NONPOINT SOURCE CONTROL GUIDANCE

CONSTRUCTION ACTIVITIES

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Water Planning & Standards
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Project Officer

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PREFACE

In accordance with EPA's policy, as presented in the "Draft Guidelines For State and Areawide Water Quality Management Program Development" February 1976, a clear responsibility has been placed on organizations developing water quality management plans to establish regulations for control of nonpoint sources. Where needed, Best Management Practices such as those presented in this technical guidance document, will be implemented through such regulations. Nonpoint source regulatory guidance is now being developed by EPA to provide additional assistance to State and areawide 208 Agencies in their nonpoint source control programs.

This construction nonpoint source pollution control guidance document is only one of a series designed to provide State and areawide 208 Agencies, the Federal agencies, and other concerned groups and individuals with information which will assist them in carrying out their water-quality planning and implementation responsibilities. It is provided in accordance with policies and procedures for the "Preparation of Water Quality Management Plans" (40 CFR, Part 131) which states that "EPA will prepare guidelines concerning the development of water quality management plans to assist State and areawide planning agencies in carrying out the provisions of these regulations". Additional documents to be issued will involve silvicultural (forestry), mining, agricultural, hydrologic modification and other activities. The basic guidance information included in this nonpoint source control document is principally technical in nature and presented in four main chapters. They include information on the identification and assessment of existing construction nonpoint source problems; analysis and procedures needed for selection of controls; descriptions of individual and systems of Best Management Practices (BMP), with a method for determining their effectiveness; and several methods for predicting potential pollution problems from future construction activities.

Effective control of nonpoint sources of pollution can best be achieved through proper planning of construction activities, adequate review and approval of the plans by a responsible management agency, adjustment of the plans to maximize effectiveness of Best Management Practices prior to their implementation, monitoring by the management agency for adherence to the plan, and effective and when required, aggressive enforcement of compliance to the law. Sixteen states now have direct sediment control laws which apply to construction activities. Most of them require the submission of a plan which must be approved prior to initiating construction. The plans are developed in accordance with criteria, guidelines, specifications, standards, etc. provided in documents issued by State or local agencies responsible for sediment control. This nonpoint source pollution control guidance follows the general format of these documents which were developed as a result of sediment control laws or ordinances. This is particularly true of Chapter 3, "Selected Practices for Control, Construction Activities".

All existing data indicate that construction activities, when soils and foundation materials are disturbed and left exposed to erosion by rainfall, wind, and runoff water, are responsible for causing extraordinary environmental damages, especially to waterways, lakes, and impoundments. Off-site damages often are difficult to trace to their source and on-site damages are not readily apparent until excess quantities of sediment or other pollutants have been transported from the site in runoff. As a result, one must conclude that retaining potential pollutants to the site area is the Best Management Practice. The principal theme throughout this guidance document emphasizes pollution prevention rather than treatment.

Every effort must be taken to keep sediment and other potential pollutants from leaving the site area. Control of pollution at the source is the only viable option to mitigate water quality and stream condition problems. To attempt to control sediment and other nonpoint source pollutants through water quality standards is not feasible. Even if the sediment could be traced back to its source, implementation of corrective measures during the wet season, rather than preventative practices before, would be difficult, if not impossible. Water quality standards have a function in the management of a larger watershed, however, they must form a second line of control behind construction on-site or source control Best Management Practices.

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INTRODUCTION

The nonpoint sources of pollution can be separated into categories, each of which may be further subdivided into subcategories. Man's land-disturbing construction activities is one of the main categories and, although management practices presented in this document apply in general to all types of construction, some subcategories such as dams, power lines, canals, etc. may require more elaborate measures. As a result, additional, and more specific BMP guidance may be required.

Advance planning can limit, through management decisions the generation of conditions which could add materially to the pollution potential Planning can avoid or limit exposure to potential problems through identification and allowance for natural hazards such as areas of unstable soils, limitations imposed by climate and topography; or land capabilities in terms of soil productivity or vegetative recovery potential

Control of nonpoint source pollution from construction activities should be considered during the planning stages of a project in order to ensure that the most effective application of measures is achieved during the actual construction period. An adequately developed plan should involve preventing sediment losses; reduction of peak surface runoff; preventing the generation, accumulation, and runoff of oils, wastewaters, mineral salts, pesticides, fertilizers, solids, and organic materials from the site area.

Specific instructions as to specific control measures and systems of measures needed, scheduling and coordination of activities, and the use of permanent and temporary techniques should be required in contracts between owners or developers and the contractors responsible for carrying out construction activities.

Adequate Planning

Adequate plans for construction nonpoint source pollution control should be based upon the known soils, topographic, geologic, hydrologic, and other pertinent factors applicable to the site area. Particular care should be taken to identify and evaluate possible problems which could result from the construction of the facilities planned.

Fitting the construction site, or facilities, to the landscape, particularly with regard to its weaknesses, may prevent potential pollution problems from arising. The natural ground contours should be followed as closely as possible and grading minimized. Areas of steep slopes, where high cuts and fills may be required, should be avoided. Generally, areas adjacent to natural water courses should be undisturbed. Extreme care should be used in locating artificial drainageways so that their final gradient and resultant water discharge velocity will not create additional erosion problems. Natural protective vegetation should be undisturbed if at all possible. Steep slopes and areas of erodible materials should be avoided or the exposed soil surfaces protected from the energy of rainfall and runoff before erosion occurs. If these things cannot be done, runoff of pollutants will have to be prevented by the development of specific structural or other control measures.

Effective plans should consider proper scheduling and coordination of construction activities and the provision of adequate maintenance of control measures to ensure pollution prevention. The plans should consider the time of year construction is to occur; extent of grading for surface elevation changes to be done; amount of ground to be exposed to the elements compared to that covered by protective vegetation; quantity of runoff expected to enter the site from upslope areas; occurrence and characteristics of ground water underlying the site, and other factors which can create or minimize pollution problems. A combination of fitting the development to site conditions, limiting the grading and exposure of bare soils, and applying adequate control measres and techniques at proper times will prove the most effective nonpoint source control mechanism.

Early in the planning process, existing construction activities control requirements, or limitations, imposed by Federal, State, and local agencies should be determined and followed. Contact should be established with agencies involved with water development, transportation, pollution control, conservation, and the like to obtain information regarding prior construction problems they have had and to obtain guidance with regard to solutions.

Controlling Erosion and Sediment Runoff

Erosion and runoff of sediments can be controlled effectively and economically by using the following procedures:

1. Limiting the time of duration that disturbed ground surfaces are exposed to the energy of rainfall and runoff water.
2. Diverting runoff from upper watershed which would contribute runoff to areas subject to erosion.
3. Reducing the velocity of the runoff water on all areas subject to erosion below that necessary to erode the materials.
4. Applying a ground cover sufficient to restrain erosion on that portion of the disturbed area which further active construction is not being undertaken.
5. Collecting and detaining runoff from a site in sediment basins to trap sediment being transported from the site.

6. Making provision for permanent protection of downstream banks and channels from the erosive effects of increased velocity and volume of storm water runoff resulting from facilities constructed.
7. Limiting the angle for graded slopes and fills to an angle no greater than that which can be retained by vegetative cover or other adequate erosion control device or structure.
8. Minimizing the length as well as the angle of graded slopes to reduce the erosive velocity of runoff water.

<u>Preventing Accumulation and Runoff of Pollutants Other Than Sediments</u>

Practices that prevent transportation of sediments from a site area will also deter movement of many other pollutants such as oils, pesticides, solid wastes, metals, etc. from the site area. Pollutants carried in solution however, will pass through all sediment control defenses. In this case, proper application of materials and "good house-keeping" activities must be used to do the job. They will involve such things as optimun dosages and proper use of pesticides and fertilizers with special attention to not applying them in excess of quantities required, limiting application only to points of need, and prohibiting application in periods of weather extremes such as freezing conditions which render the ground impermeable and ensure runoff of materials. Washing facilities for equipment should be located and concentrated at specific points where draining waters can be collected in impervious holding ponds. Washing of finished surfaces to remove excess concrete or other chemical residues should be undertaken only after holding ponds have been provided to catch drainage waters. Waste quantities of paints, oils, and greases should be collected and transported off site for sanitary disposal. Pollution from other waste materials such as rubber, plastic, or wood building materials; food containers; sanitary wastes; and miscellaneous solid and liquid materials can be controlled by the use of adequate disposal facilities and the transport of these materials from the sites to authorized disposal areas. Anti-litter requirements should be enforced by regular visual checking of the construction site.

Management of Increased Stormwater Runoff

Stormwater management involves regulating the release of runoff from a site under construction in order to prevent increased peak flows from eroding downstream channel areas. Peak flows, caused by changed conditions during, (and after) construction, may increase tremendously over those which naturally developed the drainageways. In order to accomodate increased flows, channels downstream from construction sites will have to increase their cross-sectional area. This can only be done naturally by erosion; and sediments resulting from this erosion causes pollution in downstream areas.

Stormwater management regulates the release of this runoff by temporarily retarding the flow. This can be done by providing temporary storage facilities which release the water slowly, increasing the infiltration capacity of soils and foundation materials by micro-benching or roughing the surface of slopes, while ensuring that exposed soils are stabilized; adopting site drainage patterns that increase flow distances and thus inccease time of travel of the runoff, leaving trees and other vegetated areas in as many areas as possible to prevent rainfall from rapidly becoming runoff; and other means. Consideration should be made to design stormwater management facilities into the completed project to be operational through its estimated life.

CHAPTER 1

Problem Identification and Assessment, Existing Problems--Surface Waters

The generation and runoff of pollutants from construction sites are strongly dependent on the local climatic events such as precipitation, wind, and overland flow of water resulting from rainfall or snowmelt. As climatic conditions are dynamic and generally highly variable, the runoff of pollutants often changes drastically and unpredictably. The nature and quantity of pollutants leaving a site also depends upon the particular activities being conducted, extent of disturbed area, soil characteristics in the vicinity, local topographic and geologic conditions, the number of people and equipment involved and their impacts on the area, extent of protective vegetative covering on the site and other factors. Implementation of effective control measures will involve preventing the generation of pollutants as well as restricting the runoff of those already generated so that waters are not affected by these contaminants.

Identification of Pollutants

Sediment resulting from erosion of disturbed soils is one of the principal pollutants originating from construction activities (Reference No. 1). It includes solid mineral and organic materials in fragment form which are transported by runoff water, wind, ice, and the effect of gravity. Chemical pollutants derived from construction activities originate from inorganic and organic sources and occur in solid form such as asphalt, boards, fibers, or metals; or in liquid form such as paints, oils, glues, pesticides, fertilizers, and the like. Biological pollutants include organisms derived from soils, animal or human orgins. They may be bacteria, fungi, or viruses.

Sediment includes solid mineral, and organic materials which exert physical, chemical, and biological effects on receiving water bodies. Physical damage resulting from excess quantities of sediment deposited in, or carried in, water includes: reduction of reservoir storage capacity thus requiring costly dredging or decreasing the life of the project; filling harbors and navigation channels thereby disrupting their functioning; increased frequency of flooding through the filling of water courses; increased turbidity effects and sediment content in waters, and reduced light penetration thus destroying aquatic plants and organisms; increased cost of downstream water treatment; damage to fish life; and covering destruction of organisms on the bottom of streams and other water bodies; reduction of the velocity and carrying capacity of streams; and impairment of drainage ditches, culverts, and bridges; altered shape and direction of stream channels; degradation of water recreational areas; and the imparting of undesirable taste to water.

Other potential pollutants from construction activities include petroleum products, pesticides, fertilizers, metals, soil additives, construction chemicals, and miscellaneous wastes from construction debris. Many petroleum products impart a persistent odor and taste to water, thus impairing its use for drinking and contact sports. Oils often have the ability to block the transfer of air from the atmosphere into water, causing the suffocation of aquatic plants, organisms, and fish, and other water-living organisms. Petroleum products often contain quantities of organo-metallic compounds (nickel, vanadium, lead, iron, arsenic), pesticides, and other impurities which can be toxic to fish and other organisms and seriously impair on their use for human consumption.

The three most commonly used forms of pesticides at construction sites are herbicides, insecticides, and rodenticides. Unnecessary or improper application of these pesticides may result in direct water contamination, indirect pollution by drift or transport off soil surfaces into water. Pesticides are generally toxic to man and other vertebrate animals and have strong adverse effects on lower organisms. Persistent pesticides often accumulate in the environment with magnification of effects resulting in higher biological organisms which have consumed contaminated organisms lower in the food chain. The latter problem is of extreme concern as other forms of life may be destroyed along with the target pests.

Nitrogen, phosphorous, and potassium are the major plant nutrients used for the successful establishment of vegetation on disturbed soils of construction sites. Heavy use of commercial fertilizers result in movement of these materials to water bodies where they may accelerate the eutrophication process.

Metals often are transported by sediment particles in runoff water leaving a construction site. Copper, cobalt, chromium, manganese, iron, and nickel are at times associated with sediment particles. Some of these metals are toxic to man. There is limited information on their precise biological function in animal life. They may be concentrated in marine organisms such as shellfish and often act synergistically with other substances to increase their toxicity. This means that the total effects of the pollutants are greater than the sum of their individual effects.

Soil Additives, commonly used to improve soil characteristics for construction uses, include lime, fly ash, asphalt, salt (NaCl) and calcium chloride. They may be transported from the site in runoff waters, along with sediment. Little work has been done to show the net environmental effects of soil additives.

Construction chemicals include those used for glueing boards together, sealing cracks in foundations, solvents for oils and paints, and dying and cleaning. Construction activities leading to pollution by these materials involve dumping of excess materials and wash water into streams or storm sewers, improper handling procedures with the accompanying spills of materials, and leaky containers being placed in storage. Chemical material's effects upon the environment depend upon their concentration and persistence. Many of these materials decompose with their total effects on water quality unknown.

Miscellaneous wastes include wash from concrete mixers, solid wastes resulting from trees and shrubs removed during land clearing, wood and paper materials derived from packaging of building products, food containers such as paper, aluminum, and metal cans and packets, and sanitary wastes. The miscellaneous waste products can provide physical damage to stream systems similar to sediments, they can decompose and creat nutrient or chemical problems, or even create health hazards. Biological pollutants, including bacteria, fungi, and viruses from soil, human, and animal origin, are generally found in or on topsoil layers where they can feed on dead plants, animals, and other organic materials. The greatest pollution potential results from those of animal or human origin. They are most prevalent on construction sites where improper sanitary conditions exist.

Assessment of Nonpoint Source Polluution From Existing and Completed Sites

Most, if not all, construction activities which involve disturbance of surface soils or underlying geologic materials result in the generation of

nonpoint source pollutants. Surface water runoff will transport these materials from the site unless extreme care is taken to provide control measures which contain them within the area of development.
It is extremely difficult to assess, with any reasonable accuracy, the magnitude and extent of future pollutant discharge from the construction areas. This is due to the fact that the runoff from each construction site varies tremendously depending on the intensity and duration of rainfall, and other inclement weather conditions; topography, geology, and soil types occurring in the area; areal extent of disturbed soil; type of construction involved; character of vegetative cover; and other local conditions. The techniques and strategies to be applied are different from region to region so survey of existing problems at existing sites is valuable in drawing up plans for controlling such pollution from future construction sites. Techniques and strategies should be devised to restrict pollution runoff under anticipated natural and manmade conditions.

The initial step in understanding construction nonpoint source pollution in an area should involve a survey of all existing and recently completed construction projects where the ground surface has been disturbed. Information should be obtained regarding site locations; particularly with regard to their proximity to water bodies; their surface area, slope, and geometric configuration; foundation conditions; the duration of construction activities; and other pertinent factors. A construction site for a linear facility, such as a highway or pipeline, may cause much greater areawide pollution problems than a site with a much larger local surface area with more nearly equal dimensions, such as a shopping center. Construction of many dams, recreation facilities, and some power plants do not result in the disturbance of excessively large areas of the ground surface; however, they are often on, or extremely near, streams of good quality and so have a high pollution potential.

Runoff of pollutants other than sediment are even more difficult to assess than readily visible sediment. Evidence of petroleum products in runoff may be found in oil sheens on the water or in oil scums on surfaces downstream from the site. Wastes from solid materials can show up as debris. Soluble pollutants can be assessed by leaching and analyzing samples of fine-grained sediments for suspected materials. Toxic materials in runoff may be apparent by fishkills and evidence of excess nutrients by algae blooms in water bodies.

An extremely valuable source of information regarding pollution resulting in areas downstream from existing and completed construction areas is the local public. Many people, particularly older residents in the area, remember the condition of the local streams prior to construction and can convey pertinent information concerning changes which have occured. Areas of prior extreme sediment deposition, channel erosion, oil spills, fish kills, etc. may be located, and perhaps documented in local papers if dates can be recalled.

Limited research data indicate that up to 70 per cent of the sediment removed by erosion from a construction site without adequate pollution control measures is transported from the site by runoff water and deposited further downstream. Field surveys of existing, or recently completed, construction sites can provide reliable information that sediment runoff problems are, or have been, occurring. They should involve estimates, on site, of the amount of erosion that has occurred and the volume of sediments deposited in the site area and immediately downstream. An extremely pertinent time to make observations is during a period of intense rainfall when the processes of erosion and sediment transport and deposition actually are taking place. At this time erosion and transport of sedimentary materials can be observed. Deposition of sediments will occur later as runoff velocities decrease or the runoff waters collect in impoundments at which point suspended sediments will settle.

Erosion by wind is a significant factor to be considered, particularly in Western areas of the country where winds may blow continuously and over long distances with no topographic obstructions. Observations regarding erosion by this mechanism should be made during and after windstorms when information on the direction of movement and the location of wind-blown deposits can be obtained. Materials deposited by the wind can often be differentiated from water-laid materials by their location with regard to streams, the uniform grain size of the materials, the angularity of fragments, and the generally low density of deposits. Water deposits are usually near the water sources that transported them, generally composed of a mixture of different sized materials that are more less rounded by the action of water transport processes, and of much higher density than that of wind blown sediments.

Erosion of rainfall and runoff occurs as sheet and rill erosion and gully erosion. Sheet and rill action occurs when water is not concentrated while gully erosion involves concentrated flows. Estimates of the volume of sediments derived from gulley erosion can be made from field observations and measurements. That resulting from sheet and rill erosion, is less apparent; however, and more difficult to reliably estimate. Gullys, where concentrated flow of water has occurred, are readily observed as they are incised into smooth construction cut and fill slopes. Computations, using gully dimensions, can provide information on the volume of material removed by water. If this total volume of material has not been deposited in the site area where slopes decrease, and runoff water has lost its energy to transport sediment particles, some of it has been carried further downstream to become a pollution load.

To estimate the volume of sediment that has been carried by runoff into downstream areas from gully erosion in the site area, it is necessary to determine the approximate volume of this material that has been deposited on the site itself and subtract it from that eroded from the gully areas. The deposited materials is apparent as small deltas which generally are seen at the bottom of cut and fill slopes or wherever runoff velocities have decreased. Diversion ditches, swales, or depressions also may be filled with sand-sizes particles and sheets of sediments deposited in low, flat areas. In some instances, buried survey markers, or other objects can provide information on the thickness of deposits. The areal extent of the deposits times their thickness will provide an estimate of the volume of materials involved. Extreme judgement will be necessary to define valid thickness measurements in this type of estimate.

The volume of excess sediments deposited downstream from construction sites can be estimated also in this manner, particularly if information, such as that provided in photographs, on the condition of the streams prior to construction are available. Recent contour maps, particularly those provided by the U.S. Gelogical Survey on a scale of 1:24,000, may also provide pertinent information on the condition of the stream before construction started. Evidence of excessive sediment loads in the stream system can be observed where the stream seems to be constricted by materials in low gradient areas; small pools are filled, or filling, with deposits; the channel is "braided" and flowing on a bed of uniformly-sized material (when it was previously flowing on bedrock); or where massive sediment deposits cover areas adjacent to and at a higher elevation than the present stream. A braided stream is one that flows in several dividing and reuniting channels, similar to the strands of a braid. This latter evidence indicates that the stream had an excess sediment load during flood stage and deposition occurred as the runoff volume decreased and the stream level dropped. Probably the most reliable measure of the quantity of sediments that have left a construction area can be obtained by conducting reservoir sedimentation surveys. If no other construction site, or other man-induced sediment-generating activity is being conducted in the drainage basin for the reservoir, measurements of the quantity of sediment deposited in the reservoir as a result of the construction, are very reliable. A reservoir deposition survey consists of measuring the areal extent and thickness of the sediment delta accumulation formed by the deposition of excess sediment. Some useful information on conducting reservoir and flood plan studies is presented in Reference No. 2.

The field surveys are intended only to provide information that erosion is occurring, or has occurred, on construction sites where no sediment control measures were applied, or were inadequate, and that sediment runoff is a problem. Estimates of the volume of sediments eroded from the sites and deposited either in the site area or further downstream should, not be considered precise or accurate. Even if the quantities of material eroded by both sheet and rill and gully processes could be accurately measured, they would not be equal to the total of materials deposited, even if the latter can be accurately determined. This is due to the fact that a volume of some eroded material increases greatly when in a state of loose deposition. Also, if clays or other fine-grained materials are present in the volume of eroded sediments they will remain in suspension in the runoff water and be transported entirely out of the site area.

Chemical and biological runoff from a site during construction can be difficult to assess after construction has been completed and conditions have stabilized. Sampling is one way to obtain information on the sediment, chemical, and biological pollution, being transported by a stream at a particular location. Existing sampling data may be readily available from records; however, to compare sediment loads immediately upstream of the site with those immediately downstream. The difference should be due to sediment runoff from the construction area. In addition, stream quality prior to construction when compared to that during and after should indicate sediment loads contributed by the construction activities. Extraneous influences on stream regimens should be carefully assessed prior to evaluation. As the principal sediment loads are transported during flood flows, it is entirely possible that a sediment load determined in the stream at the site resulted from an anomalous inflow of materials several miles upstream and in the past. Landslides often cause this problem and these sediment loads move downstream as "slugs" to be detected several years later in downstream areas.

Assessment of sediment runoff resulting from construction sites may be accomplished by estimating the potential quantity of materials that can be eroded and transported from each site, assuming no control measures have been implemented. The sum of all site estimates should provide a fairly reliable indication as to the magnitude of pollution in the area and whether or not it will increase or decrease in the future. Estimates regarding natural sediment losses from sites prior to construction should be considered in the assessment as these values must be subtracted from the total losses estimated above. Only those sediments resulting from the construction should be considered as the pollution load.

Estimates of sediment resulting from construction and the background, or natural, sediment losses prior to construction in an area can be obtained through the use of soil loss equations developed principally by the U.S. Department of Agriculture (Reference No. 3, 4, 5 and 6). Extreme care must be used, however, in assigning values to particular factors in the equation involving slopes, soil properties and characteristics of the construction site, as these conditions often are much different and more variable than those occurring in farmlands where the soil loss equations are normally used. In addition, one should be aware that these estimated losses involve sheet rill erosion only and do not consider how much of the sediment is transported from the site. Movement of sediment is extremely complex and quantitative evaluations are difficult due to the nature of the site variables involved.

Assessment of nonpoint source pollution resulting from ongoing or completed construction facilities, particularly sediments, should involve (1) a field examination to determine the materials have been eroded, and are being eroded from construction sites and that excess quantities of sediments or other materials are accumulating in channels immediately downstream and (2) evaluating existing gaging, monitoring, and sampling information to establish stormwater runoff quantities and the gross sediment yield from the sites. Much readily available data on sediment problems may be obtained from records of local, State, and Federal agencies such as the Conservation Districts; County Public Works Departments; State Conservation, Transportation, Water Quality, and Water Development agencies; and the United States Geological Survey, Bureau of Reclamation, Soil Conservation Service; Corps of Engineers, and others.

References

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2. "SCS National Engineering Handbook - Section 3, Chapter 7" USDA - SCS, March 1968.

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4. "A Soil Erodibility Nomograph for Farmland and Construction Sites", Journal of Soil and Water Conservation, Sept-Oct, 1971

5. "Present and Prospective Technology For Predicting Sediment Yields and Sources", USDA-ARS-S-40, June 1975.

6. "Procedures for Computing Sheet and Rill Erosion on Project Areas", USDA-SCS, Technical Release No. 51 (Rev.), Jan. 1975.

CHAPTER 2

Data Needs and Analysis for Selection of Controls

Precipitation, whether it falls as rain or snow, is the principal source of all water that moves through a watershed. The characteristics of the soils and vegetative cover occurring in the area, natural topographic conditions, and the results of mans alteration of these natural characteristics have a major effect on the amount of precipitation that actually becomes runoff water. Precipitation and runoff water are the agents responsible for the generation and transportation of pollutants from disturbed areas in any watershed.

As the runoff of nonpoint source pollution from construction sites, particularly sediment, is strongly dependent on local climatic events such as the rainfall, wind, and snowmelt, these factors must be considered during the development of effective Best Management Practices. Additional information required includes the rate, velocity, and quantity of runoff; erodibility, chemical, and physical properties of soils and geologic materials at the site; length, steepness, and roughness of slopes; extent and effectiveness of protective vegetative cover in the area; and results of man's prior earth-changing activities. Changes in the drainage system during construction are of extreme importance. Both the macro-drainage system of the watershed and the micro-drainage system above, on, and below the site should be considered.

Precipitation Information

Data on precipitation can be obtained from several sources. Published data on daily rainfall measured at standard gages are available principally from U.S. Weather Bureau (now the National Weather Service, Department of Commerce) in monthly issues of "Climatological Data". Other Federal and State agencies or universities publish rainfall data on an irregular basis, often in special storm reports or research papers. Unpublished data is available from various Federal and State agencies as a result of field surveys following unusually large storms. These surveys obtain measurements of rainfall caught in buckets, bottles, and similar containers and provide added detail to rainfall maps developed from standard rain gage data.

To make the information more useful for hydrologic work, the U.S. Weather Bureau (now the National Weather Service) published analysis of rainfall data in the fifty States, Puerto Rico, and the Virgin Islands (Reference Nos. 1 through 4). The western States also are covered by the National Oceanic and Atmospheric Administrations Precipitation Atlas 2 (Reference No. 5). Methods for making a more precise analyses of the data is presented in publications such as the Soil Conservation Service's "National Engineering Handbook, Section 4 Hydrology", the Bureau of Reclamation's "Design of Small Dams" and others (References 6 and 7). They provide essential information for determining, or estimating, the depth of rainfall to be expected in the area; the intensity, duration and seasonal distribution of storms with associated probabilities of occurrence; the antecedant conditions in the drainage, and other factors.

Wind Data

Sediments blowing off areas denuded by construction may be a serious problem in areas where non-cohesive soils occur, particularly in arid or semi-arid regions. Data regarding the capacity of the wind to cause erosion, the prevailing wind directions, and the preponderence of wind erosion forces in the prevailing directions are presented in U. S. Department of Agriculture

Handbook No. 346 "Wind Erosion Forces in The United States and Their Use in Predicting Soil Loss", (Reference No. 8).

Characteristics of Soils and Underlying Geologic Materials

Evaluation of available soils and foundation information is of particular importance for development of Best Management Practices. They include such factors as the density, permeability, composition, degree of consolidation, and thickness of materials present. Many of these characteristics are inter-related and all may have an effect on the generation and movement of pollutants from construction sites. Data on possible ground water bodies underlying the site are also essential. The depth to this water body and its quality and direction of movement should be determined. It could possibly introduce transporting waters into the site area to carry pollutants into or from the area to degrade adjacent supplies.

Information regarding the physical characteristics of soils and/or underlying geologic materials in site areas can be obtained from soil survey reports published by the U. S. D. A., Soil Conservation Service, in cooperation with other Federal or with State agencies; geologic reports provided by Federal State and local agencies; from documents available from Universities or other institutions of higher learning; and from the agency or company to do the construction. This information is normally fairly generalized as it is done on an areawide basis and often for a different purpose than pollution control. The level of detail of the information in such documents varies according to the objectives of the work but almost all of them are valuable for analysis of hazards and potentials and for development of Best Management Practices.

Specific soils and foundation information regarding in-place characteristics can often be obtained from engineering project reports, case histories of prior construction projects, or by sampling the materials at the sites and evaluating the properties of the materials sampled. In construction sites, where cuts and fills are common, extreme caution must be used, particularly with regard to soil erodibilities, to ensure that material characteristics are determined at the final grade elevation and not at higher elevations where the material is to be removed or below where it is protected by overlying soils.

Ground Water

Ground water conditions are of critical importance in construction sites as the inflow of water into a construction site can cause pollution problems. Movement of runoff, with pollutants into an underlying ground water body can cause additional problems. Data needed for pollution prevention with regard to ground water includes depth to the water body, direction of movement, whether it occurs under confined (artesian) or unconfined (water table) conditions, and its natural quality. Ground water information may be obtained from U. S. Geological Survey Water Supply Papers and other technical reports, State Water development agency reports, from local data obtained regarding studies of wells in the site area, and other sources.

Topographic Conditions

An evaluation of topographic conditions at a construction site prior to earth-changing activities, and in adjacent areas, can be made from information on existing maps such as the Geological Survey's topographic maps, the Department of Agriculture's Soil maps, and other maps of this type. More detailed data on topography and conditions will usually be available from the site plans prepared by the developers, engineers, and surveyors.

Data on the length, steepness, and roughness of slopes is important and may be obtained through actually surveying the site or from interpretation from the published reports discussed above, as well as from the topographic maps developed by the U.S. Geologic Survey, Army Map Service, and other sources.

Runoff Determinations

Water erosion, and resulting soil loss from a site area, is negligable until runoff actually begins. The quantity and frequency of precipitation needed to initiate runoff is a function of the interrelationship of many variables such as the rainfall intensity, temporary surface storage in the area, physical character of soils or foundation materials, time since prior precipitation has occurred, location and percentage of the area protected by vegetation, and steepness and length of slopes at the site.

The combined effect of soils, vegetative cover, man's earth-changing activities (conservation practices) on the amount of rainfall that actually becomes runoff from an area can be estimated in several ways. Probably the most applicable is presented in the Soil Conservation Service's "National Engineering Handbook, Section 4, Hydrology". It provides information on estimating runoff through the use of Watershed Curve Numbers. Similar information is presented in this same Agency's "Engineering Field Manual" (Refernce No. 9). The State of North Carolina's "Guide for Sediment Control on Construction Sites (Reference No. 10), and the Bureau of Reclamation's "Design of Small Dams". The curve numbers (CN's) are hydrologic "soil-cover" complex numbers and indicate their relative value as direct runoff producers. The higher the number, the greater the amount of direct runoff to be expected from a storm.

Additional information on runoff evaluation is presented in the publications "Urban Runoff for Small Watersheds" and "Guidelines for Hydrology" (References 11 and 12). Existing hydrologic data developed for existing projects in the area, or for other purposes by engineers for developers or by State or local development agencies also can be useful.

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CHAPTER 3

Selected Practices for Control, Construction Activities

In order to minimize the generation of nonpoint source pollutants resulting from construction activities and prevent the transport of these materials from site areas, Best Management Practices must be selected in accordance with specific natural conditions occurring in the vicinity. They include:

- o Physical and chemical characteristics of soils and geologic materials
- o Topography
- o Intensity, duration, and frequency of precipitation
- o Time distribution of annual precipitation
- o Prevailing wind direction and velocity
- o Expected runoff quantities, peaks, and velocities
- o Occurrence and character of ground water
- o Density, gradient, and relationships of surface drainage to the site area
- o Climatic conditions for vegetation development

In addition, the selection of BMP should involve a consideration of the construction activities to be conducted such as the type of construction, time and duration of each activity, and kinds of equipment to be used.

Sediment is the major pollutant resulting from construction, as a result, practices for erosion and sediment control are described in the first portion of this chapter. Other pollutants such as pesticides, nutrients, oils, solid wastes, and similar materials can be controlled, to a large extent, by sediment control measures because they cling to sediments in transit. Additional management practices are needed, however, to make the control more effective. They are discussed under "Good HouseKeeping Practices".

Storm water is not a pollutant by itself. Artificially high peak flows, however, created by impervious surfaces covering the construction area or by drainage structures which increase the velocity of runoff, will generally act as generators of pollution by eroding sediments and other materials from drainageways and stream channels, particulaly downstream from the site area. Best Management Practices to control, or manage storm water runoff are discussed in the section entitled "Storm Water Management".

Control practices can be designed and installed as temporary or permanent measures. Temporary measures are those that are used to correct detrimental conditions that: develop during construction activities, were not predicted during project design, or are temporarily needed to control erosion or sediment problems that occur during construction but are not associated with permanent measures. Permanent measures are those that are intended to remain in place during the life of the project facilities, and are needed where drainage characteristics will be permanently stressed by the completed facility.

Erosion and Sediment Control

Erosion and sediment control practices include providing protective coverings of mulches over bared soils and seeded areas, protecting existing vegetation or reseeding or replanting exposed surfaces; netting over exposed surfaces; controlling the erosive and transport energy of runoff water; and trapping sediments being transported by runoff from the site area. Many management practices devised for water erosion and sediment-control purposes also are useful for control of wind-generated pollutants. Their location and orientation for the latter purpose should be designed on the basis of wind direction and velocity rather than that of surface water flow.

Protecting Exposed Ground Surfaces

Existing natural vegetation should be preserved as much as possible on construction sites, particularly where grading, or soil disturbance is not necessary. If removal of the vegetation is required, only a necessary minimum of soil should be exposed at any one time. If the duration of exposure is extensive and erosion probable, vegetation or some other type of protective covering should be provided and/or sediment control measures installed to prevent the material from leaving the site. Revegetation should be accomplished as quickly as possible following completion of the work item. Regardless of the type of surface covering provided, runoff waters with erosive velocities should be prevented from entering the area at all times.

1. Vegetation

Establishment of vegetation to protect soil surfaces from erosion and reduce the runoff of sediments can either be temporary or permanent. Temporary vegetation should be used to provide control during construction, or until permanent vegetation develops fully. Permanent vegetation stabilizes the site following completion of the construction project. Vegetative soil stabilization should be considered as being an integral part of, and equal in rank to, mechanical structures for erosion and sediment control. Prior to initiating grading operations, plans should be made to preserve as much of the sites existing plant cover as possible. Many times these areas can serve as filter strips or buffers to control sediment runoff. Special care should be taken to protect buffers of natural vegetation along streams and drainages. Topsoil stripped from the ground surface should be stockpiled (and protected from erosion) for future replacement on exposed ground prior to revegetation.

Procedures for establishing vegetation are different in each area of the U. S. (Reference No's. 1 through 16). They depend upon the climatic, hydrologic, soil, slope, and other conditions in the specific area and the type of plants to be used. In general, the site has to be prepared for the seeding or installation of plant stock. This involves protecting the surfaces from erosive effects of rain and runoff, particularly concentrated runoff on steep slopes, and preparing the seedbed. Soil additives such as lime and fertilizers should be applied in accordance with needs as determined by soil tests; recommendations provided by local conservation districts, farm advisors, Extension Service, Universities, and landscape architects; or data presented in erosion and sediment control guidebooks, handbooks, or standards and specifications which cover the site area (Reference No's 1 through 12, and 16).

Maintenance of established vegetative cover is particularly important for effective control. Many "domesticated" types of vegetation, particularly grasses and legumes, need considerable maintenance and can be forced out by native vegetation if this maintenance is not regular. In many cases, however, if it provides adequate ground cover and prevent erosion, native vegetation may be found to be the more desirable product to use.

Figure 1 - Seeding of temporary, fast growing grasses often is most desirable when final grading cannot be done until a later date. (Reference No. 17).

2. Mulches (organic residues)

Mulching consists of applying plant residues, or other suitable protective materials to the surface of the soil. Organic residues consist of plant residues, wheat or oat straw, hay, or other materials such as wood chips, bark, sawdust, and the like. Production of mulch materials from usable waste products generated during the construction activities should be encouraged as these materials would otherwise have to be disposed of elsewhere. Mulches can be used before, during, or after seeding to aid in the establishment of a vegetative cover or to prevent erosion and runoff of sediments, reduce soil compaction and surface crusting, conserve soil moisture, and minimize temperature changes in ground surfaces. They can also be used without seeding to temporarily protect exposed and erodible soils from erosion and sediment losses.

Quantities of mulch applied should be based upon the results desired and the characteristics of the materials used. Smothering of potential vegetation should be avoided but enough mulch used to prevent erosion and loss of sediment from the area. Generally, it is applied with power equipment such as "hydro-mulcher" and anchored to prevent removal by water or wind. Anchoring is done by "tacking" with asphalt emulsions, chemical mulches covering with netting, using a serrated straight disc to punch it into the soil surface, or some other means. Since the environmental effects on water quality of asphalts and inorganic chemical mulches are generally unknown, physical binders are preferred.

Figure 2 - After seeding and fertilizing, the slope was mulched and covered with netting (Reference No. 16).

3. <u>Pervious Blankets, Nets and Similar Protective Materials</u>

These materials are used to provide protective coverings in critical areas which are highly susceptible to erosive processes due to erodible soils, steep slopes or concentrated runoff water. They include excelsior blankets; fiber glass matting; fiber glass "angel hair" which is dispensed and spread by compressed air; jute netting; and biodegradable sheet paper products, with or without reinforcing for strength. Extreme care should be taken that none of these products contain exotic pollutants of some sort.

These products are generally used to provide temporary protection of the underlying soils while a more permanent protective cover of permanent vegetation is developing. As their cost is generally higher than mulching, their use is most justifiable where steep slopes and erodible soils exist or where runoff water concentrates such as in swales, waterways, ditches, and the like.

Application of the pervious blankets, nets, and other materials will depend on the conditions in the area to be protected, characteristics of the materials to be used, and future activities to be conducted at the site. The manufacturers of these materials generally provide information applicable for proper installation procedures; and they usually make technical representatives available for consultation regarding problem conditions.

Being extremely flexible, pervious blankets and nets generally conform well to irregularities in the ground and restrict movement of runoff water. Some method of fastening these materials to the ground, such as stapling, is usually required. When materials come in rolls, overlap of adjacent materials is necessary. As a result, the direction of water flow must be carefully considered prior to installation. In general, blankets should be installed so that the up-slope layer overlaps the downslope layer. In swales, or ditches, the material is generally unrolled from the top of the channel in a downstream direction, with overlaps parallel to the channel (Figure 3). On steep cut or fill slopes, the material is unrolled parallel to the contours with the upslope materials overlapping the downslope layer. The upper ends of blankets and nets should be installed in erosion checks to prevent movement of water beneath the layer and subsequent erosion. Checks involve a technique whereby the porous mat is installed into a slit trench excavated perpendicular to the flow of runoff and then contained by backfill. (See Erosion Check, Figure 14). Information on methods for use in utilizing various types of flexible channel linings; including vegetation and riprap is presented in Reference No. 30.

Figure 3 - Jute netting being installed (Reference No. 15)

4. Chemicals

Chemicals used for surface soil protection generally function by infiltrating the ground surfaces and binding particles of soils and other foundation materials into a coherent mass that resists erosion and reduces water evaporation losses. In addition, these chemicals may be used as tack material to bind organic mulch residues into a coherent protective blanket.

Chemical soil binders are used primarily to protect exposed soils from wind and water erosion during delays in construction activities, during hot and dry periods after final grading, or until permanent seeding is possible. As tacks to bind mulch materials, chemicals are more rapid curing than asphalts. This makes them particularly useful in land development projects where tracking of sticky asphalt into homes can create problems.

Many chemical soil binders can be applied with garden-type hand sprayers, hydroseeders, or other types of equipment (Reference No. 15). They generally are mixed in a water solution and can be applied with seed and fertilizer. Numerous dilution ratios and application rates have been developed by manufacturers of these chemicals for use with different soil types and textures. In general, the greater the percentage of water, the deeper the penetration of the solution into the soil and the weaker the binding strength. The soil characteristics must be evaluated carefully to determine the proper dilution ratio to achieve adequate depth of penetration of the material and effective binding strength.

According to their manufacturers, the chemicals used for surface protection are nontoxic to humans and animals and generally nonflammable. Additional information is needed, however, to determine their toxicity with regard to fish and aquatic organisms. Technical representatives from the manufacturing firms will provide consultation for treating specific problem areas.

Controlling The Erosion and Transport Capacity of Runoff Water

Runoff water moves over denuded surfaces of construction sites as sheet flow or as concentrated flow in rills and gulleys. It is dynamic in that it has energy to erode as well as transport sediment particles. If the available energy in the moving water is greater than that required to transport the sediment it has entrained, erosion of the underlying material will occur. If the sediment load is greater than the transport capacity under the existing conditions, deposition will take place and continue until a balance between energy available and sediment load is achieved. Controlling runoff water in construction areas is essential to prevent the generation and transport of sediments which can pollute downstream areas.

Structures, with or without the use of vegetation, have been devised to reduce or prevent excessive erosion and even to induce sediment deposition, by preventing runoff water from reaching erosive or transport velocities. They intercept, divert, and dissipate the energy of runoff; reduce hydraulic gradients; prevent concentration of flows; retard and filter runoff; and contain concentrated flows in nonerodible channels.

Structural measures used to accomplish these tasks include diversion structures such as dikes and ditches, waterways, level spreaders, downdrains, check dams or flow barriers, filter berms, and inlets; and grade stabilization structures. These measures can be temporary or permanent. Temporary control measures are used to correct detrimental conditions in a site area that develop during construction operations; were not predicted during project design, or are needed to control erosion and sediment that become problems during construction but are not associated with permanent measures. Permanent measures are intended to remain in place during the life of the project facilities.

A formal design is generally required only for permanent erosion and sediment control structures. The expected life of the structures, the estimated maintenance requirements, the potential hazard from failure, and other factors should be used to determine the design of erosion and sediment control structures. Rainfall and runoff frequencies, are important when analyzing the size and desired control characteristics of both temporary and permanent structures. Minimum capacity for structures should be that required to control the peak runoff calculated to result from the selected design storm. For example, a 100 year frequency storm would not be considered appropriate for the design of a temporary measure intended for use only during the short construction life of a small project. This would be "over designing" and impractical.

1. <u>Dikes, or Berms, and Ditches</u> - Dikes and berms are different terms used for diversion structures, linear ridges built of compacted earth or other materials. They may be temporary or permanent. Ditches and dikes are used conjunctively with one another, or independently, to intercept and direct runoff, to prevent the concentration of water, reduce slope lengths so that runoff velocities are reduced, and move water to stable outlets at nonerosive velocities (See Figures 4 and 5). As the length of a slope increases, the quantity and velocity of runoff water it collects increases. The effects of these factors on erosion of materials on the slope can be controlled through the use of dikes, berms, and ditches which break up the intensity of the slopes.

The number of structures needed on any construction project and their size and spacing depend on the land slope, soil types, and runnoff rate. Runoff from the areas immediately upslope from the project site must be considered in their design. They should have sufficient capacity to convey, or store, the peak runoff to be expected from a storm

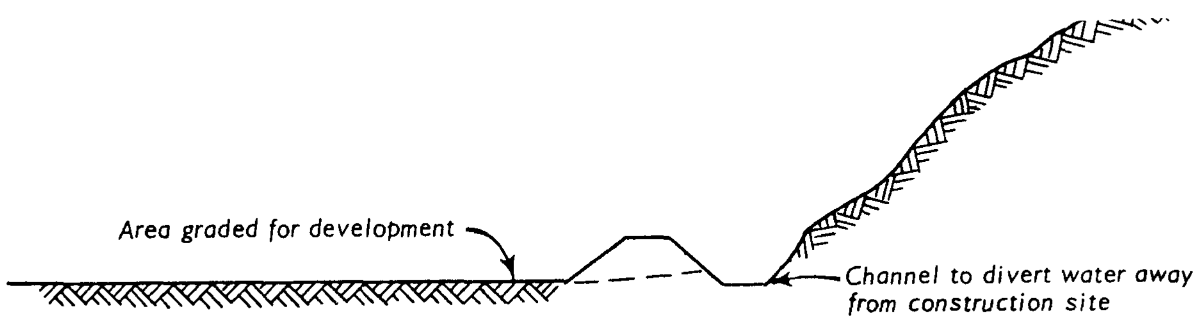


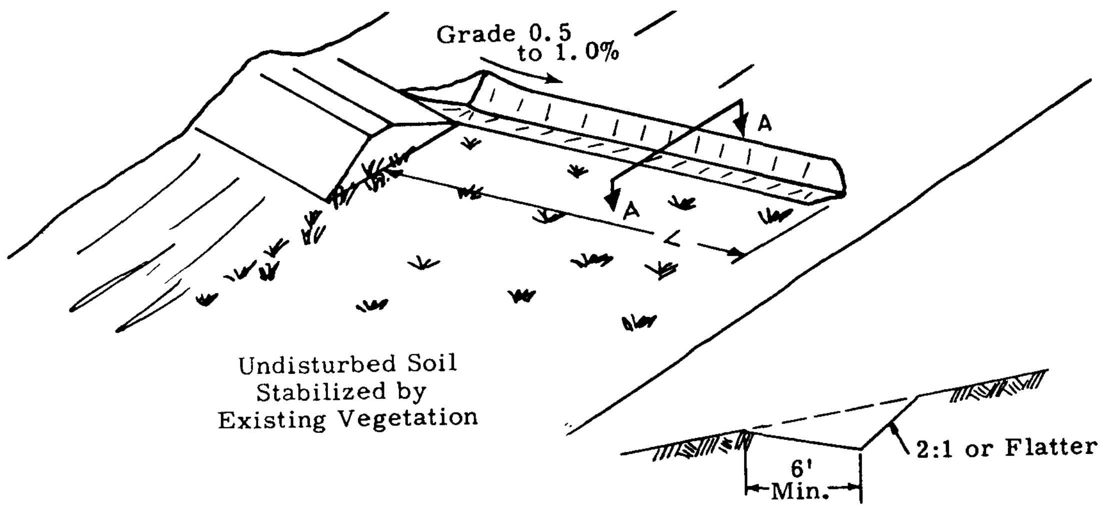
Figure 4 - Diversions should also be constructed across graded areas to shorten slopes and reduce erosion on the sloping areas. (Reference No. 2)

Figure 5 - Small Diversions. If both lip and bed are constructed at zero grade, these diversions would be level spreaders. (Reference No. 18)

frequency consistent with the hazard deemed acceptable by the control agency. Most organizations involved with sediment control require these type of structures to be designed for the peak flow to be expected from a storm of at least a 10 year frequency and 24 hour duration (See References). Where structures are to be permanent, and schools, dwellings, or commercial buildings, etc. are to be protected, the storm frequency period often is lengthened consistent with the hazards from overtopping or structural failure. Similarly, if the structures are temporary, with an extremely short expected, life a shorter frequency may be considered practical for design purposes.

All structures composed of erodible materials should be protected by establishing a vegetative or other type of cover; and maintenance should be conducted periodically to ensure that they perform up to design capacities and are not damaged. This may involve removing sediment accumulations, repairing eroded or overtopped sections, or even revegetating where needed. Berms and dikes paralleling natural drainages and streams should be constructed so as to protect the natural qualities of the watercourse from degradation by runoff from the site. Runoff should be diverted by such techniques into holding ponds for settling or other water treatment before discharging into the stream.

2. Level Spreaders - Level spreaders are outlet structures provided at the downstream end of diversions to dispose of concentrated runoff as sheet flow at non-erosive velocities into stabilized areas (See Figure No. 6). They are constructed on undisturbed ground and where the area directly downslope from the horizontal discharge lip is stabilized by existing vegetation. Water must not be permitted to concentrate below the discharge area.



Note: Drawing not to scale.

Figure 7 - Level Spreader (Reference No. 15).

Most authorities do not specify formal design, however, they suggest the spreader length be determined in accordance with the estimated discharge from a 10 year storm. The following table presents information for selecting appropriate spreade lengths.

DESIGNED Q (CFS)	MINIMUM LENGTH ("L" IN FEET)
Up to 10	15
10 to 20	20
20 to 30	26
30 to 40	36
40 to 50	44

TABLE 1 (From Reference No. 1)

3. Downdrains - Downdrains can be of the flexible, or rigid, sectional type (Figures 7 and 8). They are used to convey storm runoff from the top

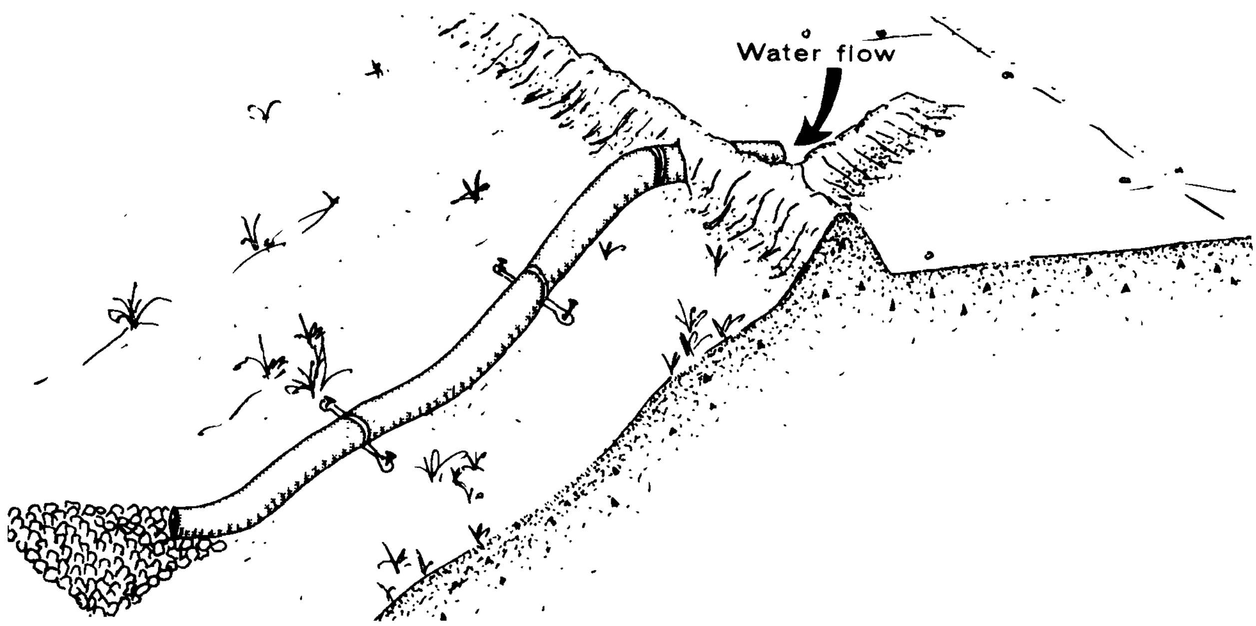


Figure 7. Temporary, flexible slope drain. Discharges on gravel energy

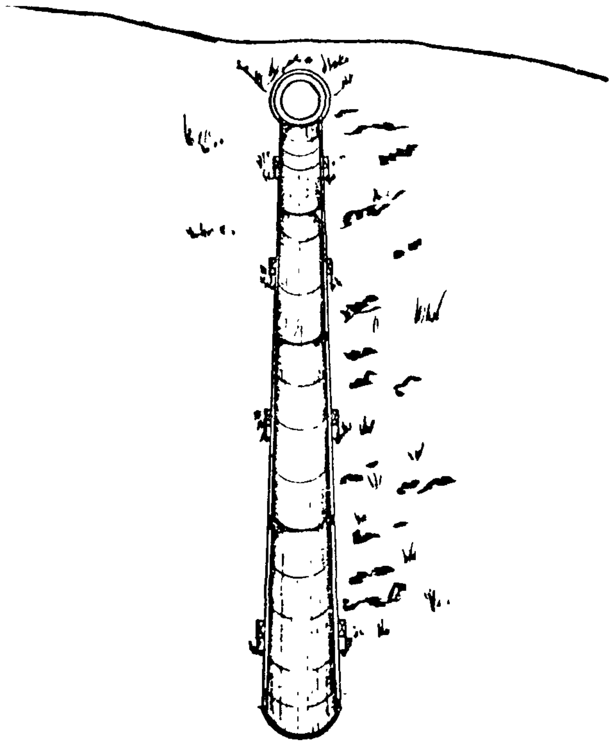


Figure 8 - Sectional Downdrain (Reference No. 18).

of a slope to the bottom without causing erosion. Flexible downdrains, consisting of conduits of heavy-duty fabric or other materials, may be used as temporary or interim structures to prevent erosion of slopes. Sectional units also may be for temporary use. They are prefabricated half-round, or third-round pipe, corrugated metal, concrete, asbestos cement, and other materials.

Formal design is generally not needed for these temporary structures, however, they should have sufficient capacity to convey the maximum quantity of runoff expected during their period of use.

Care must be taken that discharges from these types of structures do not create additional erosion problems at their downslope ends. Generally some type of energy dissipator will be required such as riprap, rock rubble mound, or even a designed structure. The disposal area downstream from the energy dissipator should be well protected and the surface soil stabilized by vegetative cover.

4. Chutes and Flumes - These structures are rigid channels constructed of concrete, asphalt, or comparable materials and used to conduct runoff downslope from one elevation to another without causing erosion. They can be installed as temporary or permanent structures (See Figure 9 and Reference Nos. 2, 15, and 17).

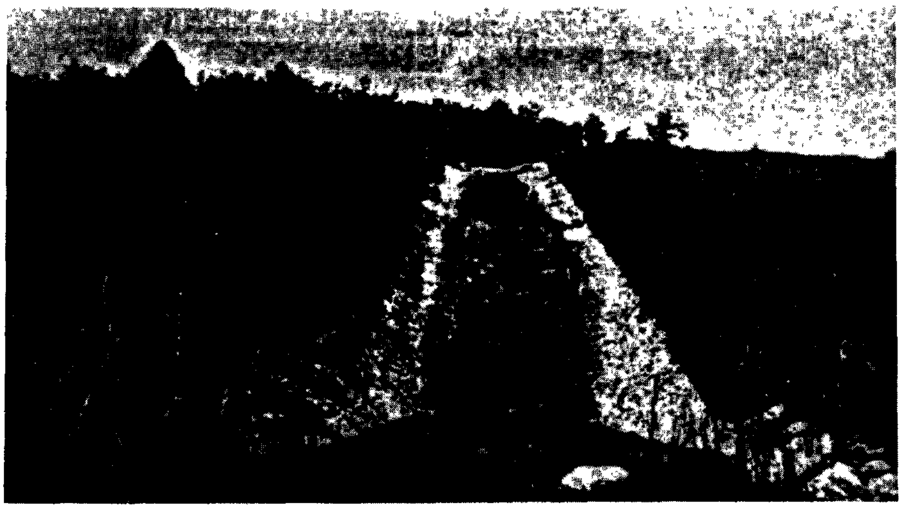


Figure 9 - Temporary flume made of concrete (Reference No. 14).

Chutes and flumes should not be used on slopes steeper than 1.5:1 (34 degrees) or flatter than 20:1 (3 degrees). The underlying foundation must be either firm undisturbed material or well-compacted fill. The rigid lining should be fairly dense, free of voids, and relatively smooth surfaced. Design criteria for areas in the eastern U.S. are presented in References No. 1 and 7 for information purposes. Essentially they divide the structures into two groups, based upon dike height at the structure's entrance, the depth of flow down the chute, and the length of inlet and outlet sections as follows:

Size Group A

1. The height of the dike at the entrance (H) equals 1.5 feet.
2. The depth of flow down the chute (d) equals 8 inches.
3. The length of the inlet and outlet sections (L) equals 5 feet.

Size Group B

1. The height of the dike at the entrance (H) equals 2 feet.

2. The depth of flow down the chute (d) equals 10 inches.

3. The length of the inlet and outlet sections (L) equals 6 feet.

Each size group has various bottom widths and allowable drainage areas as shown on the following table:

Size 1/	Bottom Width, b, ft.	Maximum Drainage Area acres	Size 1/	Bottom Width, b, ft.	Maximum Drainage Area acres
A-2	2	5	B-4	4	14
A-4	4	8	B-6	6	20
A-6	6	11	B-8	8	25
A-8	8	14	B-10	10	31
A-10	10	18	B-12	12	36

1/ The size is designated with a letter and a number, such as A-6 which means a chute or flume in Size Group A with a 6-foot bottom width.

If a minimum of 75% of the drainage area will have a good grass or woodland cover throughout the life of the structure, the drainage areas listed above may be increased by 50%. If a minimum of 75% of the drainage area will have a good mulch cover throughout the life of the structure, the drainage areas listed above may be increased by 25%.

These structures in all areas of the country should be designed based upon runoff flows to be expected at the frequency inteval selected. Care must be exercised in their construction, as well as their design, as overtopping by flows, differential settlement of foundation materials, or opening of construction joints may cause failure.

As in downdrains, chutes and flumes will require some sort of energy-dissipating device incorporated into their lower, or outlet, section at the bottom of the slope being protected.

5. Waterways or Outlets These structures are wide, shallow natural or constructed channels which are shaped, graded, and vegetated for the purpose of conveying and disposing of excess runoff without causing

erosion or flooding (See Figure No. 10). Many authorites design them to accomodate the expected runoff from a storm of selected frequency (generally a 10 year frequency, 24 hour duration storm) without damaging the channel or its lining (References 1, 2, 5 and 7). Design may include structural measures to keep runoff velocities below erosive limits, protective vegetative coverings, or some type of lining, to prevent erosion. The success of a waterway depends upon it having a stabilized outlet area. If this has not been provided, failure could occur, with erosion progressing, in a headward direction up the waterway.

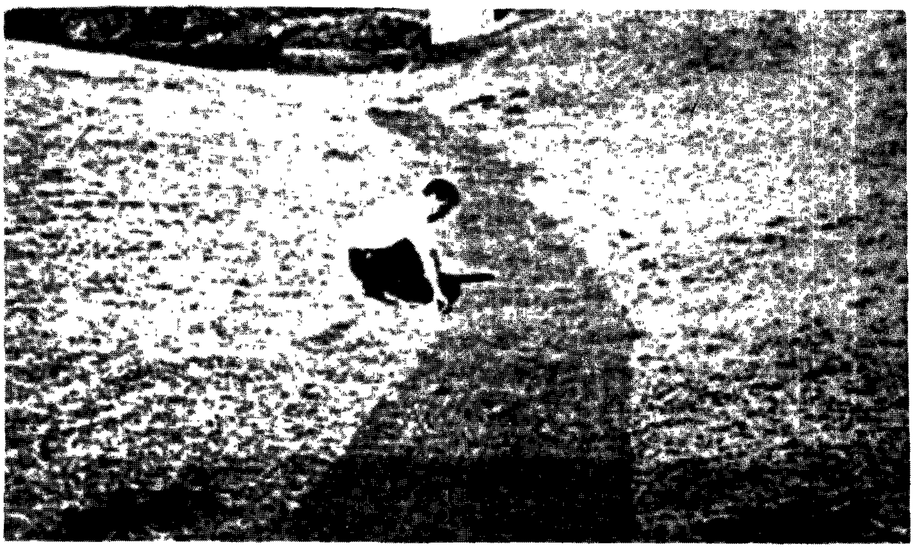


Figure 11 - Jute Netting Over Straw Mulch in Waterway (Reference No. 15).

6. Grade Stabilization Structures - These structures are provided to reduce the slope of natural or artificial channels. They prevent concentrated runoff from reaching excessive (erosive) velocities and prevent headward erosion (upward advance) of channels. Generally, they are permanent and expensive structures and should be used only where vegetative, diversion, or other types of measures cannot prevent concentrated water from reaching

high enough velocities to cause erosion. Grade control structures include check dams, drop structures, and erosion stops.

A. Check dams generally also provide partially-lined channel sections and overfall structures of concrete, wood, rock, and other materials. They protect channel surfaces and reduce flow velocities below that required to erode (See Figure No. 11). They should be situated in a fairly straight section of a channel, after careful consideration of site conditions. Generally, a formal design is required.

Figure 11 - Rock Check Dams (Reference No. 18).

B. Drop, or overfall, structures are made of rock, concrete, metal or treated wood while pipe-drop facilities are usually constructed of metal or pre-cast material (See Figures 12 and 13). Suitable inlet and outlet facilities are normally required for each structure unless foundation conditions dictate otherwise; and channel protection, through linings or other means, is essential.

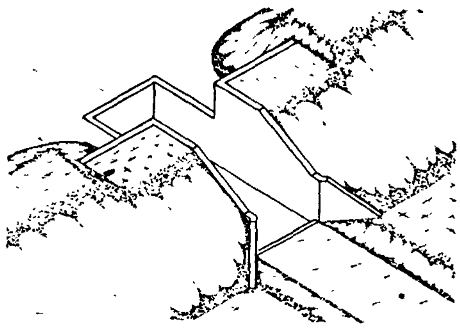


Figure 12 - Box Inlet Grade Control Structure (After Reference No. 13).

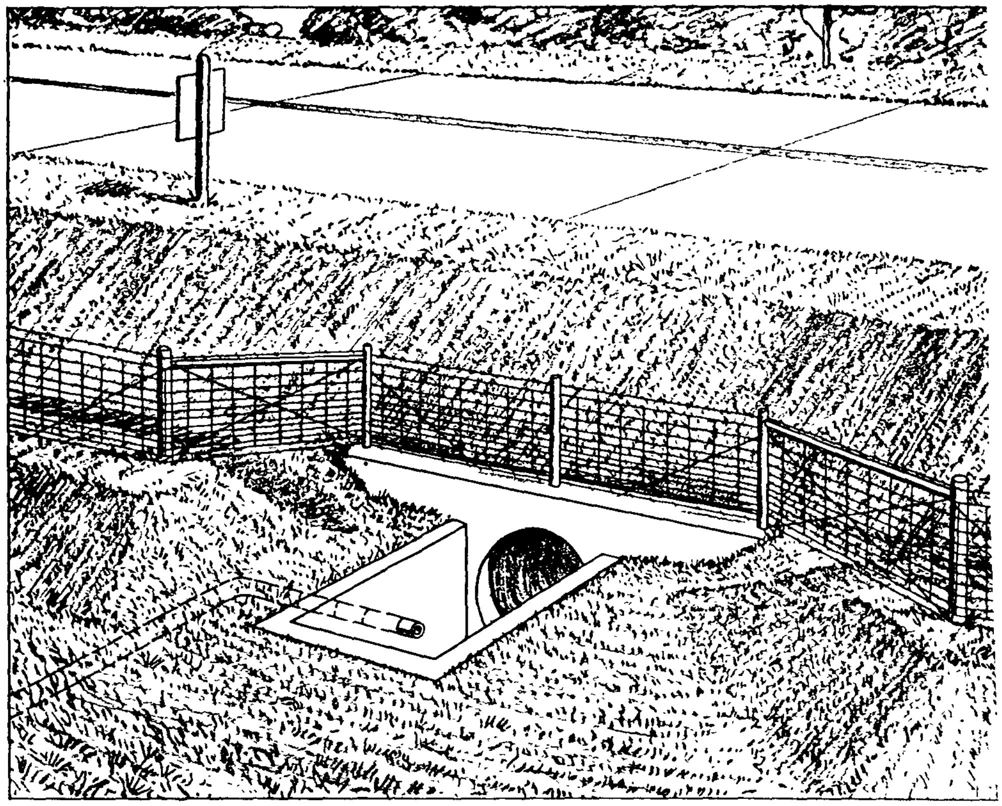
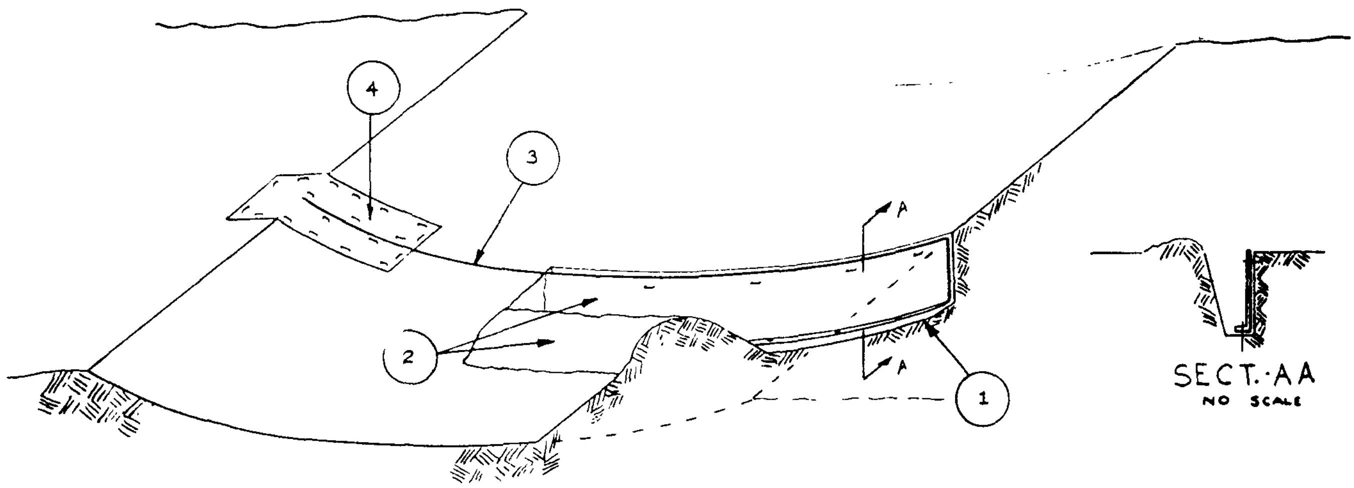


Figure 13 - Drop Box Structure Combined With Culvert (After Reference No. 13).

C. Erosion checks, or stops, are measures used to prevent channel erosion through the installation of non-erodible materials, into a trench oriented normal to the flow of water (See Figure 14). They can be installed in channels and swales or on extremely erodible slopes. Depths should be below the estimated depth of possible erosion or, to 12 inches. The check should extend laterally above water surface expected from design storms for the facility being protected.



1. Cutaway of fiber glass installation in bottom of trench.
2. Cutaway of fiber glass installation in trench with spoil pile.
3. Trench with fiber glass erosion check installed.
4. Cap strip of blanketing material over completed erosion check.

Figure 14 - Erosion check (Reference No. 15).

Trapping Sediments

Structures used to trap sediments are developed principally to stop the movement of materials being transported by runoff water and prevent them from leaving the site area. They consist of filter berms, sandbag or straw-bale barriers, filter inlets, culvert risers, sediment detention basins, and similar facilities. Many other structures and vegetative measures also act, to a limited extent, as partial sediment traps.

1. Filter Berms - Filter berms usually consist of pervious barriers composed of gravel, crushed rock, or similar materials. They temporarily detain runoff water to allow sediment to deposit and act as a filters, permitting water to move through them but not the sediment being transported (See Figure 15). Formal design is not required but pervious gravelly materials must be sized so that sediments do not pass through the berm too readily.

Figure 15. Filter berm (Reference No. 18)

2. Sandbag or Straw-Bale Barriers - These temporary structures may be used independently as control structures or in conjunction with filter berms. They can act as diversion or detention facilities and used to protect other structures, such as inlets from sediment, laden flows. Water passes through straw bales as well as the sand and gravel filter-berm spillways, but the sedimen is retained (See Figure 16 and 17).

They are used to detain sediments resulting from small drainage areas in the order of 1/2 acre in size. The bales must be securely staked and preferably bound with wire rather than twine. Water must not be allowed to escape freely under the bales.

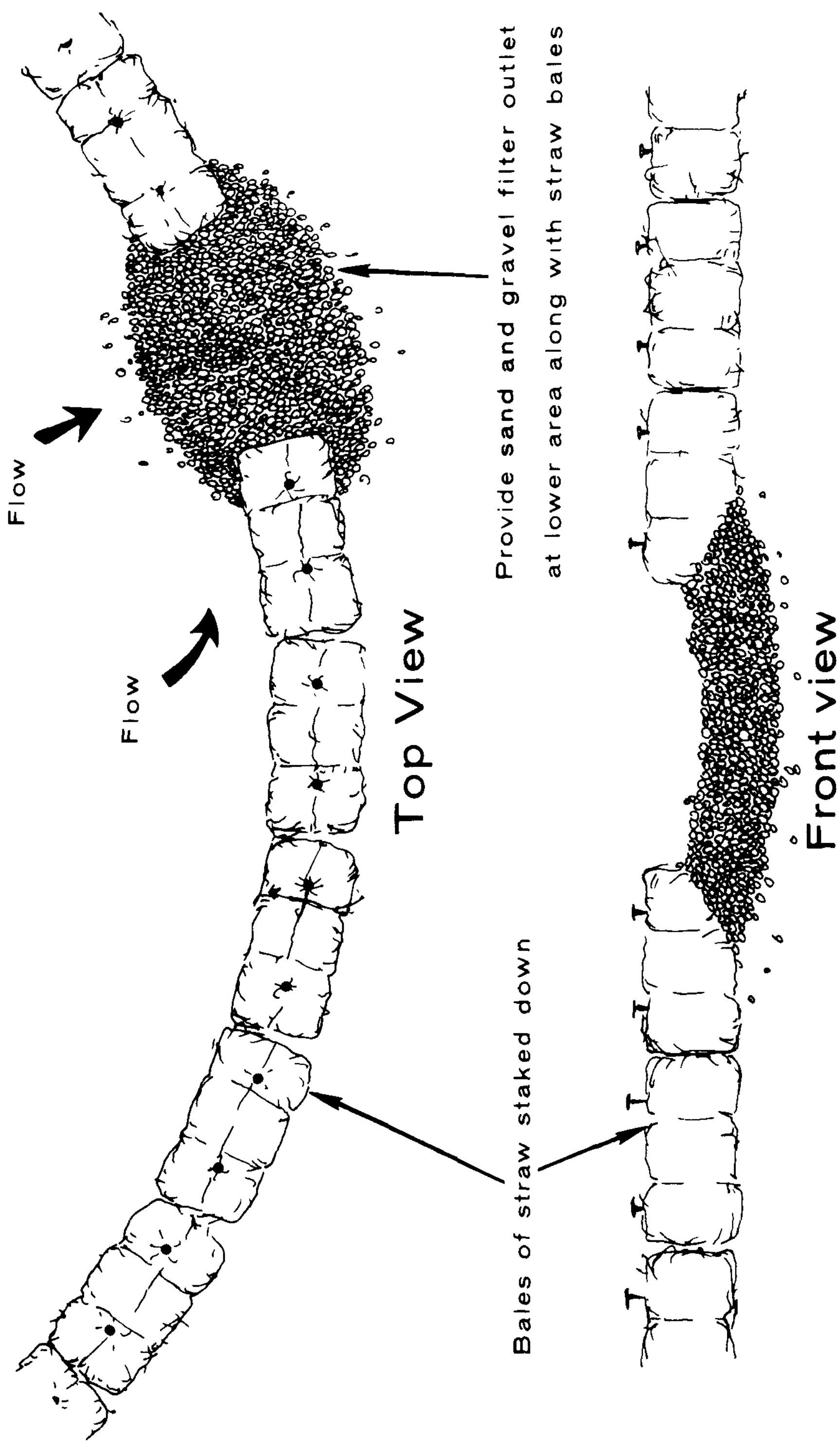


Figure 16 - Semi-pervious barrier of hay bales with more pervious embankment of sand and gravel for spillway (Reference No. 17).

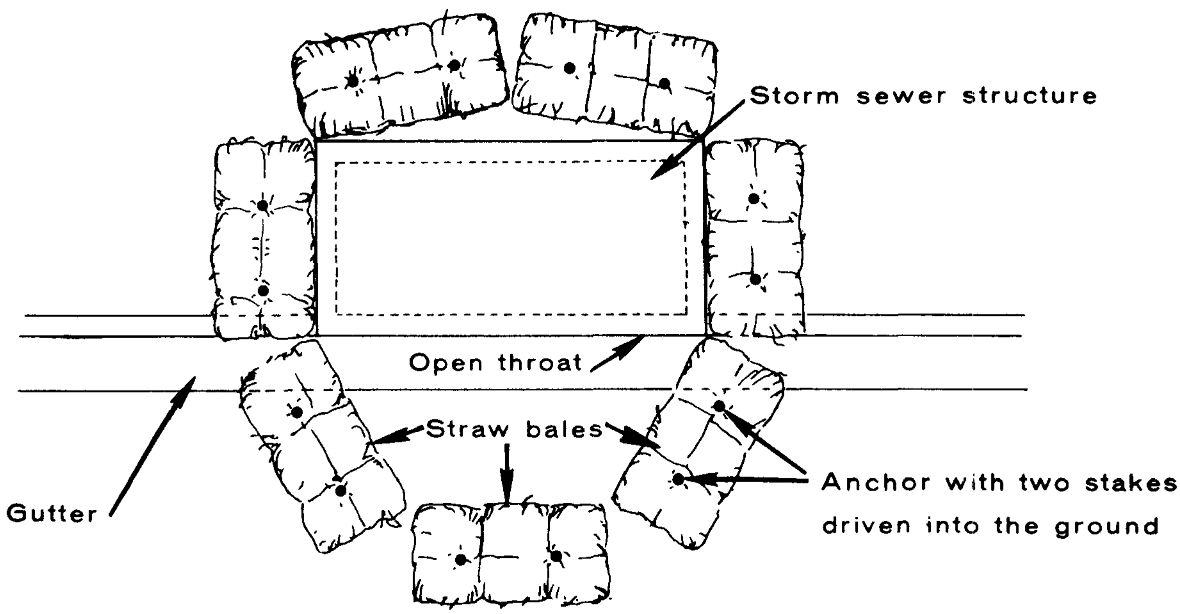


Figure 17 - Temporary Barrier of Hay Bales to Prevent Sediment-Laden Water From Entering Storm Sewer (Reference No. 17).

3. Culvert Risers - Culvert risers are upward-extending, often perforated pipes forming the intake area of culverts. Their purpose is to pond runoff water temporarily and enable its sediment load to settle out. Gravel filters may be used around perforated pipe sections. Their function and design are similar to that for sediment basin outlet works (principal spillways).

4. Sediment Detention Basins - A sediment detention basin (sometimes referred to as a debris basin) probably can be considered as the "last line of defense" in a system of Best Management Practices developed to prevent runoff of sediments from a construction site. Probably the most expensive and precisely-designed structures used for sediment control purposes, they may be installed as temporary structures or as permanent facilities used to provide storage of water for aesthetic and other useful purposes. The design used must reflect the intended use of a detention basin.

Sediment detention basins usually consist of small compacted earth-fill dams, reservoirs which may be partly excavated to provide embankment materials, uncontrolled outlet pipe (or spillways) and emergency spillways (See Reference Nos. 14 and 15). This latter spillway is usually cut into undisturbed materials around the end of the embankment. It is unlined but vegetated to prevent erosion. Sometimes a lined over-pour spillway is used over the top of a small dam embankment. The lining of this latter spillway must be well-designed to prevent lining failure and a possible dam failure also.

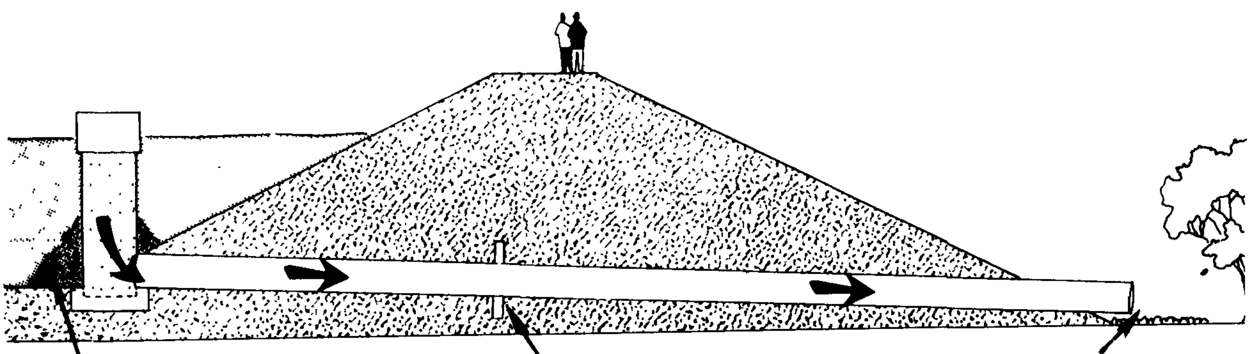


Figure 18 - Large, Well-Engineered Sediment Basin Dam. Note Principal Spillway Pipe with Riser, Gravel Core Filter, and Seepage-path Cut-off Collars on Outlet (Reference No. 17).

Most existing sediment control guidelines, handbooks, and other such documents require that detention basins be designed to store 0.5 inches of water from the watershed (67 cubic yards/acre) and that they be cleaned out when storage is decreased, by sediment deposits, to 0.2 watershed inches (27 cubic yards/acre) as measured to the crest of the emergency spillway, or pipe spillway crest if there is no emergency structure. (Reference No's. 2, 4, 7 and 15). In addition, they provide for principal (pipe) spillways to

Figure 19 - Sediment retention structure - small, less than 1/4 acre (Reference No. 15).

handle at least 5 inches of runoff from the drainage area in 24 hours and emergency spillways to pass the peak runoff from a 10 year 24 hour storm (less reduction in flow due to pipe spillway). Drainages more than 20 acres in size generally are designed for a 25 year frequency storm. Maximum allowable flow velocity in vegetated unlined emergency spillway channels is 6 feet per second (See Table 1). These design concepts are based on "rule of thumb" storage capacity for sediments and dam safety. They certainly are important factors, and must be considered in the design; however, they do not fully result in the achievement of adequate sediment detention.

Since the main purpose of a sediment detention basin is to temporarily detain, or store, runoff water long enough for sediment particles which are being transported to settle out at their natural settling rate, this must be the principal factor in the design. Fine-grained materials such as silts and clays, which settle out at extremely slow velocities, are extremely difficult to trap in most of the presently-designed basins. As a result, considerable effort must be made to design the facilities to trap materials of these sizes. If it cannot be done, flocculation or some other technique may be required. Flocculation involves causing the aggregation of these fine-grained materials through the use of chemical or other materials.

In order to trap sediments of a certain size, a detention basin must detain runoff water long enough for these materials to settle to the bottom of the basin naturally. Table 2 gives settling velocities for various sediment sizes. A detention reservoir should be large enough (in area),

TABLE 2 (From Reference No. 20)

Settling Velocities of Selected Particles

Kind of Material	Particle Diameter (microns)	Settling Velocity (cm/sec)
Coarse sand	1000	10.0
Coarse sand	200	2.1
Fine sand	100	0.8
Fine sand	60	0.38
Fine sand	40	0.21
Silt	10	0.015
Coarse clay	1	0.00015
Fine clay	0.1	0.0000015

to enable sediment-laden inflow water to be diffused and dispersed so that it must move vertically to gain access to the outlet. Design of this outlet is critical and perforated, easily accessible structures such as that shown in Figure 18 are not desirable unless sediment is extremely coarse-grained. This design facilitates "short circuiting" of the flow path and enables currents to transport sediment loads directly through the reservoir and into the outlet facilities without dispersion.

The area of the detention reservoir and its depth are the critical factors for design purposes. Increases in the surface area of a correctly designed reservoir will result in decreases in the velocity of the sediment-laden water as it moves upward and into the pipe outlet, or spillway (See Figure 20, and Reference No. 20). The area required to trap each size sediment particle can be determined by the following formula:

$$A \text{ (area in square feet)} = \frac{Q \text{ (pond outflow rate, in cubic feet per second)}}{V_u \text{ (upflow velocity, in cubic feet per second)}}$$

If the settling velocity of a particle of given size (V_s) is greater than V_u, the velocity of the upward-flowing water, deposition of all particles of this size and larger will settle to the bottom and be trapped. Smaller-sized materials will pass through the outlet and spillway and escape. Table 3 presents minimum reservoir surface area required to trap various sediment sizes.

TABLE 3

Minimum Area for Sediment Detention Basin
To Trap Sediment Particles (1 cubic foot/second outflow)

Kind of Material	Particle Diameter (microns)	Minimum Area Required (sq ft)
Coarse sand	1,000 (1mm)	3.0
Coarse sand	200	14.5
Fine sand	100	38.2
Fine sand	60	80.0
Fine sand	40	145.0
Silt	10	2,030.0
Coarse clay	1	203,000.0 (4.66 acres)
Fine clay	0.1	20,300,000.0 (466 acres)

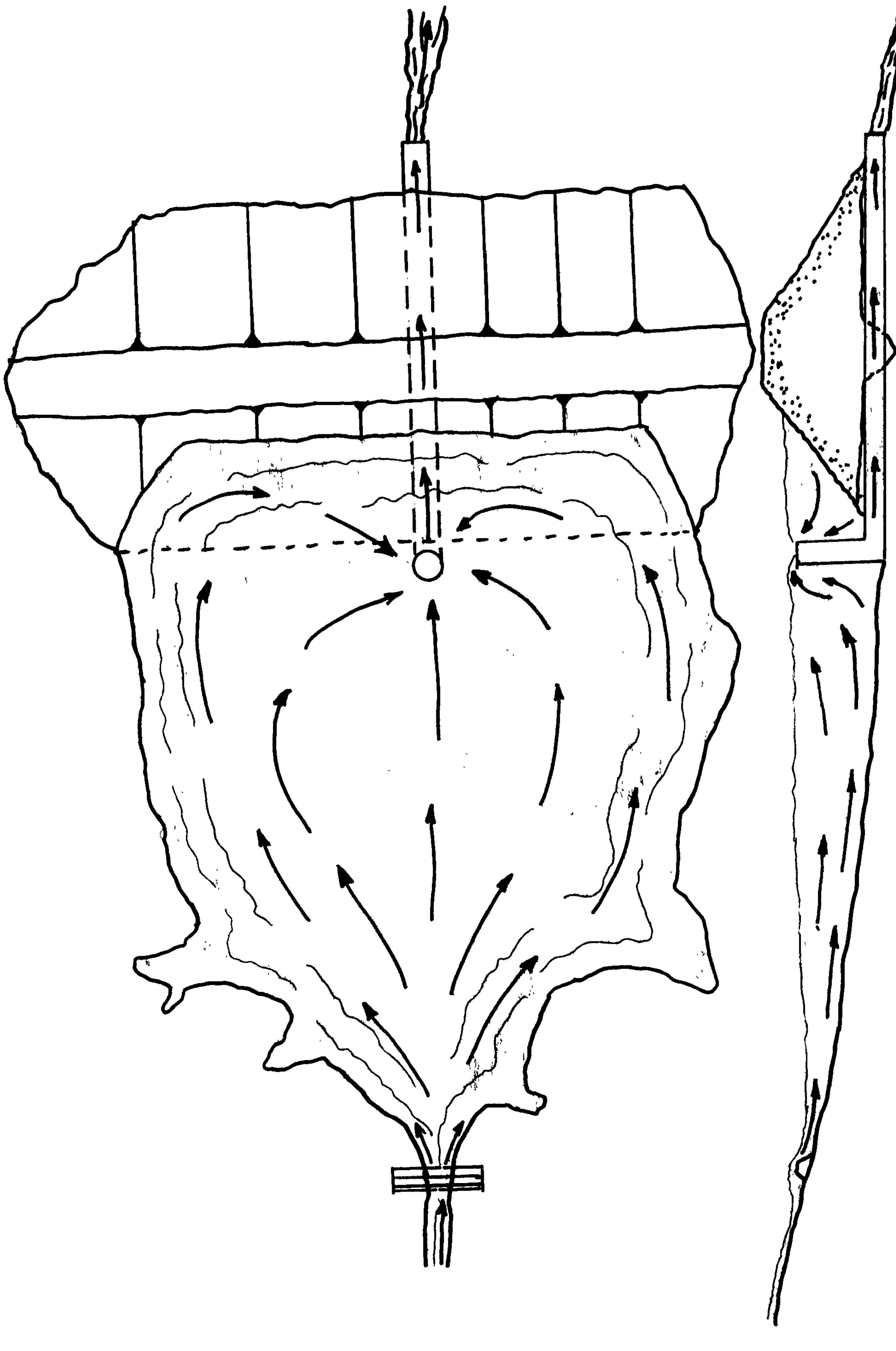


Figure 20 - Theoretical Movement of Sediment Through Properly Designed Basin

Depth of the reservoir is important to provide storage for adequate quantities of sediment and still maintain dispersion of inflow and upward movement into discharge facilities. Detention time should be determined at the point that sediment storage has reached its maximum and no "short circuiting" has occurred. In this way the reservoir is designed for maximum efficiency. Periodic sediment removal will maintain this storage volume and is required for good operations. Sediments should not be disposed of in an area where they will create additional pollution problems.

The shape of the reservoir and design of its headwater, or inlet, area are important in preventing short circuiting of flows. If concentrated, high-velocity currents enter the reservoir without being dispersed and their velocities decreased, they will not only continue transporting their sediment loads through to the outlet areas but may stir up and erode deposits that had already been trapped on the reservoir bottom. Multiple inlets, level spreaders or weirs of some type, and even baffles may be devised for use in dispersing the inflow and reducing its velocities.

Principal outlets, or spillways, are also important for good sediment trapping efficiences. Multiple spillway intakes, trough-type outlets, or even syphon-type structures will prevent concentration of flow and the accompanying high velocities which may again place sediment back into transport. A standpipe full of perforations such as that in Figure 18 is a poorly-designed facility because it results in short circuiting. Unless the gravel envelope is a well-graded filter, sediment will be able to move through it easily and downstream. If the envelope is clogged, concentration of flow into the remaining section may occur causing bottom scour and additional sediment entrainment and loss.

For outflow rates above one cubic foot per second, the minimum area shown in Table 3 must be increased equivalently. For example, in order to trap a coarse sand with a particle size of 200 microns, and an outflow rate of 3 cubic feet per second, the reservoir area should be 14.5 square feet x 3 cfs = 43.5 square feet (See Table 3).

Additional guidance for design, construction, and maintenance of sediment basins is presented in references listed at the end of this chapter. It involves principally factors for structural safety, good construction practices, and location and capacity of overflows structures, not sediment detention capacity. In many states, the larger-sized sediment detention dams and reservoirs may fall within the jurisdiction of a dam safety organization. These organizations have mandatory criteria for minimum spillway capacity. design and construction procedures, seismic coefficients, and the like.

Good Housekeeping Practices

Good erosion and sediment control, in conjunction with management of stormwater runoff, will prevent the movement of many pollutants other than sediments. Those pollutants that are in solution; however, or are carried on fine-grained sediments, may pass through all sediment control measures and reach downstream water bodies. Materials, such as pesticides, petrochemicals, and fertilizers are nearly impossible to control once they are present in the runoff water. The only practical control options available are either to provide expensive water treatment facilities on stormwater detention basins or preferably to prevent these pollutants from reaching runoff waters through the use of proper application techniques and "best housekeeping practices".

Pesticides

Use of many insecticides, herbicides, and rodenticides is restricted by Federal, State, or local regulations. In order to limit the possibility of these materials creating detrimental environmental effects as a result of construction activities, strict adherence to recommended practices is required. Application rates should conform to registered label directions, and application equipment cleaned after use, or properly disposed of (Reference No's. 21, 22, and 23). All pesticides are listed in issues of the "EPA Compendium of Registered Pesticides", which can be obtained from the Superintendant of Documents, U. S. Government Printing Office. This document provides information on dosage and application rates, tolerances, formulations, use limitations, and the pests controlled. Supplements to the Compendium are issued periodically. Similar data can be obtained from each State's Cooperative Extension Service.

Pesticide storage areas should be protected from the weather and from public contact. Areas that have been recently treated with particularly potent pesticides should be clearly marked to warn trespassers or unwary persons.

Time of pesticide application is of particular importance in preventing runoff of pesticides from the site area as pesticide losses occur principally when high-intensity rainfall occurs shortly after application. Also chemicals should not be applied during periods of weather extremes such as freezing conditions when the chemicals will not be absorbed, thus assuring their eventual runoff. Often, more pesticide quantity is contained in solution in runoff water than attached to sediment particles because the volume of water that runs off is much greater than the volume of sediment lost. The concentration of pesticide carried by the sediments is much greater, however, and subsequent pollutional impacts may occur when the sediments are deposited in the bottom of a water body. (See Reference No. 24).

Petrochemicals

Control of petrochemical runoff, such as oils, gasolines, and greases involves mainly sediment control as these materials adhere to, or coat, sediment particles. Additional measures include proper collection and disposal of the waste products, prevention of oil leaks, and proper maintenance of equipment. Used oils and greases and rags and papers impregnated with this material should be disposed of in proper receptables and kept out of contact with rainfall or runoff water. Dumping of waste materials at the construction site should be prohibited. Liquid and solid wastes should be collected in containers and regularly transported from the site to sanitary landfills. When machinery is to be maintained, lubricated, or repaired on site, it can be placed upon a pad of absorbent material to intercept and contain leaks, spills, or small discharges. Equipment washing should be undertaken at specified locations and the runoff collected in holding ponds. In no case should any of these latter operations be conducted closely adjacent to a stream or water body.

Fertilizers

Inorganic nutrient pollution is derived principally from fertilizers used to develop adequate vegetation on exposed ground surfaces. Effective sediment control measures and stormwater management practices as well as good vegetative cultivation practices are useful for controlling fertilizer losses. Proper timing of fertilizer applications to avoid bad weather, harsh seasonal weather extremes, and to pinpoint periods of optimun plant generation, and provisions for working these and other materials into the soils at the required depth will do much to minimize runoff of pollutants.

More efficient use of fertilizers may be achieved, and loss of nutrients reduced, by applying the required quantity in several rather than one application. Evaluating essential fertilizer and other additive requirements from actual soil test in the site area is essential to ensure that only optimum quantities are applied. This alone should reduce the possibility of material losses.

Solid Waste

The major mechanism for control of solid wastes such as residues from trees and shrub generated during land clearing; wood and paper from packaged supplies; and scrap metals, sanitary wastes, rubber, plastic, glass fragments, and the like resulting from normal day-to-day operations, is the provision of adequate and effective disposal facilities. These wastes should be removed from the site frequently and transported to authorized and suitable disposal sites. Inert materials which do not leach and cause groundwater problems may be used effectively to refill borrow pits or other excavated areas. The same material can be considered for use in road fills or fills for other facilities. Trees and other vegetation may be chipped up and used on site areas as inexpensive and convenient mulch materials. Any solid wastes trapped in sediment detention basins should be removed as quickly as possible. Adherence to State and local anti-litter ordinances should be enforced with regard to construction personnel, site visitors, and others. If no violation of air pollution requirements is involved, inflammable wastes may be burned. Reference Nos. 25 through 28 will provide information on air and solid waste requirements.

Storm Water Management

Storm water management involves controlling the rate of storm water runoff from construction sites. It must consider control of storm water during the life of facilities being constructed as well as during the construction period itself.

In past periods, the philosophy for storm water control was to route it through areas as quickly as possible. Under this concept, areas downstream from the sites had to accept the brunt of accelerated and increased peak storm runoff. Flooding, excess channel erosion, and other damaging effects resulted.

The present concept of storm water management is to reduce and delay runoff water peak discharges. Management may be achieved by increasing infiltration in the drainage area to reduce the amount of precipitation that actually becomes runoff, increasing time of runoff concentration by accentuating the meandering of drainageways to reduce gradients and runoff velocities, and providing temporary storage facilities to release the stored water at controlled rates.

Increasing Infiltration of Runoff

Methods used to increase infiltration of runoff into soils and other subsurface materials have been used for a number of years in parking areas. They involve periodic perforation of lawns, development of subsurface facilities, and the provision of porous pavement materials. Extreme infiltration care must be used with regard to the quality of water being infiltrated as it is possible to create a groundwater pollution problem with the resolution of a surface water pollution problem.

Periodic perforation of golf course fairways has been used for quite some time to increase infiltration and aeration. This same process will help increase infiltration of storm water in vegetated areas of construction sites. In addition to reducing runoff, the practice should accelerate movement of fertilizers into the subsoil and provide for better vegetative growth.

Infiltration facilities may involve wells or excavations which have been backfilled with pervious materials. Their purpose is to provide vertical, highly-pervious conduits through which surface waters can gain access to permeable subsurface strata. If these strata contain usable ground water supplies, the infiltrating water must not be poor enough in quality to degrade them. These types of infiltration systems have been used in areas of suburban development and along highways to accommodate excess runoff.

Porous pavements are used principally in parking areas of shopping centers. They consist of irregularly-shaped aggregate precoated with asphalt binder. Water can move vertically through this layer into an underlying lower level of compacted gravels and then, if conditions are favorable, into underlying natural foundation materials. Favorable conditions are situations where existing ground water bodies will not be degraded by infiltration of poor quality runoff. If ground water pollution is possibly a problem, porous pavement facilities can still be used for storm water management if designed properly. This design could involve construction of a clay blanket or some other inpervious material below the compacted gravel layer. Infiltrating water would then have to slowly move laterally through the gravel and, after a delayed period of time, be discharged into a storage basin where it can be treated and released.

Altering Time of Runoff Concentration

This aspect of storm water management should focus on the conservation and use of existing natural drainageways. Conditions to avoid are long, narrow, V-shaped channels with steep gradients. as they tend to promote concentration of flow with accompanying high erosion hazard if the channels are not adequately lined. The discharge end, where gradients decrease, can create severe problems with respect to erosion if an effective energy-dissipation structure is not provided.

To effectively decrease time of runoff concentration, wide, meandering, vegetated channels with gentle gradients and side slopes are required. Velocities in major channels of this type should be less than 5 feet per second with side slopes of less than 3 to 1. Curves, or bends should be gentle with radii not less than 100 feet (Reference No. 29). Increasing the time of concentration by reducing the runoff velocities in channels also acts to increase infiltration as the runoff has longer contact with the ground surface. Small check dams can be placed in the vegetated drainage channels, or swales, to reduce runoff velocities, provide short-term minor storage, and increase infiltration.

Providing Temporary Surface Storage

Almost all measures used to prevent erosion and sediment losses on construction sites also function to control the runoff of storm water. Probably the principal storm water management technique available, however, involves temporarily storing surface water runoff and releasing it at a predetermined decreased rate. Consideration of the runoff characteristics in the entire basin must be made as improper releases of stored water could cause increased rather than decreased flows in downstream areas. In addition, in some channels, moderate downstream flows maintained for longer periods of time may cause more problems than the peak flows themselves.

Storage can be provided on rooftops and in subsurface holding structures or temporary or permanent surface impoundments. These surface impoundments may be in or near drainageways or even constructed in parking lots or other facilities.

Rooftop storage can be achieved on relatively flat roofs by limiting the release of precipitation which falls on the roof. Control is through specially-constructed roof drains which cause the water to be ponded to a particular level and release it at a reduced rate (See Figure 21). Flow from the roof occurs through small holes or slots in the drains. Water released should be spread, if possible over vegetated areas, to provide for infiltration.

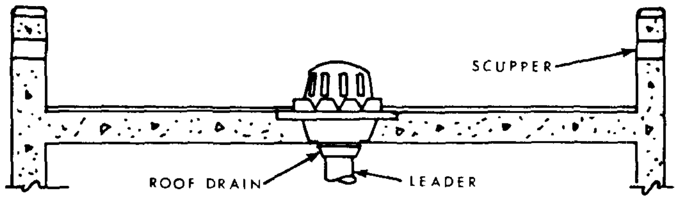


Figure 21 - Typical Roof System Illustrating Controlled Release Roof Drain and Overflow Scupper (After Refernce 24).

Most buildings will structurally support a water load of approximately 3 inches, however, water-proofing techniques may have to be up-graded to prevent leakage.

Subsurface storage of storm water runoff can be obtained in metal or concrete tanks placed below ground level. Their inflow capacity to accept runoff flows is designed to be much greater than their capacity to release water, as a result, they provide temporary storage. Subsurface storage facilities generally are used in expensive developments, such as shopping centers, where there may be little available area for surface storage. Intake and outlet structures and devices should be provided with screens and have easy access for maintenance to prevent clogging.

Surface impoundments can be designed to provide for permanent or temporary reservoirs which contain water only during periods of excess runoff. Permanent impoundments provide an aesthetically- pleasing urban environment as well as flood-detention storage for attenuating peak runoff flows. The creation of permanent water storage areas, the "blue-green" development concept, can be highly beneficial to a community. They are generally developed through the construction of a small dam, with necessary appurtenant structures such as spillway, outlets, and the like, across a drainageway. The permanent water level of such reservoirs is designed to be several feet below emergency spillway crest. Reservoir volume above this elevation accommodates flood storage to attenuate peak runoff flows. An outlet with a valve should be provided to facilitate reservoir drainage when repair or maintenance of the structure is required.

Temporary reservoir storage in "dry" impoundments stores water only during flood events. They are dry during the remainder of the time. These reservoirs are created by some type of permanent water-detaining structure or embankment. Outlet facilities, however, are ungated (no valve). As a result, runoff which enters the reservoir at a high rate is immediately free to discharge at a pre-designed lesser rate. This reduces peak runoff to prevent or reduce downstream flooding, channel erosion, and other problems. Since the same quantity of water must be released, longer periods of moderate flows will occur in downstream channels. Dry impoundments, or reservoirs, can be developed in any area that is topographically depressed, whether due to natural or man-made conditions. Parking lots, tennis courts, playgrounds, and other areas can be used to provide temporary storage facilities for runoff if adequate outlet facilities can be installed. (See Figure No. 22).

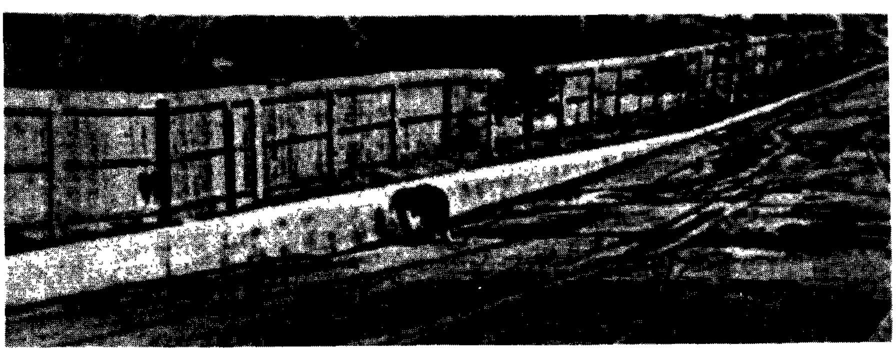


Figure 22 - Storm Water Detention Storage Structure in Lower Portion of Parking Lot (Reference No. 14).

Off-stream impoundment of storm water runoff may be created adjacent to existing stream channels or drainageways. A diversion embankment is often used to divert water into a selected area during high flows. When flood-levels decrease, the diverted water drains back into the main channel at a decreased rate. Use of side-channel storage areas in flood plain areas often is an inexpensive way of achieving effective storm water control.

Systems Approach to Sediment Control

Rarely will single erosion or sediment control measures be effective enough to achieve desired results. Generally, several different measures are provided as first, second, third, and even more "lines of defense". This is termed the "systems approach" to sediment control. For example, on a construction site, the area of exposed soils may be limited. Then vegetation may be required on all areas which are left exposed more than a certain length of time. In addition, various structures may be required to protect the ground surface from rain and runoff water, control the energy in runoff, and filter or trap sediments being transported. All of these measures are included within the total system which is devised to prevent loss of sediments from the site area.

The lack of reliable effectiveness factors hampers the optimization of erosion and sediment control systems development. The effectiveness of some individual measures in these systems may be found in published literature, however, information on the various combinations in the system is limited. In addition, most effectiveness factors have been developed for agricultural practices and should not be assumed to be equivalent to those used on construction sites.

A method to determine the effectiveness of a system of control measures has been obtained from References 18 and 31, "Comparative Costs of Erosion and Sediment Control, Construction Activities", and "An Economic Analysis of Erosion and Sediment Control Methods for Watersheds Undergoing Urbanization". This method involves a comparison of the soil losses from a construction site without control measures with that from a site with measures installed. All other factors in the site area remain the same.

The various individual measures are viewed as cropping-management (C) and conservation practices (P) factors for reducing soil losses. Thus, the soil loss (A') from a given construction site having erosion and sediment control treatments can be computed by the universal soil loss equation:

$$A' = RLSKCP \qquad (1)$$

If the same construction site was denuded and employed no erosion and sediment control treatments, the soil loss (A'') would be:

$$A'' = RLSK \qquad (2)$$

<u>since the factor C and P values equal 1.0</u>. Values for RLSK are equivalent in Equations (1) and (2) since the same construction site is used for both equations. The soil retained on the construction site, because erosion and sediment control treatments were employed, is computed by:

$$\text{soil retained} = A'' - A' \qquad (3)$$

Therefore, the effectiveness percent of the treatments in retaining soil on the construction site is:

$$\%\ \text{Effectiveness} = \frac{A'' - A'}{A''} \times 100$$

$$= \frac{RLSK - RLSKCP}{RLSK} \times 100$$

$$= (1 - CP) \times 100 \qquad (4)$$

Equation (4) can now be used to compute effectiveness for the various erosion and sediment control alternatives, providing Factor C and P values are assigned for the individual treatment comprising a particular system.

Published Factor C (conservation) values need to be adjusted for urbanizing areas because stabilized surfaces are disturbed by construction traffic. Two assumed construction conditions have been considered:

(1) Construction is completed within 18 months following initial groundbreaking.

(2) When building is started six months after seeding, then construction is completed within 24 months.

It is further assumed that three months of the 18- or the 24- month construction periods are consumed by grading operations, and that construction sites are without surface protection during this time.

Factor C values change with time following surface treatment. For example, Factor C values for grass decrease from 1.0 to about 0.01 between seeding and when the grass is reasonably well established. For construction sites, Factor C values are assumed altered additionally by urban development activities.

A typical example of estimating average Factor C value for seed, fertilizer and straw mulch is as follows, after Reference No. 18:

Months	Representative Factor C Value	Fraction of Construction Period	Product
0-3*	1.00	3/18	0.167
3-6	0.35	3/18	0.058
6-18	0.19	12/18	0.127

Average Factor C value for 18-month period = 0.352

*During 0-3 months, Factor C value is 1.0 because the construction area has no surface stabilizing treatment.

Table 4 lists the average values of Factor C for various surface stabilizing treatments from (Reference No. 18) and Table 5 lists additional erosion-reducing values for more specific ground cover.

TABLE 4

AVERAGE FACTOR C VALUES FOR VARIOUS SURFACE STABILIZING TREATMENTS (REFERENCE NO. 18)

Treatmemt	None*	Factor C Values for Time Elapsed Between Seeding and Building 6 Months **
Seed, fertilizer and straw mulch. Straw disked or treated with asphalt or chemical straw tack.	0.35	0.23
Seed and fertilizer	0.64	0.54
Chemicals (providing 3 months protection)	0.89	--
Seed and fertilizer with chemicals (providing 3 months protection)	0.52	0.38
Chemical (providing 12 months protection)	0.56	--
Seed and fertilizer with chemical (12 months protection)	0.38	--

* Assumes 18 month construction period.
** Assumes 24 month construction period.

TABLE 5

EFFECTIVENESS OF GROUND COVER ON EROSION LOSS AT CONSTRUCTION SITES (REFERENCE NO. 18)

Kinds of Ground Cover	Soil Loss Reduction Related to Bare Surfaces (Percent Effectiveness)
*Seedlings	
Permanent Grasses	99
Ryegrass (Perennial)	95
Ryegrass (Annual)	90
Small Grain	95
Millet and Sudangrass	95
Field Bromegrass	97
Grass Sod	99
Hay (2 Tons per Ac)	98
Small Grain Straw (2 Tons per Ac)	98
Corn Residues (4 Tons per Ac)	98
Wood Chips (6 Tons per Ac)	94
** Wood Cellulose Fiber (2-3/4 Tons per Ac)	90
** Fiberglass (1,000 Lbs per Ac)	95
Asphalt Emulsion (125 Gal per Ac)	98

* Based on full established stand

** Experimental - not fully validated

Structures used in the various control systems are considered as requiring Factor P values to describe their efficiency (Reference No..31). These components include small sediment basins, erosion reducing structures, and downstream sediment basins with or without the use of chemical flocculants. Diversion structures, grade stabilization measures and level spreaders are collectively considered as erosion reducing structures. The practice factor P reflects the runoff and erosion-reducing effects of structures. The effectiveness of terraces and diversions, which reduce effective slope lengths and runoff concentration should be similar on construction sites and farmlands (See Reference No. 32).

Small Sediment Basins - The conventional method employs small sediment basins having inflow (cubic feet per second) to area (square feet) ratios of 0.03 to 0.04, with an average trap efficiency of 70 percent. Thus, if the sediment basin collects sediments coming from only 70 percent of the construction area then its Factor P value is about (1.00 - 70%) x 70% = 0.50. On the other hand, if it collects sediments from 100 percent of the construction area then its Factor P value is (1.00 - 70%) x 100%) = 0.30 (See Table 6).

Downstream Sediment Basins - The larger size basin constructed downstream of the construction site, and having inflow to area ratios of 0.06 to 0.07, will have a trap efficiency of 80 percent, thus the corresponding Factor P value is 0.20. Chemical flocculants may be added to this downstream basin to cause more efficient settling of incoming sediment. Such chemicals are assumed to increase the trap efficiency of this basin 90 percent, giving a Factor P value of 0.10.

<u>Erosion-Reducing Structures</u> - Diversion berms, sodded ditches, interceptor berms, grade stabilization structures and level spreaders are collectively referred to as one system called "erosion-reducing structures". The overall effectiveness of erosion reducing structures is estimated at 50 percent. The Factor P value for this normal usage is then 0.50. For higher usage, the erosion reducing structures are estimated to be 60 percent effective, giving a Factor P value of 0.40 for this case.

Factor P values for these systems are summarized in Table 6 and discussed below.

In using these Factor P values to estimate effectiveness of the erosion and sediment control alternatives, it is assumed that 100 percent of the sediment not caught by the surface stabilization treatments and/or erosion reducing structures is delivered to the sediment basins.

TABLE 6

FACTOR P VALUES FOR COMPONENTS OF EROSION AND SEDIMENT CONTROL SYSTEMS (REFERENCE NO'S 18 and 31)

Component	Factor P Value
Small sediment basin: (0.04 ratio)	
Sediment from 70% construction area	0.50
Sediment from 100% construction area	0.30
Downstream sediment basin: (0.06 ratio)	
With chemical flocculants	0.10
Without chemical flocculants	0.20
Erosion reducing structures:	
Normal rate usage (165 ft per ac)	0.50
High rate usage (over 165 ft per ac)	0.40

The effectiveness of various erosion and sediment control systems is computed and listed in Table 7, using the equation:

$$\text{Percent Effectiveness} = (1 - CP) \times 100$$

Factors C and P are taken from Tables 4 and 6, respectively.

Factor P values are multiplied if a particular erosion and sediment control alternative has two or more components represented by a Factor P. An example of this calculation is shown using the conventional method of erosion and sediment control.

Conventional Method	Factor C or P Value
Sediment basin (.04)	0.50
Erosion reducing structures (normal)	0.50
Seed, fertilizer and straw mulch	0.35

Percent Effectiveness = 1-(0.35 x 0.50) x 100 = 91.25 percent.

TABLE 7

PROMISING CONTROL SYSTEM AND EFFECTIVENESS

(AFTER REFERENCE NO. 18)

System Numbers	Components	Percent Effectiveness
1	Seed, fertilizer, straw mulch. Erosion structures (normal). Sediment basins (0.04 ratio, and 70 percent of area)	91
2	Same as (1) except chemical (12 months protection) replaces straw.	90
3	Same as (1) except chemical straw tack replaces asphalt.	91
4	Seed, fertilizer, straw mulch. Diversion berms. Sediment basins (0.04 ratio, and 100 percent area)	90
5	Seed, fertilizer, straw mulch. Downstream sediment basin (0.06 ratio).	93
6	Seed, fertilizer, chemical (12 months protection). Downstream sediment basin (0.06 ratio).	92
7	Seed, fertilizer, straw mulch. Downstream sediment basin using flocculants.	96
8	Same as (7) without straw mulch.	94
9	Chemical (12 months protection) sediment basin using flocculants.	94
10	Same as (9) with seed, fertilizer.	96

Selected References

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CHAPTER 4

Methodology for Assessment of Potential Pollution Problems and Their Magnitude

This chapter will discuss methods that have been developed to predict approximate magnitude of nonpoint source pollution that could occur if an area is to be subjected to construction activities in the future and no control is provided. Methods provide approximations only and should be used only with extreme caution by professionals that are competent in their use.

Certain areas are so sensitive to environmental change that alternative locations for the proposed construction activity should be utilized. Potential problems created by areas where combinations of long, steep slopes highly unstable soils exist, extremely sensitive or high-quality water bodies occur immediately downstream, or geologic instability is suspected can be avoided by providing for less intensive use. These areas can act as buffers to retain sediment and other pollutants before they reach water bodies.

Construction activities involve a broad range of projects. They maybe located in, or extend across, areas with drastically different site conditions. Projects can include land developments which involve construction of housing, schools, shopping centers, office buildings, and commercial facilities; transportation and communications networks such as highways, roads, railroads, and bridges; energy facilities which include power plants, dams, and their appurtenant transmission lines; water development structures such as dams, aqueducts, canals, and flood-control measures; and recreation projects including ski facilities, campgrounds, parking and other multiple use developments. The assessment of potential pollution problems which may result from these types of projects can involve an entire drainage area where development seems imminent, and yet no project or development plans have been prepared, or a proposed individual site where complete plans including information on existing and proposed conditions are readily available

In order to assess the potential of a proposed construction project, or many projects, in an area to generate nonpoint source pollutants and release them into downstream areas, all available pertinent information must be obtained concerning the type of construction activities to be conducted and the local site conditions. Information on each construction activity should include whether or not the ground surface is to be disturbed, the areal extent and nature of materials disturbed, the kind of equipment, materials, and number of people involved, and the scheduling of events. Data on site conditions necessary for the assessment of the nonpoint source pollution potential include information on the proximity of projects to surface water bodies; surface and subsurface drainage aspects; topographic, geologic, and soils characteristics, extent of vegetative cover in the area; and the climatic effects. Chapter 1 provides sources for obtaining this data and emphasizes that the generation and runoff of pollution from construction sites are strongly dependent on climatic and other conditions which are dynamic and generally highly variable.

Pollutants To Be Considered

Nonpoint source pollutants resulting from construction activities are discussed in some detail in Chapter 1; as a result, they will only be summarized here. Excessive sediment is the principal pollutant with others being chemical petroleum products, biological materials, pesticides, metals, soil additives and miscellaneous wastes. Independently, or in combination with one another, they may have detrimental effects on biota existing in our nation's waters, the regimen of drainage systems, and water uses.

Sediments are generated by erosion of ground surfaces that have been disturbed by construction activities and possibly stripped of their protective

Solid wastes should be collected at the site and removed for disposal in authorized disposal areas. Frequent garbage removal is essential. Often, borrow pits, or excavations can be filled with inert solid wastes. Such pits should be located away from slopes, drainages, and ground water recharge areas.

Runoff of construction chemicals resulting from paints, cleaning solvents, concrete curing compounds, and petroleum products, can be largely restricted by sediment control measures as many of these materials are carried by sediment particles. Good "housekeeping" procedures such as proper disposal of empty containers, prompt cleanup of accidental spills, and neutralization or deactivation of excess chemicals and wash waters should minimize runoff of the remaining materials. Holding ponds should also be used to collect surface runoff of waters containing these chemicals. Biological pollutants from human sources can best be controlled by installing and maintaining portable toilets at construction sites.

Information Sources

Nonpoint source pollution control practices discussed above in summary form are described in more detail in the following publications:

"Processes, Procedures, and Methods to Control Pollution Resulting From All Construction Activity" EPA 430/9-73-007, October 1973.

"Comparative Costs of Erosion and Sediment Control, Construction Activities" EPA 430/9-73-016, July 1973.

"Guidelines for Erosion and Sediment Control Planning and Implementation" EPA R2-72-015, August 1972.

Additional data regarding design of structures, specifications for vegetative practices, instructions for installation of surface protective coverings, and other useful measures are available in numerous published standards and specifications, manuals, handbooks, or guides. They are generally prepared and issued in local areas by States, Counties, or Conservation Districts, with the assistance of the U.S. Soil Conservation Service.

Basis For Best Management-Practices Development

Best Management Practices for construction are the most practical and effective measure or combination of measures which, when applied to the land development or building project, will prevent or reduce the runoff of pollutants.

Since the amount of pollutant runoff from construction sites depends on numerous variables such as the type of construction involved, the quantity and intensity of rainfall, the soil characteristics, etc., it is recognized that those particular types of control measures that will prevent this runoff must be installed on the site. The proper mix of control measures must be established on site-specific basis. Whether they are properly installed and maintained must be checked periodically by on-site inspection as there is no way that effluent monitoring can accomplish this.

Best Management Practices for construction activities consist of measures which will prevent the movement of pollutants from construction sites. While sediment is the principal pollutant resulting from earth-disturbing construction activities, chemicals, hydrocarbons, solid wastes, and other materials must also be considered, as well, in selecting techniques and devising pollution-prevention plans for the construction site.

Description of Preventive and Reduction Measures

There are essentially three basic measures for controlling the runoff of sediment from construction sites. They include (1) preventing erosion of exposed soil surfaces, (2) restricting the transport of eroded particles, and (3) trapping sediments being transported. Measures developed for controlling movement of sediment and other materials by water generally are useful also for controlling that generated by wind action.

Preventing erosion of exposed soil surfaces is achieved by protecting these surfaces with such coverings as mulch; sheets of plastic, fiberglass roving, burlap, rock blankets, or jute netting; temporary growths of fast-growing grasses; or sod blankets. Mulch consists of hay, straw, wood chips, bark, or any other suitable protective material. Sheets of plastic and netting materials are generally used on steep slopes where vegetation is difficult to establish or erosion rapid. Seeding of temporary fast-growing grasses is most desirable when final grading cannot be done until a later date and climatic conditions permit. Sod often is used as a covering in critical areas susceptible to erosion.

Limiting the areal extent of soils disturbed at any one time is a usable mechanism for minimizing erosion. It can be achieved by planning and carrying out the job so that as work progresses existing vegetation is removed only on the area of soil surface essential to immediate work activities. Thus, construction activities are completed on each exposed area and revegetation accomplished as rapidly as feasible.

Soil additives are chemicals and materials that are applied to the soil during construction activities in order to obtain desired soil characteristics. Often construction activities cover large areas consisting of several different types of soils. The nature of soils is dependent on the climatic, topographic and geological conditions. The type of soil additive applied depends on the objectives of the construction activities. Soils may vary from one location to another in the amount of water they contain, particle size distribution (clays, silt, sand and gravel), water infiltration rate, ability to support heavy structures, and resistance to compaction by construction equipment. Soil additives are used to control the amount of moisture absorbed by roadway surfaces, to reduce the degree of shrinking and expanding of clay soils in order to prevent structural damage of buildings and air field runways, and to increase the firmness of soils. Several materials are used to obtain desired soil properties. Commonly used materials include lime, fly ash, asphalt, phosphoric acid, salt, and calcium chloride. The soil additives carried in runoff from construction sites alter, and may seriously affect, the quality of receiving waters. However, little work has been conducted to show the net environmental effects of these soil additives.

Many other chemicals are used in construction for purposes such as: binders for pasting boards together, sealants for cracks, applications for surface treatment, solvents for oils and paints, and dyeing and cleaning compounds. The amounts of chemicals leaving construction sites as pollutants have not been established. Poor construction activities that are liable to contaminate water resources include the following practices: dumping of excess chemicals and wash water into storm water sewers; applications of chemicals in bad weather or severe seasonal conditions such as freezing weather; application of excess quantities of chemicals; indiscriminate discharging of undiluted or unneutralized chemicals; disregard for proper handling procedures resulting in major or minor spills at the construction site; and leaking storage containers and construction equipment.

Miscellaneous pollutants include wash from concrete mixers, acid and alkaline solutions from exposed soil or rock units high in acid, and alkaline-forming natural elements. Cuts through coal beds can result in the seepage of mine acids into streams unless retained in ponds and neutralized before discharge. Areas with high lime content often increase the alkalinity of receiving waters unless neutralization procedures are followed.

3. Biological Materials - Biological pollutants from construction include soil organisms and organisms of human and animal origin. They include bacteria, fungi, and viruses. The majority of biological pollutants are found in the topsoil layer where they can feed on dead plants, animals, birds and other organisms.

The biological pollutants resulting from construction activity indicate that the greatest pollution potential are of animal and human origin. They are more prevalent on construction sites where improper sanitary conditions exist.

filling of watercourses thus increasing the frequency of flooding, increasing turbidity in water and reducing light penetration thus destroying aquatic plants and organisms, increasing the cost of downstream water treatment, damaging fish life covering and destroying organisms on the bottom of streams, reducing the flowing speed and carrying capacity of streams, and impairing operation of drainage ditches, culverts, and bridges, altering the shape and direction of stream channels, destroying water recreational areas, and imparting undesirable taste to water.

2. Chemicals -- The major categories of chemical pollutants are: petroleum products, pesticides, fertilizers, synthetic materials, metals, soil additives, construction chemicals, and miscellaneous wastes from construction.

Some petroleum products impart a persistent odor and taste to water, impairing its use for drinking water and contact sports. Many oils have the ability to block the transfer of air from the atmosphere into water, resulting in the suffocation of aquatic plants, organisms, and fish. Some petroleum products contain quantities of organo-metallic compounds (nickel, vanadium, lead, iron, arsenic) and other impurities which can be toxic to fish and other organisms.

The three most commonly used pesticides at constrution sites are herbicides, insecticides, and rodenticides. The unnecessary or improper application of these pesticides may result in direct contamination of water, or indirect pollution by chemicals clinging or absorbed to sediment or other solid materials which are transported into water.

Nitrogen and phosphorous are the major plant nutrients used for the successful establishment of vegetation on disturbed soils of construction sites. Heavy use, or improper application, of commercial fertilizers can result in these materials reaching water bodies to accelerate the eutrophication process.

The construction industry utilizes many different types of synthetic products. These include structural frames, window panes, wall board, paints, and many others. Heavy duty construction materials are synthesized from nondegradable organic materials. They are little affected by biological or chemical degradation agents, and are usually designed to withstand the most severe physical conditions. However, they can collect in drainages and cause blockages which degrade water course capacities.

The concern over metal pollution of water bodies is associated mostly with the heavy metals (mercury, lead, zinc, silver, cadmium, arsenic, copper, aluminum, iron, etc.). Metals are used extensively in construction activities for structural frames, wiring, ducts, pipes, beams, and many other uses. Construction vehicles, gasoline, paints, pesticides, fungicides, and construction chemicals are also potential sources of heavy metals pollutants. When these latter materials are weathered, decomposed, and disintegrated by various agents, they utlimately form oxides and salts that can harm aquatic organisms and impair water quality.

1. Land Development -- Land Development involves the construction of housing subdivisions, shopping centers, schools, recreation areas, and related facilities. The areal extent of the land affected is generally large although a project may be completed in segments. Topographic slopes are usually gentle with cut and fill sections relatively minor.

2. Transportation and Communication Networks -- Construction of transportation and communication facilities involves disturbance of the land principally in a linear direction. Areas may be quite large but the width of the disturbed areas is minor compared to their linear extent. Where they bisect or parallel water courses they are particular problems especially if located in areas of high relief where slopes may be steep and rugged. Here the prevention of NPS pollution will be challenging. Climatic differences are extremely diverse in many of these areas with torrential rains prevalent in higher altitudes.

3. Water Resource Facilities -- Construction of water resource facilities involves disturbing the ground surface for installation of dams, aqueducts and their appurtenant structures. Dams may be located in relatively steep river valleys or canyons, or in areas of fairly low relief. Aqueducts have a great linear extent and are generally located along valley or foothill areas. Climatic differences at these sites may be extremely variable with intense rainfall occurring in mountain areas.

Dams in higher topographic areas may be underlain by hard, non-erodible bedrock. Dams and aqueducts in lower areas generally are located in erodible soils and/or parent materials.

4. Other -- Construction of factories, major office buildings, airports, power plants, etc., which occur on more restricted surface areas, is included in this subcategory. Except for airports, the areal extent of these facilities is generally limited and almost all require extensive subsurface excavation. They are generally located in areas of fairly low relief with relatively low cut and fill slopes involved.

Identification of Pollutants

Sediment, resulting from erosion or disturbed soils on construction sites, is one of the principal pollutants. It includes solid mineral and organic materials which are transported by runoff water, wind, ice, or the effect of gravity. Chemical pollutants derived from construction activities originate from inorganic and organic sources and occur in solid form such as asphalt, boards, fibers, or metals; or in liquid form such as paints, oils, glues, pesticides, and fertilizers. Biological pollutants include organisms resulting from soils, animal, or human origins. They may be bacteria, fungi, or viruses. High volumes of storm water runoff due to loss of retention capacity on site can cause large quantities of pollution. They result from changed conditions due to construction activities.

1. Sediment -- Sediment exerts physical, chemical and biological effects on the receiving stream and water bodies. Physical damage resulting from sediment deposition includes: reduction of reservoir storage capacity, thus requiring costly dredging or decreasing the life of the project, filling harbors and navigation channels thereby disrupting their functioning,

BEST MANAGEMENT PRACTICES CONSTRUCTION NONPOINT SOURCES WATER POLLUTION

Construction is a broad category covering the alteration and development of land for differing uses including the installation of structures on the land. The types of projects within the category generally have two common characteristics, namely; (1) They involve soil disturbance, resulting in modification of the physical, chemical, and biological properties of the land; and (2) They are short-lived in the sense that the "construction phase" closes when the development and building activities are completed. Stormwater runoff volumes, however, may be permanently increased as a result of the project necessitating permanent structures to prevent future stormwaters from generating NPS pollution.

Introduction

This guidance is intended to provide information regarding management practices for prevention of nonpoint source pollution from construction activities, and to supplement information regarding control of construction associated discharges under the provisions of NPDES and Section 404 of the FWPCA.

Construction activities can result in the development of significant sources of pollutants which may reach surface or ground waters. About one million acres of land are being disturbed for construction purposes each year in the United States. Pollution resulting from these constructionn areas can be catastrophic in downstream areas, particularly in small drainages. This statement is intended to provide guidance in the control of construction nonpoint sources and for the selection of pollution prevention or reduction measures that are useful both preventing deterioration of water quality and achieving and maintaining in water quality goals.

Construction nonpoint sources are the land development and building projects that result in the runoff, seepage or percolation of pollutants to the surface and ground waters. The runoff of pollutants generated by these activities is strongly dependent on climatic events such as rainfall or snowmelt. In general, the runoff is intermittent and does not provide a continuous discharge.

The nature of the pollutants depends on the particular activities underway and the condition of surface areas at the time of the rainfall or snowmelt. Both the nature and amount of pollutants are also dependent on other factors such as soil types, topography, proximity to drainages and watercourses, project characteristics, and the number of people and equipment involved. Appropriate practices can limit or prevent NPS pollution from occurring.

Description of Construction Activities

There are many types of projects that fall within the construction category. They generally can be classified into the following sub-categories:

APPENDIX

19. U.S. Department of the Interior, Geological Survey "Field Methods For Measurement of Fluvial Sediment" Book 3, Chapter C2 of Techniques of Water-Resources Investigations of the United States Geological Survey, 1970.

20. - - - -, "Computations Of Fluvial-Sediment Discharge" Book 3, Chapter C3 of Techniques of Water-Resources Investigations of the United States Geological Survey 1972.

21. U.S. Department of The Interior, Bureau of Reclamation "Design of Small Dams" 1974.

22. U.S. Department of Agriculture, Soil Conservation Service " National Engineering Handbook, Section 3, Sedimentation", April 1971.

23. - - - -, "National Engineering Handbook, Section 4, Hydrology", August 1972.

24. California Department of Transportation, Office of Transportation Laboratory "Methods of Measuring Erosion From Road Slope" Interim Report CA-DOT-TL-7108-6-76-17, January 1976.

25. California Department of Transportation, Office of Transportation Laboratory "Highway Slope Erosion Transect Surveys" CA-DOT-TL-7108-4-74-05, March 1974.

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10. U.S. Environmental Protection Agency, Office of Water Program Operations "Comparative Costs of Erosion and Sediment Control, Construction Activities. EPA-430/9-73-016, July 1973.

11. - - - -, Office of Research and Development "Prediction of Subsoil Erodibility Using Chemical, Mineralogical, and Physical Parameters. Research Project No. 15030 HIX.

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13. State of California, Department of Conservation "Erosion Control Handbook" under preparation

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3. W. H. Wischmeier "Use and Misuse of The Universal Soil Loss Equation" Journal of Soil and Water Conservation. January - February 1976.
4. U. S. Department of Agriculture, Soil Conservation Service "Procedure For Computing Sheet and Rill Erosion On Project Areas" Technical Release No. 51. January 1975.
5. U. S. Water Resources Council, Sedimentation Committee "Proceedings of The Third Federal Inter-Agency Sedimentation Conference 1976" Pages 2-13-2-23, March 23-25, 1976.
6. H. P. Guy and D. E. Jones, Jr. "Urban Sedimentation - - - - In Perspective" Presented at the American Society of Civil Engineer's National Water Resources meeting, Jan. 24-28, 1972.
7. J. K. H. Ateshian "Estimation of Rainfall Erosion Index" American Society of Civil Engineers, Journal of The Irrigation and Drainage Division, September 1974.
8. U. S. Department of Agriculture, Agricultural Research Service "Rainfall-Erosion Losses From Cropland East of The Rocky Mountains" Agricultural Handbook No. 282, May 1965.
9. W. H. Wischmeier and L. D. Meyer "Soil Erodibility on Construction Areas" National Academy of Sciences, Highway Research Board. Special Report No. 135, 1975.

activities. As a result, to predict the potential pollution from future construction activities with any degree of accuracy is impractical. Probably, the most logical way will be to compare the problems that have occurred in the past with those that may occur in the future. This will involve determining if pollutants which caused problems in the past are going to be used in the proposed construction and whether they are to be used under the same conditions. If no changes are to occur, the same problem will recur. If no precautions have been made to prevent spills of petroleum products and other materials; dispose of chemical, solid, chemical, and biological wastes; and require proper dosage of fertilizers, pesticides, and other materials as well as disposal of waste products, pollution will occur in the future as in the past. The magnitude of this pollution will be directly related to the magnitude of pollution-generating activities conducted in the past and that to be done in the future.

during low-flow periods. The sediment concentration is usually computed as the ratio of the weight of sediment to the weight of the water-sediment sample and expressed as parts per million or milligrams per liter. The total quantity of sediment being transported is determined from the sediment-concentration and water discharge data for a given period of time.

Precipitation data can be obtained through the use of recording and non-recording gages. Total precipitation, rainfall intensity, duration, etc. can be determined from the precipitation records or from the sources discussed in Chapter 2 of this guidance document. Rainfall events with very short intensities are usually of interest with regard to construction sites but this data is difficult to obtain.

Information on current and historic construction activities can be obtained from aerial photographs of the drainage area, records of governmental agencies, and/or from actual field observations. It should include data on the areal extent of ground disturbance, scheduling of construction, and other relevant factors which may influence sediment loads in the streams.

Results of study of sediment discharge from streams may also be transferred to adjacent areas to predict, or approximate, sediment discharge from future construction if slopes, soils and geologic conditions, topography, runoff, and other conditions are similar. If conditions are significantly different, techniques are available to correlate significant factors and still make results usable (See Chapter 2 and Reference Nos. 21, 22, and 23).

Assessing Runoff of Pollutants Other Than Sediment

There is little available data on the magnitude of pollution resulting from petroleum products, pesticides, biological materials, soil additives, miscellaneous wastes, and other potential pollutants used during construction

These studies generally involve obtaining streamflow, sediment concentration, precipitation, and construction activity data on the particular drainage basin being surveyed. Data from the sampling program should provide an informational basis for prediction of future events. It should include instantaneous and average characteristics of sediment movement as well as the range, variations, and patterns of fluctuations. Present and future land disturbing activities will determine the optimum distribution of sediment data needed for an area. That portion within the path of possible land development, or other proposed construction, must receive more intensive coverage than that of a more stable area.

Streamflow generally is measured continuously with a water-stage recorder which provides records of the water levels in the stream. These records are used with discharge measurements, to develop a continuous record of the stream discharge in cubic feet per second or some other value. The runoff, which involves the complete regimen of streamflow, may be measured by the number and characteristics of the rises of streamflow. The quantity of sediment being moved is directly related to these water level rises. It involves both suspended and bedload sediment portions. Suspended sediment is those materials suspended, or carried, in the water and bedload include the materials that rolls or slides near the streambed. Suspended sediment loads in streams are computed from measurements obtained with various types of equipment on a continuous basis, during selected levels of streamflow, or at periodic intervals. Bedload quantities may be obtained through the use of bedload samples or from computations based upon the suspended loads and sediment size analysis (Reference No. 21). Since the program involves determining the quantity of sediment moved by the stream it is desirable to sample at short intervals during high flows and longer intervals

Sediment discharge records may be available for streams draining small basins prior to, during, and following construction (Reference Nos. 16, 17, and 18). Assuming precipitation and runoff conditions are similar during all periods, the difference in sediment yields will be due to the ground disturbing construction activities. In the absence of useful records, a sampling program may be developed to provide the needed data. Available data and analyses may be transferable to adjacent drainages to estimate potential losses which could occur there due to construction. Care should be used to ensure that soil, geologic, or other conditions are similar in both areas or that correlation factors to be used are appropriate.

Sediment yield can be defined as the total sediment outflow from a drainage basin, measured at a specific location and in a specified period of time. In general, sediment yield is a function of the storm level, surface conditions, sheet-flow energy level, rill and stream kinetic energy levels, and time varying streambed conditions. The greater the flow of runoff from the basin at any one time, the greater the mass of sediment being transported at any point on the stream. In-stream effects of each, relatively small, construction-related source of sediments are often lost in the mass average statistics of a basin watershed. These sources, however, may be providing 100% of the sediment pollutant load in a small drainage basin.

Many stream sedimentation studies are conducted by the U.S. Geological Survey, in cooperation with other Federal agencies and the States. The results are published for use by concerned organizations. (Reference Nos. 16 and 17). Additional studies are done by other governmental agencies, the States and local organizations. Information on techniques useful for measuring sediment and computations for discharge is also published (Reference Nos. 19 and 20).

The survey involves determining volume of sediment in the reservoir by measuring, from below a bench mark on the dam crest or other appropriate stable point, the upper surface of the sediment deposit that has accumulated since: (1) the previous survey or (2) the reservoir was completed. This can be done by sounding with a line and weight, a sounding pole, or echo-sounding equipment. The original bottom surface of the reservoir can be obtained from as-built dam and reservoir plans. If no plans are available or the lake is natural, the bottom of the reservoir, and sediment thickness can be determined through the use of a sounding pole, an auger, or some other piece of probing equipment. If natural materials underlying the lake bed are of soft consistency, the bottom may be difficult to detect accurately.

Total weight of the sedimentary material deposited can be computed from information involving the dry weight of samples obtained at various depths and the area of the deposits. If historic information is available regarding construction progress, areas of ground exposed to erosion during specific times, and the trapping efficiency of the reservoir, approximations of sediment losses from the sites may be determined. These approximations also may be transferred to similar areas if conditions are similar or correlation factors used

Use of Sediment Data From Stream Sampling

Knowledge concerning effects of man-made changes in drainage basins on the quantity and characteristics of sediment yields in streams is useful to help predict the approximate changes to occur when future basin changes are made. This is particularly true of changes caused by construction activities.

Sediment Yield	Surface Geology	Surface Soil	Area Above Site	Erosion and Deposition
	(10)	(10)	(20)	(20)
High	a-Unconsolidated sedimentary rocks b-Well-weathered rocks of all types c-Unconsolidated volcanic material, landslides, etc.	a-Unconsolidated soil with uniform grain size b-Fine-grained non-cohesive	a-Steep slopes b-Impervious surfaces c-Minor vegetative cover d-Runoff from area above has easy access to site.	a-More than 40% of surface exhibit rills. b-Sediment deltas noted at base of most slopes. c-Drains clogged with sediment. d-Vegetated areas clogged with sediment on upslope fringe.
	(5)	(5)	(10)	(10)
Moderate	a-Moderately-consolidated rocks of all types b-Moderately-weathered rocks c-Highly-densified clayey sediments d-Alternating beds of erodible and non-erodible materials	a-Gravelly, clayey soils. b-Moderately-cemented soils. c-Moderately-cohesive soils. d-Medium-grained soils	a-Moderate slopes b-Infiltration capacity moderate. c-Moderate vegetative cover d-Runoff from area above has limited access to site.	a-About 20% of surfaces exhibit rills. b-Sediment deltas noted at base of 30% of slopes. c-Some drains affected by sediment deposits. d-Some sediment apparent in vegetative strips.
	(0)	(0)	(0)	(0)
Low	a-Hard, well consolidated, massive rocks b-Hard, well-consolidated sediments.	a-Cohesive clay soils b-Dense gravelly-clay soils. c-Gravelly, highly-pervious soils.	a-Gentle slopes b-High Infiltrative capacity. c-Heavy vegetative cover d-Runoff from area above diverted from site.	a-Few signs of rill erosion. b-Few signs of deposition at toe of slopes vegetative strips. draoms. etc.

1-Numbers indicate approximate values to assign to observations
2-Letters refer to independent characteristics to which full value can be assigned
3-Experienced investigators may interpolate between sediment yield levels

TABLE 1- Sediment Yield Approximation Table (Adapted from Reference No. 13)

field data. The total sediment quantities estimated to have been deposited on site areas can be computed similarly. Differences between quantities eroded and those deposited represent sediment losses from site areas. This data can then be expanded to cover the entire area under survey.

Results obtained from the field study can be transferred readily to other areas if slope, soil and other conditions are quite similar. If conditions are different, correlation factors of some kind may still make results usable. Correlation between these areas may be facilitated through the use of factors presented in Table 1, The Yield Approximation Table. If the data indicate that the area in which field observations were made to determine sediment losses falls within the same sediment yield classification as the new area, results are correlatable. Also, if the numerical scores fall within 25 points of one another, correlation is valid.

Another very appropriate method is to make sediment-loss approximations from an area where construction has been conducted by determining quantities of sediment deposited in reservoirs and lakes downstream from sites and apply them to future construction site losses, or relate them to other areas. Sediment detention or debris basins can also provide much data on sediment quantities that have been lost from sites. Procedures for conducting reservoir deposition surveys are presented in Reference No. 15. They essentially involve determining the volume and weight of sediment that has accumulated in a reservoir during a specific period of time. Depending on the survey frequency, annual or even monthly sediment rates may be determined. Naturally-occurring sediment deposition rates may be estimated if a determination can be made as to when construction in the area under study was initiated and sediment deposition increased drastically used to plot areas of exposed ground where erosion is occurring due to prior construction. Lengths of exposed surfaces of road cuts, fills, or other sample reaches can be measured in the field by car odometer, pacing, or some other technique and the average heights of cuts and fills and widths of other areas estimated (Reference Nos., 12, 13 and 14). Average slope angles can be determined by using a Brunton-type compass. On some cut slopes, where the surface configuration may be highly irregular due to extremely variable or concentrated erosion, protrusion of hard, massive rock, or other reason, the angle can be classified as variable (Reference No. 13 and 14). The data should all be recorded for subsequent computations.

Assessment surveys should be made periodically to determine annual erosion rates and sediment losses, or if possible, monthly rates. Indicators to be used for estimating erosion include the depth, width, length, and number of rills and gullies on cuts, fills, and bare road surfaces; the extent that the toes of slopes have moved back from the edges of roads and ditches (particularly where locally erodible streaks may occur); the length of roots now extending from cut slopes, and other factors. Volumes of eroded material deposited where slopes terminate can be estimated also as they may be apparent as small deltas, filled drain ditches and sediment traps, or obstructed culvert intakes. Sediment quantities also may be noted where vegetative strips have acted to filter out or cause deposition of the materials. Records of sediment deposits removed by maintenance crews should be reviewed to provide additional data on losses and a quick check of quantities at disposal sites may give an indication of annual amounts.

Annual, or even monthly quantities of sediment eroded from each area; from all areas with similar slope and other characteristics, and from total miles of the entire surveyed area can be computed and totaled from the greater increases in sediment yield result and the use of data from Figure 5 on slopes steeper than 20% (5:1) would only be speculative and is not recommended (Reference No. 9).

The last two factors in the Universal Soil Loss Equation, C and P, represent the cropping and structural control practice factors. The C factor involves vegetative and other practices for controlling ground surfaces which have been disturbed by construction from the erosive action of rainfall and runoff. The P factor concerns structural measures used to control runoff water and prevent transport of sediments. Both factors have a value of 1 for determining potential sediment losses in a disturbed area where no effective control measures have been installed (See Page 95, Reference No. 10).

It must be emphasized again that soil losses determined with the use of the soil loss equation must be considered to be the best available rough estimate and not precise data. The equation has been derived empirically and involves experimental error as well as possible estimation error due to the effects of unmeasured variables (Reference No. 3).

Transferring Results From Field Observations

Field observations can be used to estimate quantities of sediment which are being eroded from ground surfaces exposed by construction activities in the past and still left unprotected by vegetation or other control measures. Data from these observations may be transferred to adjacent areas to permit estimating sediment losses which could result from construction activities. Again, extreme care must be used to ensure that soil, geologic, topographic, and other conditions are similar in both sites or that correlation factors used are appropriate.

For example, if sediment losses from existing roads are to be estimated, a map of suitable scale (1''=2,000 feet or less) should be

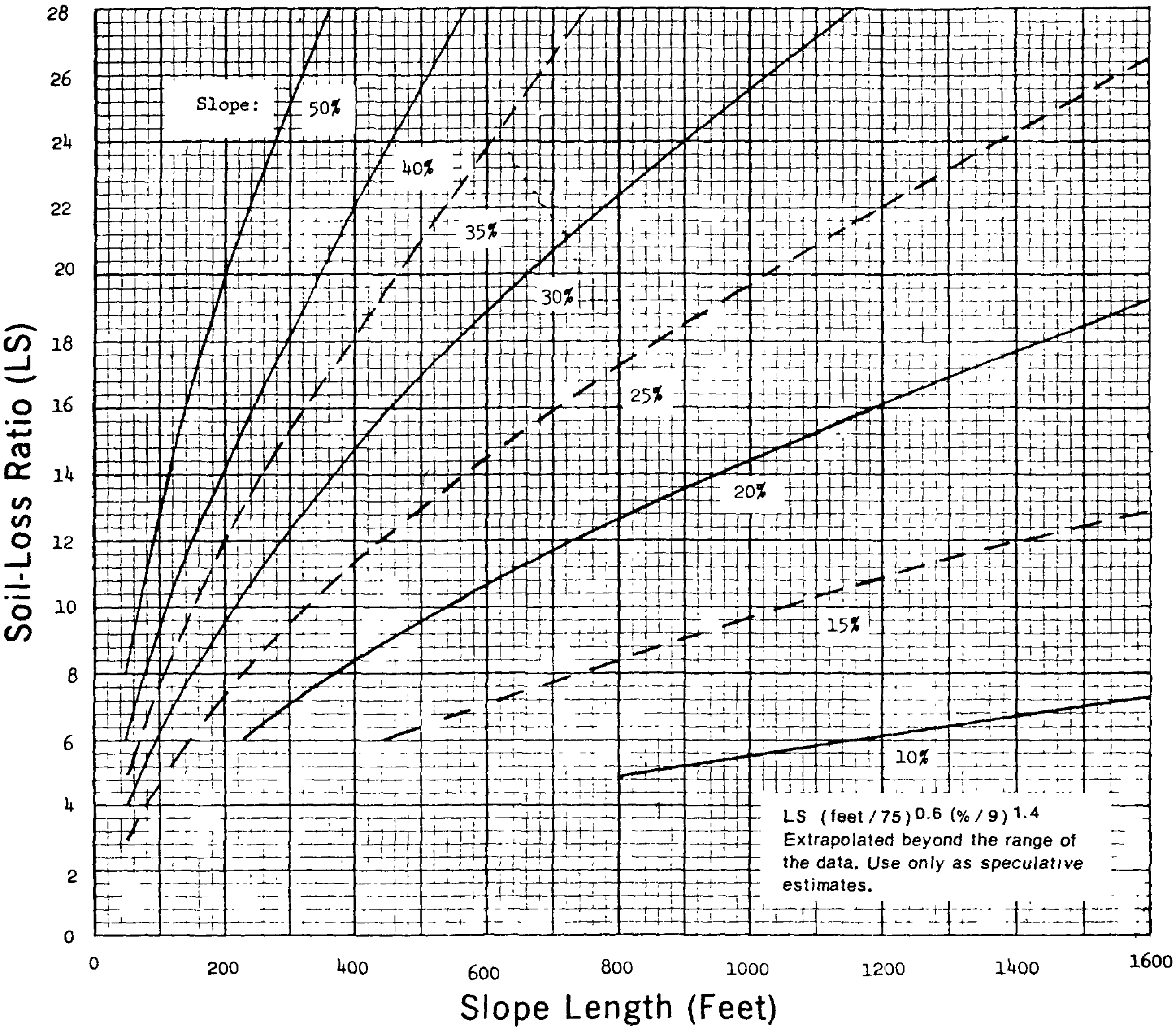

FIGURE 5 - Slope-Effect Chart for Slopes and Lengths Exceeding Those in Figure 4 (Reference No. 4)

Construction site slopes usually are developed into shorter and steeper runoff units than those under which the USLE was developed. As a result, greater quantities of runoff occur at higher velocities. This is particularly true in highway and other "heavy" construction projects. Significantly

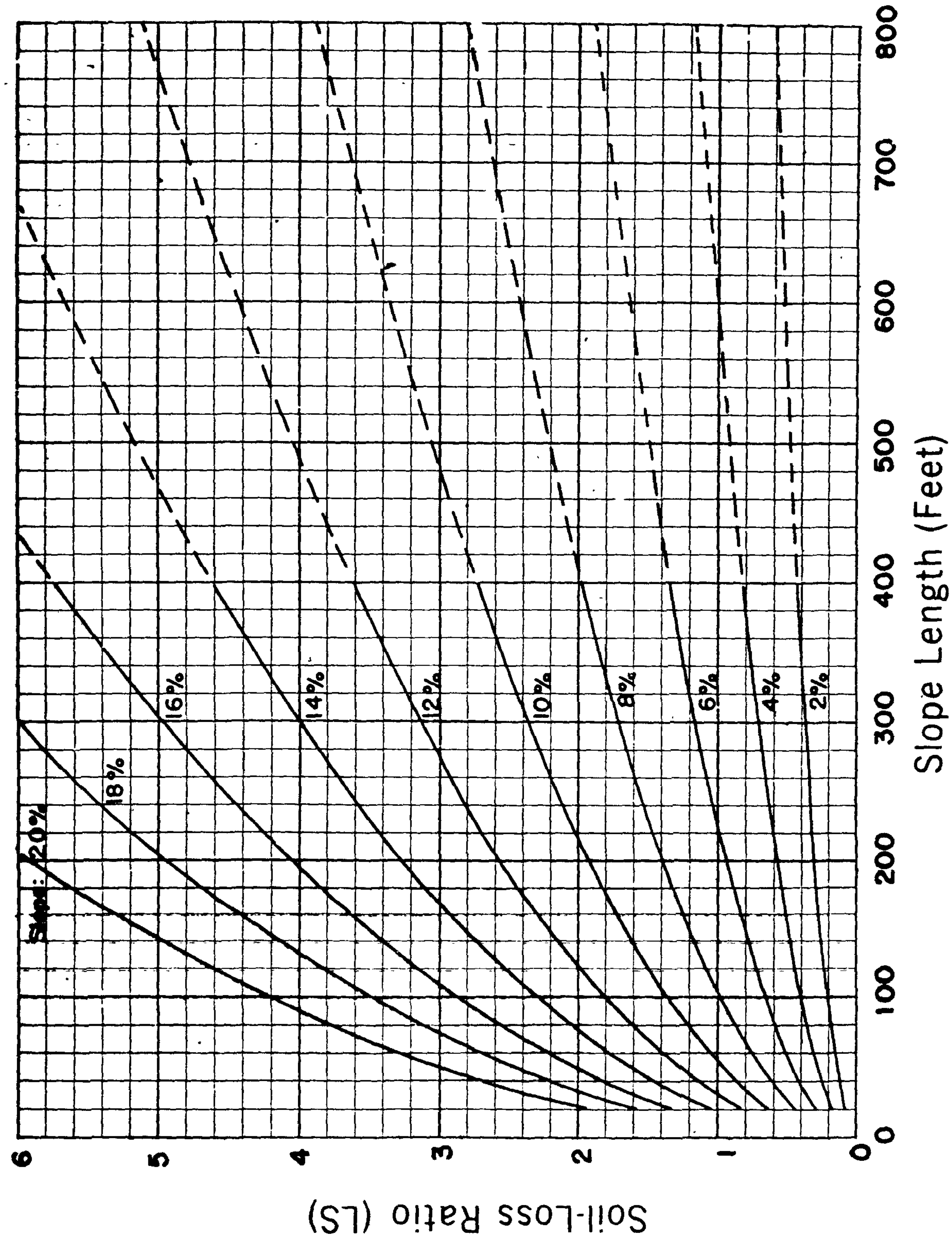

FIGURE 4 - Slope-Effect Chart (Reference No. 4)

It should be realized that the R Factor is the long-term average yearly total of the erosive potential of rainfall in the area. R, being a climatic factor, is extremely variable during a short period of time; and the erosion potential, and thus sediment yield, for an area may be several times as great during one season of the year than during another. If construction is completed during the period of low potential, sediment losses will be minimized, assuming other factors are equal.

Highly variable conditions for given months must also be considered as well as the seasonal variations. During some years, very small rains may occur during one month, resulting in a portion of the normal sediment yield, whereas in other years, the same month may have several storms, one or more of which may produce more than the expected annual sediment yield.

The slope-length factor (L) and slope gradient (S) usually, for convenience, are combined into a single factor, LS (Reference No. 4). The LS factor for gradients up to 20% and slope lengths to 800 feet, can be obtained from the Slope-Effect Chart, Figure 4. For slope lengths greater than 800 feet and gradients greater than 20%, data are extrapolated and may be used as speculative estimates from Figure 5. The computed soil loss obtained using such LS values from Figure 5 will require adjustment based on judgment.

and on Pages 2-13 through 2-23 of Reference 5. Figure 3 presents a map of the western States with erosion index values contoured. Erosion index values for areas farther to the east are provided in Handbook 282. Values may be selected from the map for use in the Universal Soil Loss Equation.

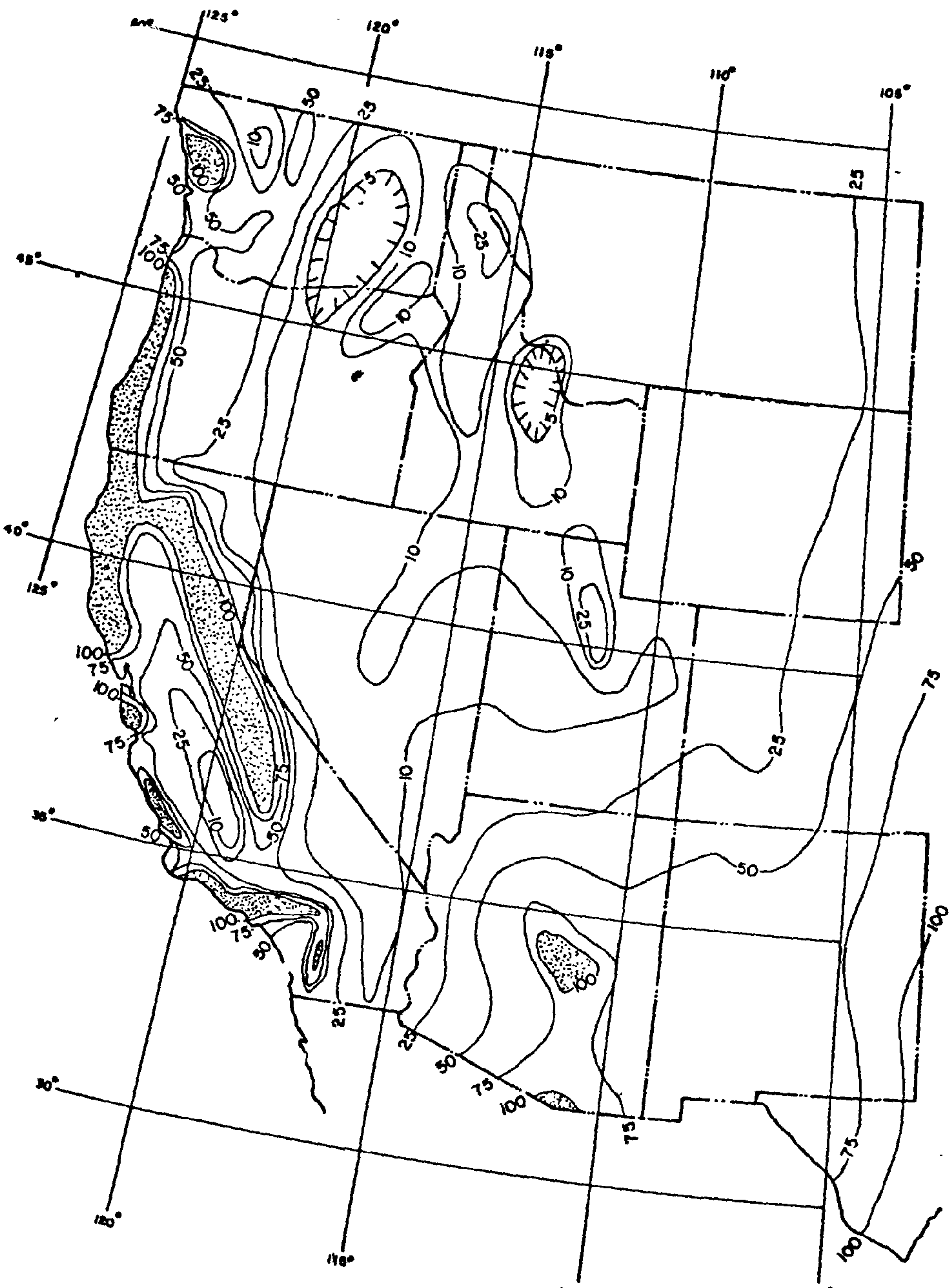

Figure 3 - Average Annual Rainfall Erosion Index (Reference No. 5)
In Western U.S.

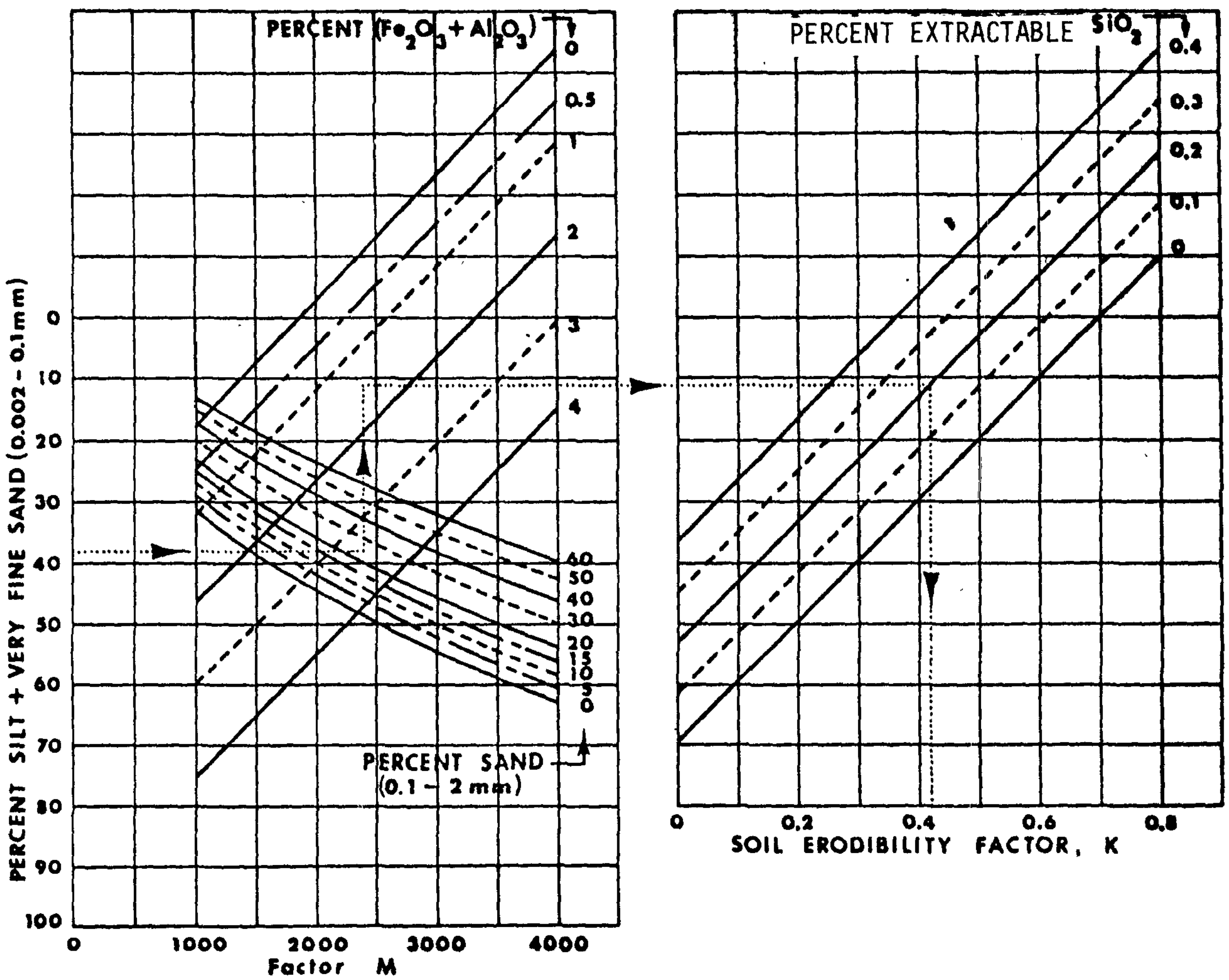

Figure 2 - Nomograph for Estimating the Erodibility Factor, K, of Subsoils with high clay content, very low permeability, blocky or massive structure and containing amorphous iron and aluminum hydrous oxides (Reference No. 11).

Information on R, the rainfall factor, is presented in the U. S. D. A. -A. R. S. Agricultural Handbook No. 282 (Reference No. 8) for States east of the Rocky Mountains and in U. S. D. A. -SCS Technical Release No. 51 (Reference No. 4) for areas in the western U. S. Many State Soil Conservation offices have developed R factor maps that are detailed for local conditions. Another method for obtaining R values, also referred to as the erosion index, in western States is presented in Reference No. 7

There are severe limitations in the use of this erodibility nomograph, particularly with materials which have no organic matter and a fairly high clay content. This has been recognized by some researchers, and work is being conducted to obtain erodibility information on these types of materials. Figure 2 presents a nomograph for estimating erodibility of clayey soils of low permeability if the gradation of the material, percent amorphous iron and aluminum hydrous oxides, and percent extractable silica are known. The theory behind this nomograph is that amorphous iron and aluminum oxides and silica are the primary binding agents in subsoils much as organic matter is the prime binding agent in surface (or agricultural) soils. Studies are still underway regarding this type of evaluation as the parameters required for the nomograph of Figure 2 are not usually available from existing soil analyses and cannot be estimated readily. Procedures for testing samples of subsurface materials may be developed in the near future to obtain this needed data.

Factors developed for use in this equation were established empirically and must be used with care and judgment. They were devised initially for farmland and erosion of agricultural soils. In most construction sites, these soils which usually contain organic matter, are generally removed and the underlying purely-mineral foundation materials exposed, excavated, transported elsewhere, and remolded by large earthmoving equipment to produce a final grade for the project facilities. As a result, K, the soil erodibility factor must be revised to make it appropriate for use in construction sites. This has been done to some extent in Reference No. 1, which presents a nomograph to derive erodibility if the percent silt, sand, and organic content, structure, and permeability of soil (or other foundation materials) can be ascertained (See Figure 1).

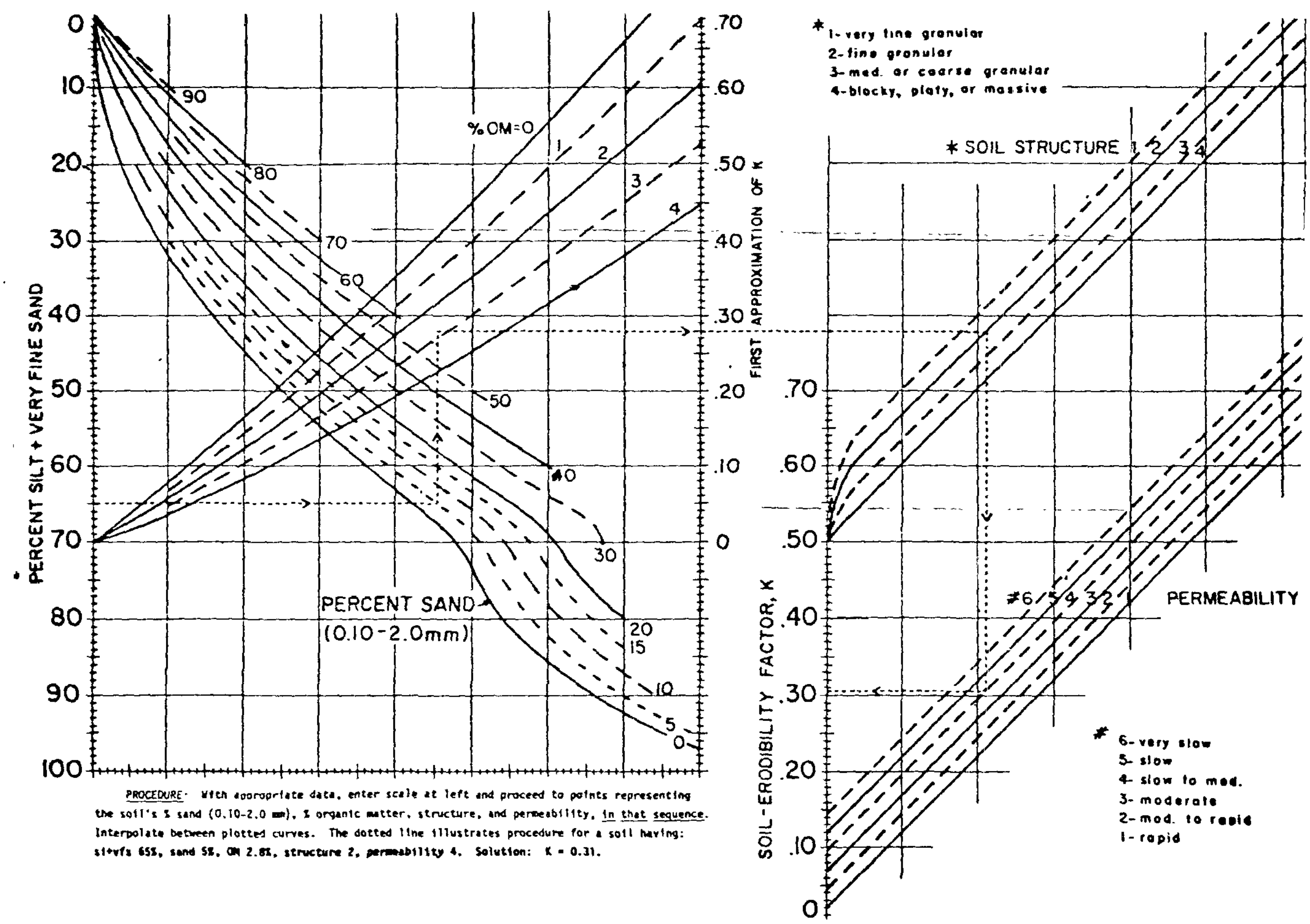

Figure 1 - Soil Erodibility Nomograph (Reference No. 1)

Approximations regarding potential sediment losses from construction sites can be made in several ways. One method is to use adaptions of the Universal Soil-Loss Equation in which soil erodibility factors have been determined from test information involving soil particle sizes, structure, permeability and other characteristics (Reference No. 1 through 5). Another is to transfer results from field observations of sediment losses in similar areas to the site under study and estimate differences. Still another method is to evaluate case histories of sediment losses determined by sampling runoff immediately downstream from sites during their construction period and relating them to the proposed site area. In all cases, extrème care should be used. Factors involved in equations or derived from other areas or studies are extremely variable and subject to judgment; as a result, only experienced personnel should be engaged in evaluating soil losses.

Sheet Erosion Approximation Using Soil Loss Equations

Approximations regarding potential sediment losses from construction sites can be made through the use of soil loss equations such as those developed and used by the U.S. Department of Agriculture (Reference No. 1 through 5 for this Chapter and References at end of Chapter 2). The complete Universal Equation is:

$$A = R\ K\ L\ S\ C\ P$$

A-is the computed average annual soil loss in tons/acre
R-is the rainfall factor, designed to account for storm energy and intensity in a normal year (also termed erosion index).
K-is the soil erodibility factor, expressing the sediment loss from a specific soil on a unit plot 72.6 feet long with a 9% slope adjusted for rainfall.
L-is the slope-length factor, the ratio of soil loss from a specific slope to that from a 72.6-foot slope of simiular characteristics.
S- is the slope steepness factor relating soil loss from a specific slope to that from a 9% slope.
C-is the cropping management factor, a ratio of soil loss from a site protected by mulch or vegetative measures to that from a site that has been disturbed and left bare to erosive forces.
P-is the structural-control factor, a ratio of soil loss from a site with with fully-installed structural control measures to that of one without.

vegetative cover. Other pollutants result from materials that have been brought in to the site and used for construction purposes, occur naturally in the area, or are adsorbed to soil particles. These materials may be used to implement construction requirements, altered or combined with other materials to produce a third product, disposed of, or even accidently spilled in the site area. If site conditions are not considered carefully, any of these materials can be transported from the site area by runoff water, wind, gravity, or some other mechanism and become water pollutants.

Assessing Potential Sediment Losses

Construction activities which involve disturbance of surface soils or underlying foundation materials will generally cause the generation of quantities of sediment that are greatly in excess of those resulting under natural conditions. Surface runoff and other transportation agents will carry these materials from the site areas to become pollutants unless effective sediment control measures are installed to prevent their movement. If no control is provided, it will not be necessary to determine whether soil losses will occur, but only to determine their magnitude.

The initial step in assessing potential sediment pollution to be expected from future construction projects should involve a consideration of the type of facilities to be constructed, the location of these proposed facilities; areal extent, depth, and type of ground disturbance or grading to be accomplished; proposed or estimated changes in the existing surface and ground water drainage systems; and other pertinent factors. For a proposed site, the project plans prepared by a design engineers may provide much of this information. In an area where development is imminent but no project plans are available, only estimates can be made regarding what land changes will definitely occur and their extent.