use of available news media (i.e., newspapers, television, trade magazines, etc.).

DO—Make sure all of your employees understand the importance of handling black material properly. In 99 percent of the cases, plants will not grow on the black material. Even if it is not acid, it will absorb so much heat from the sun that vegetation will not grow.

DON'T—Be too quick to criticize the enforcement agency. These men have a difficult job, especially with a new law to enforce. They will be fair if at all possible. Consideration, understanding, and cooperation by all concerned parties in dealing with a problem will result in the best possible solution.

DON'T—Be afraid to ask for assistance if unexpected difficulties arise. Numerous State and Federal agencies as well as coal associations provide technical advice when needed.

DON'T—Let trucks and equipment run through a creek. A culvert or a simple bridge is not costly, and the people downstream will not have a muddy creek (fig. VII-2). Mining operations can be shut down for polluting waterways. This can be costly.

DON'T—Let trucks and equipment run mud onto a highway. Such a practice is annoying to the public, can cause accidents, and in some States is illegal and can result in a shutdown.

DON'T—Forget that one careless act can make a bad impression for the whole industry.

The Inspector's Responsibilities

The responsibility assigned to the surface mine inspector is different in every coal producing State. However, all inspectors have some degree of enforcement power that can be exercised when mining laws are violated (fig. VII-3).

The surface mine inspector has the job of being a spokesman for the State, visiting mining sites, making reports, and giving technical guidance. In addition to his role as an inspector, he oftentimes must serve as engineer, agronomist, and geologist to the mining operator.

General inspection responsibilities that the mine inspector must carry out include the following:

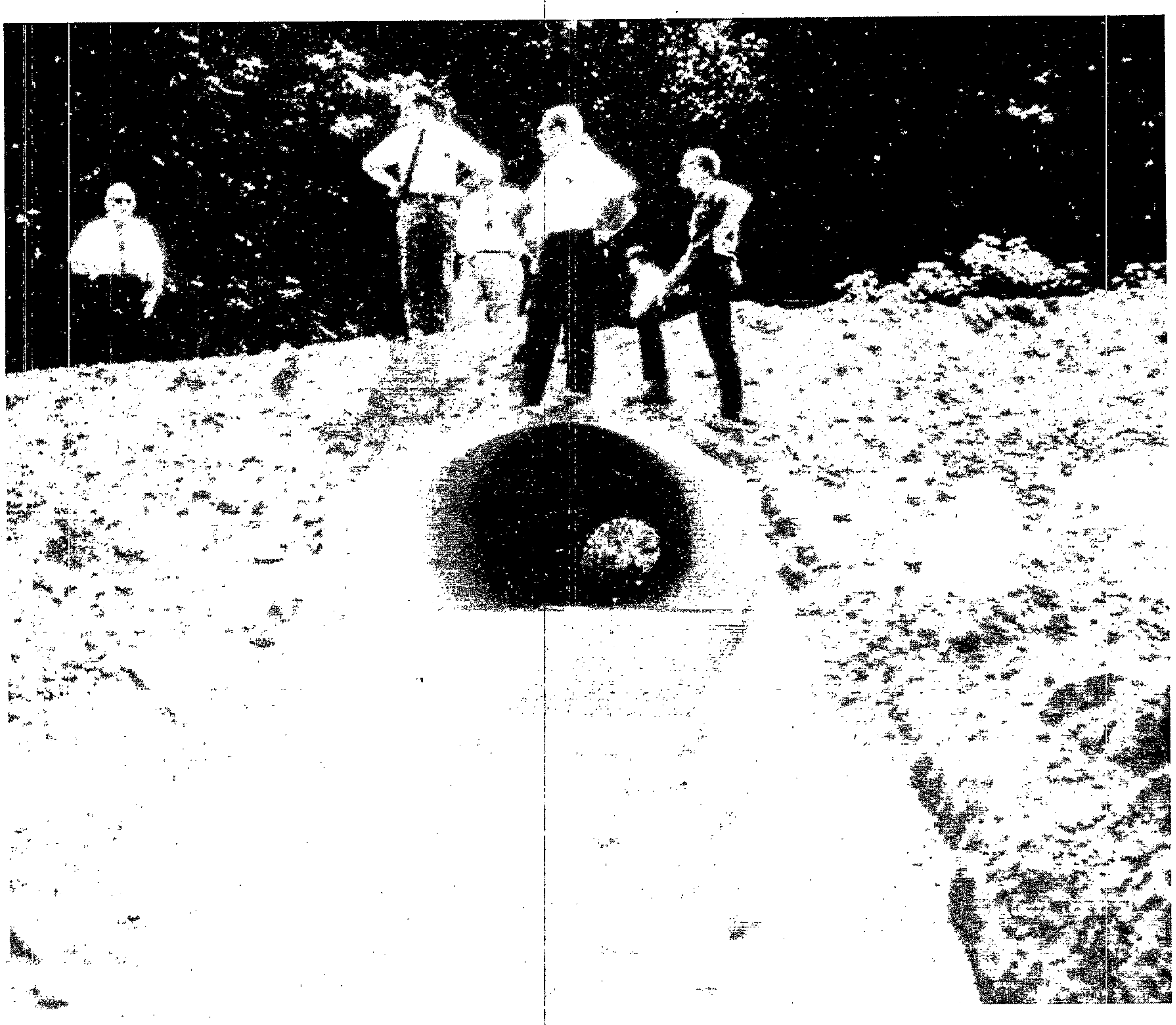

Figure VII-2. Protect streams by providing stable crossings.

Figure VII-3. Water sampling below surface mine site.

- Meeting with the operator and becoming knowledgeable on the type of mining operation, water-handling practices, and reclamation work.
- Scheduling visits with the operator, especially at critical times
- Advising mine operators on the best possible methods of controlling pollution caused by erosion, sedimentation, and acid mine drainage
- Insuring that all phases and aspects of the active operation are within the constraints of the law and according to the plan
- Keeping time schedules on the mining and reclamation phases of the operation to insure that both phases are being kept as current as possible

The degree of competence with which an inspector carries out his responsibilities will depend on four major factors:

- Training
- Personality
- Incentives
- Intelligence

Training. The surface mine inspector must be knowledgeable in surface mining technology, reclamation, State and Federal laws relating to surface coal mining, and various other disciplines. Minimum training should include a balanced combination of classroom and field training. Classroom training should be sufficient to make the inspector knowledgeable in the areas mentioned above. Field training should be conducted under the supervision of an experienced inspector before the trainee is assigned a work area.

Personality. It is especially important for a surface mine inspector to have an agreeable personality. With each new mining permit the inspector will meet another operator with a distinct personality unlike his own. The inspector must have a personality that is both firm and businesslike, yet possess an ability to laugh and be cooperative.

Incentives. Through awards, educational benefits, and other incentives a sense of pride, competitiveness, and increased spirit can be instilled in a very hard and burdensome job.

Intelligence. As in any other technical profession, the mine inspector must be intelligent enough to do his job in a knowledgeable and professional manner. His inspection responsibilities make it necessary for him to acquire skills in new and often complicated technical areas. This required knowledge can be gained through seminars, training sessions, conferences, and meetings dealing with various aspects of surface mining.

ONSITE PLAN REVIEW

Following the issuance of a mining permit it is necessary that the operator and the area mining inspector meet and review the entire mining plan in the field. By doing this, the following objectives can be achieved:

- The inspector can become more familiar with site conditions that will be affected by the mining operation. This will help the inspector when making future visits and assessing changes in the mining operation and the mining environment.
- Further discussion can take place between the operator and the inspector of specific problems that may be encountered during the operation (e.g., becoming spoil bound).
- The inspector can make suggestions and provide information to the operator that may help the operator mine coal more efficiently, and remain within the constraints of the law.
- By reviewing the mining plan in the field and walking the site, the operator and inspector can begin a cooperative relationship that will be helpful in achieving both men's goals.

ONSITE INSPECTION

The working relationship between the operator and the inspector is probably most pronounced in their routine onsite inspection duties. The operator has the best working knowledge of the site and is in the best position to take prompt preventive or corrective actions. The inspector has less working knowledge about any one site, but has a better overall view of problems and conditions in the area. The inspector is in the best position to evaluate objectively the total performance of the erosion and sediment control efforts on a site. With these complementary points of view working together, the onsite inspection can be the most valuable element of an entire control program—provided that inspections are sufficiently thorough. A partial list of items to be checked on inspection tours is given below. This list has been adapted in part from the *Sediment Control Inspectors Handbook* of the Maryland Water Resources Administration.

GUIDES FOR INSPECTION AND EVALUATION OF EROSION AND SEDIMENT CONTROL MEASURES

1. Haul and access roads
   a. Alignment
      (1) stream crossings
      (2) curves
   b. Road grades
      (1) steepness
      (2) length
   c. Road base materials
   d. Drainage
      (1) road cross section
      (2) outlet spacing
      (3) channel lining
      (4) energy dissipators

2. Clearing and grubbing
   a. Description of method and equipment
   b. Staging schedule
   c. Brush and trash disposal

3. Water-handling structures
   a. Diversion dike
      (1) location
      (2) top width
      (3) height
      (4) machine compaction
      (5) side slopes
      (6) grade
      (7) outlet
      (8) vegetative stabilization
   b. Interceptor dike
      (1) location
      (2) top width
      (3) height
      (4) side slopes
      (5) machine compaction
      (6) grade
      (7) spacing
      (8) outlet
      (9) vegetative stabilization
   c. Level spreader
      (1) location
      (2) bottom width
      (3) back slope
      (4) length
      (5) grade
      (6) outlet
      (7) vegetative stabilization
   d. Grassed waterway or outlet
      (1) location
      (2) depth
      (3) width
      (4) slope
      (5) subsurface

(6) compaction
(7) vegetative stabilization
(8) temporary protection during establishment (when possible)

e. Diversions
(1) location
(2) cross section
(3) grade
(4) outlet
(5) vegetative stabilization

f. Grade stabilization structure, chute, or flume
(1) location
(2) lining
(3) size and cross section
(4) compaction
(5) slopes
(6) placement of lining
(7) subsurface
(8) outfall

g. Sediment basin
(1) location
(2) size of storage area
(3) pipe spillway
(a) location of riser and barrel
(b) size and elevation of riser and barrel
(c) spacing and size of the perforations in the upper one-half to 2-thirds of the riser
(d) antivortex device on top of riser (if required)
(e) riser base
(f) trash rack (if required)
(g) antiseep collars
(4) emergency spillway (if required)
(a) location
(b) size—bottom, side slopes, length
(c) elevation
(d) vegetative stabilization (or other suitable means)
(5) embankment (dam)
(a) site preparation
(b) material
(c) compaction (lifts)
(d) size—top width, side slopes, length
(e) elevation (freeboard)
(f) vegetative stabilization (if required)
(6) maintenance cleanout

h. Straw bale dike or berm (extra)
(1) location
(2) size
(3) binding
(4) key trench and backfill
(5) rebar or stake pegging

i. Other as appropriate

4. Stockpiles (topsoil and overburden)
a. Location
b. Water handling
c. Stabilization
(1) vegetative
(2) other

5. Regrading
a. Staging
b. Burial of toxic material
c. Ground water drainage
d. Slope control
(1) steepness
(2) length
e. Soil reconstruction
f. Surface drainage

6. Revegetation
a. Critical area stabilization with temporary seedings
(1) location
(2) duration of use
(3) site preparation
(4) seedbed preparation (lime, fertilizer, disking)
(5) seeding (mixture and application method and rate)
(6) mulching
(7) establishment (cover density and maintenance)

b. Critical area stabilization with semi-permanent and permanent seedings
(1) location
(2) duration of use
(3) soil conditions (long-lived vegetative cover)
(4) site preparation
(5) seedbed preparation (lime, fertilizer, disking)
(6) seeding (mixture and application method and rate)
(7) mulching
(8) establishment (cover density, maintenance, and irrigation, if necessary)

c. Critical area stabilization with mulching only
(1) location
(2) duration of use
(3) site preparation
(4) mulching (materials and application, cover density)
(5) mulch anchoring

d. Critical area stabilization with Bermudagrass, grasses, and legumes
(1) location
(2) site conditions (limitations)
(3) site preparation
(4) soil preparation
(5) establishment (sprigging)
(6) maintenance

e. Critical area stabilization with sod

(1) location
(2) soil preparation (lime, fertilizer, and tillage)
(3) sod materials and installation
(4) maintenance (watering, and mowing)

f. Critical area stabilization with ground covers, vines, shrubs, and trees
(1) location
(2) planting time
(3) soil preparation
(4) mulching
(5) maintenance

g. Topsoiling
(1) location
(2) subsoil preparation
(3) topsoil material and application

Section VIII
GLOSSARY

AASHO classification (soil engineering).—The official classification of soil materials and soil aggregate mixtures for highway construction used by the American Association of State Highway Officials.

Abandoned mine.—A mining operation where coal is no longer being produced and it is the intent of the operator not to continue production from the mine.

Abrasion.—The wearing away by friction, the chief agents being currents of water or wind laden with sand and other rock debris, and glaciers.

Access road.—Any haul road or other road constructed, improved, maintained, or used by the operator that ends at the pit or bench, and is located within the area of land affected.

Acid-producing materials (acid forming).—Rock strata containing significant pyrite, which if exposed by coal mining will, when acted upon by air and water, cause acids to form.

Acid soil.—Generally, a soil that is acid throughout most or all of the parts of it that plant roots occupy. Commonly applied to only the surface-plowed layer or to some other specific layer or horizon of a soil. Practically, this means a soil more acid than pH 6.6; precisely, a soil with a pH value less than 7.0. A soil having a preponderance of hydrogen over hydroxyl ions in the soil solution.

Acid spoil.—*See also* Spoil; Toxic spoil. Usually spoil material containing sufficient pyrite so that weathering produces acid water and the pH of the soil determined by standard methods of soil analysis is between 4.0 and 6.9.

Active surface mine operation.—A mining operation where land is being disturbed in preparation for and during the removal of a mineral.

Agglomeration.—The uniting of dispersed suspended matter into larger flocs or particles that settle rapidly.

Aggregation, soil.—The cementing or binding together of several soil particles into a secondary unit, aggregate, or granule. Water-stable aggregates, which will not disintegrate easily, are of special importance to soil structure.

Agricultural limestone.—Contains sufficient calcium and magnesium carbonate to be equivalent to not less than 80 percent calcium carbonate and must be fine enough so that not less than 90 percent shall pass through a U.S. Standard No. 10 sieve and not less than 35 percent shall pass through a U.S. Standard No. 50 sieve.

Alkaline soil.—Generally, a soil that is alkaline throughout most or all of the parts of it occupied by plant roots, although the term is commonly applied to only a specific layer or horizon of a soil. Precisely, any soil horizon having a pH value greater than 7.0. Practically, a soil having a pH above 7.3.

Amendment.—Any material, such as lime, gypsum, sawdust, or synthetic conditioners, that is worked into the soil to make it more productive. Technically, a fertilizer is also an amendment, but the term *amendment* is used most commonly for added materials other than fertilizer.

Angle of dip.—The angle an inclined stratum makes with the horizontal.

Annual plant (annuals).—A plant that completes its life cycle and dies in 1 year or less.

Area mining.—Surface mining that is carried on in level to gentle rolling topography on relatively large tracts.

Aspect.—The direction toward which a slope faces. Exposure.

Available nutrient.—The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Back blade.—In regrading, to drag the blade of a bulldozer or grader in the down position as the machine moves backward, as opposed to pushing the blade forward.

Backfill.—The operation of refilling an excavation. Also the material placed in an excavation in the process of backfilling.

Basin.—A natural depression of strata containing a coal bed or other stratified deposit.

Bedload.—The sediment that moves by sliding, rolling, or bouncing on or very near the streambed. Sediment moved mainly by tractive or gravitational forces, or both, but at velocities less than the surrounding flow.

Bench.—The surface of an excavated area at some point between the material being mined and the original surface of the ground on which equipment can set, move, or operate. A working road or base below a highwall, as in contour stripping for coal.

Berm.—A strip of coal left in place temporarily for use in hauling or stripping. A layer of large rock or other relatively heavy stable material placed at the outside bottom of the spoil pile to help hold the pile in position (a toe walk). Also used similarly higher in the spoils for the same purpose.

Biennial plant.—A plant that requires 2 years to complete its life cycle.

Broadcast seeding.—Scattering seed on the surface of the soil. *Contrast with* Drill seeding, which places the seed in rows in the soil.

Buffer strip.—1. Unaffected areas between the mining operation and areas designated for other public and private use.

2. Strips of grass or other erosion-resisting vegetation between or below surface or auger mining disturbances.

Bunchgrass.—A grass that does not have rhizomes or stolons and forms a bunch or tuft.

Calcareous soil.—Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Canopy.—The cover of leaves and branches formed by the tops or crowns of plants.

Channel stabilization.—Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Check dam.—Small dam constructed in a gully or other small water course to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.

Chute.—*See* section I, volume II.

Clay (soils).—1. A mineral soil separate consisting of particles less than 0.002 mm in equivalent diameter.

2. A soil textural class.

3. **(engineering).** A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Clearing.—The removal of vegetation, structures, or other objects in preparation for earthmoving activities.

Climate.—The sum total of all atmospheric or meteorological influences, principally temperature, moisture, wind, pressure, and evaporation, that combine to characterize a region and give it individuality by influencing the nature of its land forms, soils, vegetation, and land use. *Contrast with* Weather.

Clinker.—Sometimes referred to as *scoria,* a term commonly used to identify the material overlying a burned coal bed. Clinkers usually consist of baked clay, shale, or sandstone. They weather to gravel-sized particles that are generally red in color and are used extensively as a road-surfacing material. Clinkers are *similar to* Red dog.

Clod.—A compact, coherent mass of soil ranging in size from 5 to 10 mm (0.2 to 0.4 inches) to as much as 200 to 250 mm (8 to 10 inches); produced artificially, usually by the activity of man by plowage, digging, etc., especially when these operations are performed on soils that are either too wet or too dry for normal tillage operations.

Coagulation.—The destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical.

Coal seam.—A layer, vein, or deposit of coal. A stratigraphic part of the earth's surface containing coal.

Coarse texture.—The texture exhibited by sands and loamy sands. A soil containing large quantities of these textural classes (U.S. usage).

Compaction.—The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area as in the process of leveling the overburden material of strip mine banks.

Conifer.—A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scalelike leaves, and producing wood known commercially as *softwood.*

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

Contour.—An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Contour stripping or surface mining.—The removal of overburden and mining from a coal seam that outcrops or approaches the surface at approximately the same elevation, in steep or mountainous areas.

Cool-season plant.—A plant that makes its major growth during the cool portion of the year, primarily in the spring, but in some localities in the winter.

Core drilling.—The process by which a cylindrical sample of rock and other strata is obtained through the use of a hollow drilling bit that cuts and retains a section of the rock or other strata penetrated.

Corrasion.—The wearing away of earth materials through the cutting, scraping, scratching, and scouring effects of solid material carried in the currents of water or air.

Cover crop.—A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards.

Cover, ground.—Any vegetation producing a protecting mat on or just above the soil surface. In forestry, low-growing shrubs, vines, and herbaceous plants under the trees.

Cover, vegetative.—All plants of all sizes and species found in an area, irrespective of whether they have forage or other value.

Cover, wildlife.—Plants or objects used by wild animals for nesting, raising of young, escape from predators, or protection from adverse environmental conditions.

Crust.—A dry surface layer on soils that is much more compact, hard, and brittle than the material immediately beneath it.

Culvert.—A closed conduit for the free passage of surface drainage water under a roadway or other embankment.

Cut.—Longitudinal excavation made by a strip-mining machine to remove overburden in a single progressive line from one side or end of the property being mined to the other side or end.

Cut-and-fill.—Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

Density, forage.—The percentage of ground surface that appears to be completely covered by vegetation when viewed directly from above.

Density stand.—Density of stocking expressed in number of trees per acre.

Deposition.—The accumulation of material dropped because of a slackening movement of the transporting agent—water or wind.

Detachment.—The removal of transportable fragments of soil material from a soil mass by an eroding agent, usually falling raindrops, running water, or wind. Through detachment, soil particles or aggregates are made ready for transport—soil erosion.

Direct seeding.—A method of establishing a stand of vegetation by sowing seed on the ground surface.

Diversion.—Channel constructed across the slope for the purpose of intercepting surface runoff. Changing the accustomed course of all or part of a stream.

Diversion dike.—*See* section I, volume II.

Diversion swale (ditch).—*See* section I, volume II.

Dragline.—An excavating machine that utilizes a bucket operated and suspended by means of lines or cables, one of which hoists or lowers the bucket from a boom; the other, from which the name is derived, allows the bucket to swing out from the machine or to be dragged toward the machine for loading. Mobility of draglines is by crawler mounting or by a walking device for propelling, featuring pontoonlike feet and a circular base or tub. The swing of the machine is based on rollers and rail. The machine usually operates from the highwall.

Drainage.—The removal of excess surface water or ground water from land by means of surface or subsurface drains.

Drill seeding.—Planting seed with a drill in relatively narrow rows, generally less than a foot apart. *Contrast with* Broadcast seeding.

Droughty.—Exhibiting a poor moisture-holding capacity due to excessively high permeability and a low percentage of fines.

Dugout pond.—An excavated pond as contrasted with a pond formed by constructing a dam.

Emergency spillway.—A spillway used to carry runoff exceeding a given design flood.

Energy dissipators.—*See* section IV, "Handling Disposal of Concentrated Flows."

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

Erodible (geology and soils).—Susceptible to erosion.

Erosion.—1. The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

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

The following terms are used to describe different types of water erosion:

Accelerated erosion: Erosion much more rapid than normal, natural, or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophies that expose base surfaces, for example, fires.

Geological erosion: The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plains, etc. *Syn:* Natural erosion.

Gully erosion: The erosion process whereby water accumulates in narrow channels, over short periods, and removes the soil from this narrow area to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.

Natural erosion: Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. *Syn.:* Geological erosion.

Normal erosion: The gradual erosion of land used by man which does not greatly exceed natural erosion. *See* Natural erosion.

Rill erosion: An erosion process in which numerous small channels only several inches deep are formed. Occurs mainly on recently cultivated soils.

Sheet erosion: The removal of a fairly uniform layer of soil from the land surface by runoff water.

Splash erosion: The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be removed subsequently by surface runoff.

Erosive.—Refers to wind or water having sufficient velocity to cause erosion. Not to be confused with Erodible as a quality of soil.

Esthetic.—Of beauty; beautiful.

Evapotranspiration.—A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excelsior blanket.—*See* section II, volume II.

Fertility.—The quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants when other growth factors, such as light, moisture, temperature, and the physical condition of the soil are favorable.

Fertilizer.—Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer grade.—The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent water-soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer nitrogen (N), phosphorus (P), and potassium (K).

Fertilizer requirement.—The quantity of certain plant nutrient elements needed, in addition to the amount supplied by the soil, to increase plant growth to a designated optimum.

Fibrous root system.—A plant root system having a large number of small, finely divided, widely spreading roots but no large individual roots. Usually a characteristic of most grasses.

Field capacity (field moisture capacity).—The amount of soil water remaining in a soil after the free water has been allowed to drain away for a day or two if the root zone has been previously saturated. It is the greatest amount of water that the soil will hold under conditions of free drainage, usually expressed as a percentage of the oven-dry weight of soil or other convenient unit.

Filter (sediment).—*See* section V, "Sediment Traps."

Filter strip.—Strip of vegetation that retards flow of runoff water, causing deposition of transported material, thereby reducing sediment flow.

Final cut.—Last cut or line of excavation made on a specific property or area.

Flocculation.—The process by which suspended colloidal or very fine particles are assembled into larger masses or floccules, which eventually settle out of suspension.

Flume.—*See* section I, volume II.

Fly ash.—All solids, ash, cinders, dust, soot, or other partially incinerated matter that is carried in or removed from a gas stream. Fly ash is usually associated with electric generating plants.

Forage.—Unharvested plant material that can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Gabion.—A mesh container used to confine rocks or stones and used to construct dams and groins to line stream channels.

Geology.—The science that deals with the history of the earth and its life as recorded in rocks.

Georgia V-ditch.—Grading is performed to create positively draining swales midpoint between the parallel to the highwall and longwall to convey water runoff to drains established to carry the water away from the spoil area.

Germination.—Sprouting; beginning of growth.

Grade.—1. The slope of a road, channel, or natural ground.

2. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction, like paving or laying a conduit.

3. To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation.

Grade stabilization structure.—A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further headcutting or lowering of the channel grade.

Grassed waterways.—*See* section I, volume II.

Green manure crop.—Any crop grown for the purpose of being turned under while green or soon after maturity for soil improvement.

Ground water.—Subsurface water occupying the *saturation zone,* from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called *plerotic water, phreatic water.*

Grouted.—Having the area between pieces of rock, brick, etc., filled with mortar or concrete.

Growing season.—The season that, in general, is warm enough for the growth of plants, the extreme average limits of duration being from the average date of the last killing frost in spring to that of the first killing frost in autumn. On the whole, however, the growing season is confined to that period of the year when the daily means are above 42° F.

Grubbing.—The operation of removing stumps and roots.

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

Hardpan.—A hardened soil layer in the lower A or in the B horizon caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides, or calcium carbonate. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not slake in water.

Haul road.—Road from pit to loading dock, tipple, ramp, or preparation plant used for transporting mined material by truck.

Head of the hollow (also valley fill method).—Basically, overburden material from adjacent contour or mountain top mines is placed in compacted layers in narrow, steep-sided hollows so that surface drainage is possible.

Heaving.—The partial lifting of plants out of the ground, frequently breaking their roots, as a result of freezing and thawing of the surface soil during the winter.

Highwall.—The unexcavated face of exposed overburden and coal in a surface mine or the face or bank on the uphill side of a contour strip mine excavation.

Hydrology.—The science that relates to the water systems of the earth.

Hydroseeding.—Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious soil.—A soil through which water, air, or roots cannot penetrate. No soil is impervious to water and air all the time.

Impoundment.—A reservoir for collection of water. Collection of water by damming a stream or the like. Used in connection with the storage of tailings from a mine.

Infiltration.—The flow of a liquid into a substance through pores or other openings, connoting flow into a soil in contradistinction to *percolation,* which connotes flow through a porous substance.

Inlet.—The upstream end of any structure through which water may flow.

Inoculation.—The process of adding cultures of symbiotic micro-organisms to legume seed to enhance atmospheric nitrogen fixation.

Interceptor dike (straw bale).—*See* Diversion dike, section I, volume II.

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

Land use planning.—The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Landslide.—The failure of a slope in which the movement of the mass takes place along interior surfaces of sliding.

Leaching.—The removal of materials in solution by the passage of water through soil.

Legume.—A member of the legume or pulse family, Leguminosae. One of the most important and widely distributed plant families. The fruit is a legume, or pod that opens along two sutures when ripe. Flowers are usually papilionaccous (butterflylike). Leaves are alternate, have stipules, and are usually compound. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches, and kudzu. Practically all legumes are nitrogen-fixing plants.

Level spreader.—*See* section I, volume II.

Lime.—Lime, from the strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term *lime* is commonly used in agriculture to include a great variety of materials that are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural lime are ground limestone (carbonates), hydrated lime (hydroxides), burnt lime (oxides), marl, and oyster shells.

Lime requirement.—The amount of standard ground limestone required to bring a 6.6-inch layer of an acre (about 2 million pounds of mineral soils) of acid soil to some specific lesser degree of acidity, usually to slightly or very slightly acid. In common practice, lime requirements are given in tons per acre of pure limestone, ground finely enough so that all of it passes a 10-mesh screen and at least half of it passes a 100-mesh screen.

Limestone.—A sedimentary rock composed of calcium carbonate, $CaCO_3$. There are many impure varieties.

Litter.—Freshly fallen or slightly decomposed organic debris.

Loess.—Material deposited by wind and consisting of predominantly silt-sized particles.

Log-and-pole structure.—*See* section V, "Types of Control."

Microclimate.—A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-organism.—Any living thing that is microscopic or submicroscopic in size.

Mined land.—Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mountain top removal.—In this mining method, 100 percent of the overburden covering a coal seam is removed in order to recover 100 percent of the mineral. Excess spoil material is hauled to a nearby hollow to create a valley fill.

Mulch.—Natural or artificial material used to provide more desirable moisture and temperature relationships for plant growth. It is also used to control unwanted vegetation.

Natural drainway.—Any water course that has a clearly defined channel, including intermittent streams.

Neutralization.—When associated with coal mining, neutralization is the addition of an alkaline material such as lime or limestone to an acid material to raise the pH and overcome an acid condition.

Nitrogen fixation.—The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nutrients.—Any element taken into a plant that is essential to its growth.

Operation.—All of the premises, facilities, railroad loops, roads, and equipment used in the process of extracting and removing a mineral commodity from a designated surface mine or in the determination of the location, quality, and quantity of a natural mineral deposit.

Organic matter.—The fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

Orphan lands.—Disturbed surfaces resulting from surface mines that were inadequately reclaimed by the operator and for which he no longer has any fixed responsibility. Usually refers to lands mined previous to the passage of comprehensive reclamation laws.

Outfall.—The point where water flows from a conduit, stream, or drain.

Outslope.—The exposed area sloping away from a bench cut section.

Overburden.—The earth, rock, and other materials that lie above the coal.

Perennial plant.—A plant that normally lives for 3 or more years.

Permeability.—The quality of a soil horizon that enables water or air to move through it. The permeability of a soil may be limited by the presence of one nearly impermeable horizon even though the others are permeable.

pH.—A numerical measure of the hydrogen ion concentration. It is used to indicate acidity and alkalinity. The neutral point is pH 7.0; pH values below 7.0 indicate acid conditions and those above 7.0 indicate alkaline conditions.

Piping.—Removal of soil material through subsurface flow channels or "pipes" developed by seepage water.

Pit.—Used in reference to a specifically describable area of open-cut mining. May be used to refer to only that part of the open-cut mining area from which coal is being actively removed or may refer to the entire contiguous mined area.

Pitch.—*See* Angle of dip.

Plant nutrients.—The elements or groups of elements taken in by a plant that are essential to its growth and used in elaboration of its food and tissues. Includes nutrients obtained from fertilizer ingredients.

Planting season.—The period of the year when planting or transplanting is considered advisable from the standpoint of successful establishment.

Pollution.—Environmental degradation resulting from man's activities or natural events.

Pond.—A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Preplanning.—Process of foreseeing reclamation problems and determining measures to minimize offsite damages during the mining operation and to provide for quick stabilization of the mining.

Puddled soil.—A dense soil dominated by massive or single-grain structure, almost impervious to air and water. This condition results from handling a soil when it is in a wet plastic condition so that when it dries it becomes hard and cloddy.

Pyrite.—A yellowish mineral, iron disulfide, FeS_2, generally metallic appearing. Also known as *fool's gold.*

Rain.—1. **Heavy**: Rain that is falling at the time of observation with an intensity in excess of 0.30 inch per hour (over 0.03 inch in 6 minutes).

2. **Light**: Rain that is falling at the time of observation with an intensity of between a trace and 0.10 inch per hour (0.01 inch in 6 minutes).

3. **Moderate**: Rain that is falling at the time of observation with an intensity of between 0.11 inch per hour (0.01+ inch in 6 minutes) and 0.30 inch per hour (0.03 inch in 6 minutes).

Reclamation.—The process of reconverting mined land to its former or other productive uses.

Red dog.—A gob pile after it has burned. The material is generally used as a road-surfacing material; it has no harmful acid or alkaline reaction.

Reforestation.—The natural or artificial restocking of an area with forest trees.

Regrading.—The movement of earth over a surface or depression to change the shape of the land surface.

Rehabilitation.—Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding esthetic values.

Retention.—The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between the total precipitation and total runoff.

Revegetation.—Plants or growth that replaces original ground cover following land disturbance.

Reverse terrace.—*See* Georgia V-ditch.

Revetment.—A facing of stone or other material, either permanent or temporary, placed along the edge of a stream to stabilize the bank and protect it from the erosive action of the stream.

Rhizome.—A horizontal underground stem, usually sending out roots and aboveground shoots at the nodes.

Riprap.—Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves). Also applied to brush or pole mattresses, or brush and stone, or other similar materials used for soil erosion control.

Rock-fill dam.—A dam composed of loose rock usually dumped in place, often with the upstream part constructed of handpacked or derrick-placed rock and faced with rolled earth or with an impervious surface of concrete, timber, or steel.

Runoff.—That portion of the precipitation on a drainage area that is discharged from the area in stream channels. Types include surface runoff, ground water runoff, or seepage.

Sand.—A soil particle between 0.074 (#200 sieve) and 4.76 (#4 sieve) millimeters in diameter.

Sandstone.—A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Scalping.—Removal of vegetation before mining.

Scarify.—To loosen or stir the surface soil without turning it over. Also, in the case of legume seeds, abrasion of the hard coat to decrease time required for germination.

Scheduling.—Chronological ordering of various stages of surface mining operations to minimize time and duration of exposure.

Scour.—The wearing away of terrace or diversion channels or streambeds.

Seam.—A stratum or bed of coal.

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

Sediment basin.—*See* section I, volume II.

Sediment trap.—*See* section I, volume II.

Sediment yield.—The total amount of sediment that passes any section of a stream.

Seedbed.—The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seep.—A more or less poorly defined area where water oozes from the earth in small quantities.

Selected earth material.—Suitable native material obtained from roadway cuts or borrow areas, or other similar material, used for subbase, roadbed material, shoulder surfacing, slope cover, or other specific purposes.

Semiarid.—A term applied to regions or climates where moisture is normally greater than under arid conditions but still definitely limiting to the growth of most crops. Dryland farming methods or irrigation generally is required for crop production. The upper limit of average annual precipitation in the cool semiarid regions is as low as 38 cm (15 inches), whereas in tropical regions it is as high as 114 to 127 cm (45 or 50 inches).

Shale.—Sedimentary or stratified rock structure generally formed by the consolidation of clay or claylike material.

Sheet flow.—Water, usually storm runoff, flowing in a thin layer over the ground surface. *Syn.:* overland flow.

Side slopes.—The slope of the sides of a canal, dam, or embankment. It is customary to name the horizontal distance first as 1.5 to 1.0, or frequently 1½:1, meaning a horizontal distance of 1.5 feet to 1 foot vertical.

Silage.—A crop that has been preserved in a moist succulent condition by partial fermentation. Chief silage crops are corn, sorghums, and various legumes and grasses.

Silt.—Small mineral soil grains, the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Slope characteristics.—Slopes may be characterized as concave (decrease in steepness in lower portion), uniform, or convex (increase in steepness at base). Erosion is strongly affected by shape, ranked in order of increasing erodibility from concave to uniform to convex.

Slope stability.—The resistance of any inclined surface, as the wall of an open pit or cut, to failure by sliding or collapsing.

Sludge.—The precipitate resulting from chemical treatment of water, coagulation, or sedimentation.

Sod.—A closely knit ground cover growth, primarily of grasses.

Soil.—1. The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

2. The unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro- and micro-organisms, and topography, all acting over a period of time and producing a product soil that differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics.

3. A kind of soil; that is, the collection of soils that are alike in specified combinations of characteristics. Kinds of soil are given names in the system of soil classification. The terms *the soil* and *soil* are collective.

Soil conservation.—Protection of the soil against physical loss by erosion or against chemical deterioration; that is, excessive loss of fertility by either natural or artificial means.

Soil series.—The basic unit of soil classification being a subdivision of a family and consisting of soils that are essentially alike in all major profile characteristics except the texture of the A horizon.

Soil structure.—The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Soil survey.—A general term for the systematic examination of soils in the field and in laboratories; their description and classification; the mapping of kinds of soil; the interpretation of soils according to their adaptability for various crops, grasses, and trees; their behavior under use or treatment for plant production or for other purposes.

Soil texture.—Soil texture class names of soils are based upon the relative percentages of sand, silt, and clay.

Spoil.—*See also* Acid spoil; Toxic spoil. The overburden or noncoal material removed in gaining access to the coal or mineral material in surface mining.

Spoil bank (spoil pile).—Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.

Sprigging.—The planting of a portion of the stem and/or root of grass.

Stabilize.—Settle, fix in place, make nonmoving, usually accomplished on overburden by planting trees, shrubs, or grasses, or by mechanical compaction or aging.

Staging.—Arrangement of major mining operations, such as clearing, grubbing, and scalping, into small discrete segments so that at any one time the various phases of clearing, extraction, and reclamation can be carried on simultaneously.

Stand.—1. An aggregation of trees or other growth occupying a specific area and sufficiently uniform in composition (species), age arrangement, and condition to be distinguishable from the forest or other growth on adjoining areas.

2. The number of plants per unit of area other than trees.

Stolon.—A horizontal stem that grows along the surface of the soil and roots at the nodes.

Stratified.—Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called *horizons*, while those inherited from parent material are called *strata*.

Strip mine.—Refers to a procedure of mining that entails the complete removal of all material from over the product to be mined in a series of rows or strips; also referred to as *open cut*, *open pit*, or *surface mine*.

Subsoil.—The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when *soil* was conceived only as the plowed soil and that under it as *subsoil*.

Surface mining.—Mining method whereby the overlying materials are removed to expose the mineral for extraction.

Surface soil.—That part of the upper soil of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 inches) in nonarable soils.

Surface water.—Water, from whatever source, that is flowing on the surface of the ground.

Suspended solids.—Sediment that is in suspension in water but that will physically settle out under quiescent conditions (as differentiated from dissolved material).

Swale.—A hollow or depression.

Syncline.—A fold of rock beds that is convex downward.

Tacking (mulch).—The process of binding mulch fibers together by the addition of a sprayed chemical compound.

Terrace.—An embankment or combination of an embankment and channel constructed across a slope to control erosion by diverting.

Terrace outlet channel.—Channel, usually having a vegetative cover, into which the flow from one or more terraces is discharged and conveyed from the field.

Terrace types.— **Absorptive:** A ridge type of terrace used primarily for moisture conservation.

Bench: A terrace approximately on the contour, having a steep or vertical drop to the slope below, and having a horizontal or gentle sloping part. It is adapted to steeper slopes.

Drainage: A broad, channel-type terrace used primarily to conduct water from the area at a low velocity. It is adapted to less absorptive soil and regions of high rainfall.

Texture.—The character, arrangement, and mode of aggregation of particles that make up the earth's surface.

Tillage equipment (tools).—Field tools and machinery that are designed to lift, invert, stir, or pack soil, reduce size of clods and uproot weeds; i.e., plows, harrows, discs, and cultivators.

Toe.—The point of contact between the base of an embankment or spoil bank and the foundation surface. Usually the outer portion of the spoil bank where it contacts the original ground surface.

Tolerant.—Capable of growth and survival under competitive growing conditions.

Topographic map.—A map indicating surface elevations and slopes.

Topography (lay-of-the-land).—The configuration of the earth's surface, including the shape and position of its natural and man-made features.

Topsoil.—The unconsolidated earthy material that exists in its natural state above the rock strata and that is or can be made favorable to the growth of desirable vegetation.

Toxic spoil.—*See also* Acid spoil; Spoil. Includes acid spoil with pH below 4.0. Also refers to spoil having amounts of minerals such as aluminum, manganese, and iron that adversely affect plant growth.

Tracking.—The movement of bulldozers and other cleated equipment up and down the face of a slope for the purposes of stabilization, compaction, erosion control, and vegetative establishment.

Transplant (forestry).—A seeding that has been transplanted one or more times in the nursery.

Unconsolidated (soil material).—Soil material in a form of loose aggregation.

Vegetation.—General term including grasses, legumes, shrubs, and trees, naturally occurring and planted intentionally.

Vegetative buffer.—*See* Buffer strip.

Vegetative cover.—The entire vegetative canopy on an area.

Voids.—A general term for pore spaces or other openings in rock. In addition to pore space, the term includes vesicles, solution cavities, or any openings, either primary or secondary. *Syn.:* interstices.

Volunteer.—Springing up spontaneously or without being planted; a volunteer plant.

Warm season plant.—A plant that completes most of its growth during the warm portion of the year, generally late spring and summer.

Water bar.—Any device or structure placed in or upon a haul or access road for the purpose of channeling or diverting the flow of water off the road.

Water conservation.—The physical control, protection, management, and use of water resources in such a way as to maintain crop, grazing, and forest lands, vegetal cover, wildlife, and wildlife habitat for maximum sustained benefits to people, agriculture, industry, commerce, and other segments of the national economy.

Water control (soil and water conservation).—The physical control of water by such measures as conservation practices on the land, channel improvements, and installation of structures for water retardation and sediment detention. Does not refer to legal control or water rights as defined.

Water table.—The upper limit of the part of the soil or underlying rock material that is wholly saturated with water. The locus of points in soil water at which the hydraulic pressure is equal to atmospheric pressure.

Watersheds.—Total land area above a given point on a stream or waterway that contributes runoff to that point.

Weathering.—Action of the weather elements in altering the color, texture, composition, or form of exposed objects.

Wind erosion.—The detachment and transportation of soil by wind.

Zeta potential.—A measure of the electrokinetic charge (in millivolts) that surrounds suspended particulate matter.

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