Best Management Practices Guide for Stormwater

Appendix H

Construction Site Erosion and Sediment Control Guide

Prepared for

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This document was adapted for use in the Greater Vancouver Sewerage and Drainage District (GVS&DD) from the Stormwater Management Manual for the Puget Sound Basin published by the Washington State Department of Ecology. The Department of Ecology kindly provided permission to use the text and figures from their manual, and provided a digital copy of the text. In adapting the manual for use in the GVS&DD, references to U.S. regulations and specifications were deleted from the text, units were converted to metric, and sections and figures were re-numbered. Some parts of the Puget Sound manual were summarized and abbreviated in the interests of clarity and simplicity, and the wording was changed to present technical information as guidelines, rather than as regulatory requirements. Otherwise, the text and figures contained in this manual are essentially identical to those in the Puget Sound manual.

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1.0 INTRODUCTION

1.1 Background and Objectives

This manual forms Appendix H of the "Best Management Practices Guide for Stormwater" prepared for use by municipalities within the GVS&DD and published under separate cover (1). Appendix H can also be used as a stand-alone document for controlling erosion and sedimentation on construction sites. This appendix was adapted for use in the GVS&DD from the "Stormwater Management Manual for the Puget Sound Basin" (2), as described in the Acknowledgements on page i.

This appendix provides technical information to help in controlling erosion and sedimentation from new construction activities in the Greater Vancouver Sewerage and Drainage District. Detailed guidelines and design criteria for erosion and sediment control Best Management Practices (BMPs), as well as background information on the erosion process and how it may be controlled are included. These BMPs can be used to develop detailed erosion and sediment control strategies for construction sites (see Sections 5.2 and 5.3).

The target audience for this appendix includes officials in local governments who are responsible for administering bylaws pertaining to construction activities, and the development community. In a broader sense, this volume is intended for both engineers and planners, because minimization of erosion requires good planning as well as good engineering and, most importantly, close collaboration between the two disciplines.

Section 2 of this appendix provides a general overview of the erosion and sedimentation process and the basic principles by which it may be controlled.

The discussion in Section 3 explores the concept of BMPs. Seven major problem areas that are encountered during the construction process are included, and the various erosion and sedimentation control BMPs that can be applied to each of these areas are briefly described.

Section 4 contains BMPs that are designed to deal with pollutants other than sediment. This section has been included because many pollutants are adsorbed by or otherwise associated with sediment. Many of these pollutants can be generated during the construction process as a result of the use of petroleum products, fertilizers, pesticides, and other construction chemicals. Some of these pollutants may be hazardous. The discussion in Section 4 outlines how the generation of these wastes can be minimized, and for those that are generated, how they should be handled and disposed of.

Approaches for erosion and sediment control (ESC) on construction sites can be found in Section 5.

Guidelines and design criteria for specific erosion and sediment control BMPs are presented in Section 6. In most cases, the guidelines and design criteria for BMPs are in the form of technical requirements (examples include the depth of sediment traps, length of construction entrances etc.). In some cases, the guidelines and criteria are more in the form of recommended parameters, such as seeding mixtures for cover practices. Some of the BMPs are simple and easy to apply, such as mulching, but others such as sediment ponds require design by a professional engineer, using the guidelines set out in this manual. Best Management Practices for individual family lots and small sites can be found in Sections 6.8 and 6.9.

1.2 References

(1) D&K et al. (1999), **Best Management Practices Guide for Stormwater**, for Greater Vancouver Sewerage and Drainage District, by Dayton & Knight Ltd., Consulting Engineers and others.

(2) WSDOE (1992), **Stormwater Management Manual for the Puget Sound Basin**, Washington State Department of Ecology, U.S.A.

2.0 THE EROSION AND SEDIMENTATION PROCESS

2.1 Impacts of Erosion and Sedimentation

Erosion and sedimentation produced by land development damages the environment and is costly to society. Fisheries resources, recreational resources, and aesthetic qualities may be lost or severely degraded. Harbors, lakes, and rivers fill and must be dredged. Sediments become contaminated.

Contractors, consultants, regulators, and inspectors can significantly affect soil loss. When land is developed, erosion increases by 2-40,000 times (1,2). Such erosion is estimated to produce approximately 70 percent of all sediment produced in the U.S. (7). However, using good erosion control practices can greatly reduce this. For example, a study in Lake Tahoe Basin compared practices at two similar construction sites (3). Without erosion control, estimated soil loss exceeded background levels by 100-1000 times. Using good erosion control practices, soil loss was only double background levels.

The stormwater runoff from construction sites may contain significant quantities of sediment as well as other contaminants.

In general within the GVS&DD, stormwater systems are designed to accept only uncontaminated runoff, and there are restrictions on stormwater discharges to sanitary sewer systems (see Appendix F).

In addition, sediment discharges into streams can result in charges under the Fisheries Act.

Everyone is affected by damages from increased erosion and sedimentation. There are a variety of ways as described below.

- The soil loses nutrients as clays, silts, and fine organic matter wash away. Reestablishing vegetation is difficult. The contractor must either import costly topsoil or apply fertilizers.
- Sediment clogs culverts and storm sewers resulting in frequent and costly maintenance. Without maintenance culverts may wash out and storm sewers fail. Siltation also decreases flow capacities.
- Landslides cause damage on-site and off-site.
- Detention facilities fill rapidly with sediment increasing cleaning costs.
- Infiltration devices may become clogged. This has been cited as the major cause of their failure.
- As velocity decreases, streams deposit sediment requiring dredging of obstructed channels. Additionally, harbors must be dredged more often to keep them open for navigation.

- Lakes age more rapidly. As the sediment builds, shallow areas may become covered by waterlilies or weeds. Increased nutrients may cause algal blooms, which deplete oxygen and can lead to fish kills.
- We lose aesthetics. Many citizens value clean streams. An eroded, silt-clogged stream or lake is ugly.
- Turbidity (water cloudiness) and suspended sediment increases. This impairs the feeding ability of aquatic animals, clogs gill passages of fish, and reduces photosynthesis.
- Fish spawning is seriously impacted. Clean gravels provide a habitat for fish eggs and permit a free flow of well oxygenated water around the eggs and alevines (young with egg yolk still attached). Sediment-clogged gravel prevents successful spawning. Sedimentation following spawning can smother the eggs or alevines.

The costs associated with these damages vary. Some are easy to quantify, others more difficult. The loss of aesthetic values or of recreational values is hard to quantify. People prefer to canoe in clear streams. Others, who would prefer to water-ski close to home, are confronted with a lake clogged with sediment and weeds. The costs for restoration and management of a single lake can easily run into the millions of dollars.

Reductions in spawning habitat, and thus reduction in salmon and trout production, cause economic losses to sports fisheries and traditional Native American fisheries. When lost, natural production is replaced by hatchery production. The public incurs expenses for construction, operation, and maintenance of hatcheries, and loses the natural production which many people consider superior.

Most quantifiable are the maintenance costs of man-made structures and harbors. Increased maintenance is necessary for culverts, storm sewers, retention/detention facilities, dams, rivers, and harbors. Harbor maintenance, for example, is expensive. The Seattle District of the U.S. Army Corps of Engineers, which does about one-third of the maintenance dredging in Puget Sound, currently budgets about Cdn. $1 Million yearly for direct costs of dredging. This does not include administrative and other associated costs. Total yearly costs for dredging and administration for the Corps, the Ports and others runs into several million dollars. Taxpayers pay for these costs.

Impact Prevention

The problems listed above make it imperative to minimize erosion on construction sites. This is achieved through control of runoff. Knowledge of the erosion and sedimentation process is helpful in understanding the role of Best Management Practices (BMPs) in runoff control.

2.2 The Erosion and Sedimentation Process

Soil erosion is defined as the removal and loss of soil by the action of water, ice, gravity, or wind. This section deals principally with soil erosion caused by the force of falling and flowing water.

The erosion process includes the detachment and transport of soil particles. The force of raindrops falling on bare or sparsely vegetated soil detaches soil particles. Water running along the ground surface picks up these particles and carries them along. As runoff increases in velocity and concentration, it detaches more soil particles, cuts rills and gullies into the soil surface, and adds to its sediment load.

2.2.1 Types of Water Erosion

Types of erosion caused by falling and flowing water are illustrated on Figure 2.1; they include raindrop, sheet, rill and gully, and stream and channel erosion.

1. *Raindrop Erosion:* Erosion resulting from the direct impact of falling drops of rain on soil particles. This impact dislodges soil particles so that they can then be easily transported by runoff.

2. *Sheet Erosion:* The removal of a layer of exposed surface soil by the action of raindrop splash and runoff. The water moves in broad sheets over the land and is not confined in small depressions.

3. *Rill and Gully Erosion:* As runoff flows it concentrates in rivulets, cutting grooves called rills into the soil surface. If the flow of water is sufficient, rills may develop into gullies.

4. *Stream and Channel Erosion:* Increased volume and velocity of runoff may cause erosion of the stream or channel banks and bottom.

2.2.2 Sedimentation

Sedimentation is defined as the settling out of soil particles transported by water (Figure 2.2). Sedimentation occurs when the velocity of water in which soil particles are suspended is slowed for a sufficient time to allow particles to settle out. Heavier particles, such as sand and gravel, settle more rapidly than fine particles such as clay and silt.

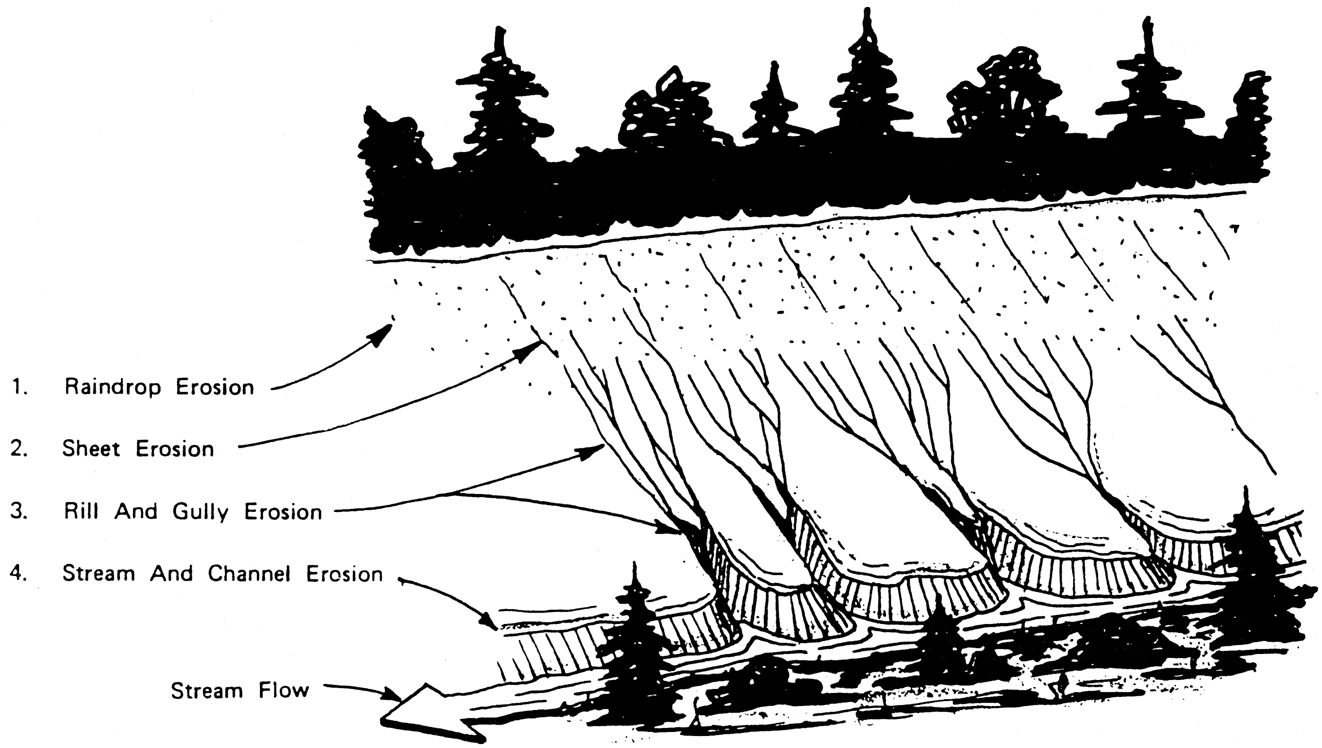


Figure 2.1 Types of Erosion

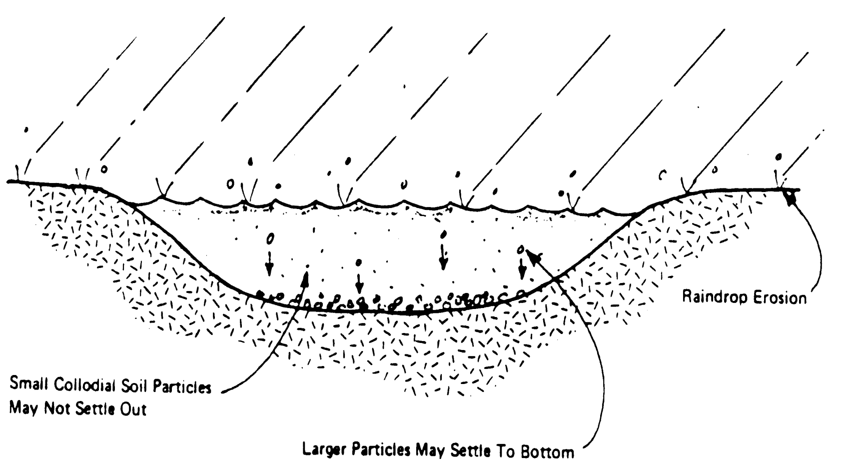


Figure 2.2 Cross-Section of Flowing Waterway

2.3 Factors Influencing Erosion

The inherent erosion potential of any area is determined by four interrelated, principal factors: soil characteristics, vegetative cover, topography, and climate (Figure 2.3).

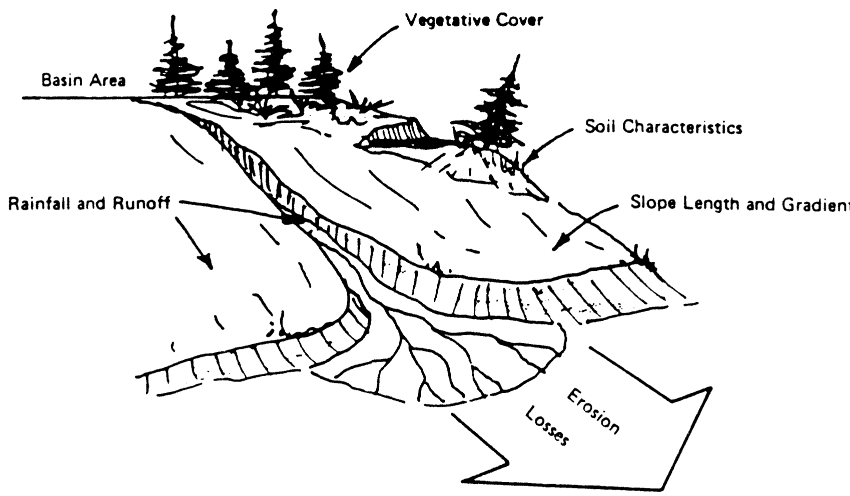


Figure 2.3 Characteristics Which Affect Erosion Losses

2.3.1 Soil Characteristics and the Geology of the Lower Fraser Basin

Soil properties which influence erosion by rainfall and runoff are those factors which affect the infiltration capacity of a soil and those which affect the resistance of the soil to detachment and being carried away by falling or flowing water. The vulnerability of a soil to erosion is called erodibility. Some key factors which control erodibility are as follows:

- particle size and gradation;
- organic content;
- soil structure; and
- soil permeability.

Particle Size

Soils that contain high proportions of silt and very fine sand are generally the most erodible and are easily detached and carried away. The erodibility of these soils is decreased as the percentage of clay or organic matter increases. Clay acts as a binder and tends to limit erodibility. Most soils with a high clay content are relatively resistant to detachment by rainfall and runoff. Once eroded, however, clays are easily transported and settle out slowly.

Organic Content

Organic matter creates a favorable soil structure, improving its stability and permeability. This increases infiltration capacity, delays the start of erosion, and reduces the amount of runoff.

Soil Structure

Organic matter, particle size and gradation affect soil structure (the arrangement, orientation, and organization of particles). Well-drained and well-graded gravels and gravel mixtures with little or no silt are the least erodible soils. Their high permeability and infiltration capacity helps prevent or delay runoff.

Soil Permeability

Soil permeability refers to the ease by which water passes through a given soil. Clay soils have high water holding capacity relative to sands and gravels, but poor infiltration characteristics. Although clay particles are harder to detach, they are more vulnerable to erosion because they tend to increase runoff.

The Lower Fraser Valley

The landscape of the Lower Fraser Valley is the product of a long history of mountain-building and subsidence, glaciation and volcanism, erosion and deposition. In addition, the makeup of surface soils is affected to varying degrees by landslide and slopewash activities.

Exposed and underlying bedrock control runoff and erosion. The properties of rocks, glacial deposits and soils exposed at the ground surface determine their reactions to weathering and erosion, and their ability to absorb and transmit water.

Glacial deposits can be divided into two broad categories: till and outwash. The till, and underlying sediments, have undergone one or more glaciations. The weight of up to 1,200 metres of ice has compacted these deposits and can greatly affect their mechanical and hydraulic properties, particularly if the deposit is fresh and undisturbed. Till deposits contain large amounts of silt or clay, often intermixed with large cobbles, and have low percolation rates. Only a small fraction of infiltrated precipitation reaches the regional ground water table through the till. The rest moves laterally through the thin surface soil above the till deposit (generally as shallow subsurface flow), often reemerging at the base of hillslopes. Soils may become saturated during large storms and produce significant amounts of surface runoff. The peak runoff rate from till areas is therefore generally quite high. The lateral flow of subsurface water may also make some types of soil more vulnerable to sloughing.

Outwash sediment deposited by streams that flowed off the front of the ice sheet are common. For the most part these sediments are coarse-grained, well-bedded, porous and loose. Some of these deposits are now terraces along modern stream valleys. Most outwash soils have high percolation rates, and rainfall in these areas is quickly absorbed. Creeks draining outwash deposits often intersect the ground water table and receive most of their flow from ground water discharge. Even for the largest storms, stream flow response is slow, with peak flow often lagging several days behind the rainfall that produced it. Erosion associated with outwash soils is much less than that associated with till. In contrast, erosion of fine-grained sandy outwash can be particularly severe (8).

2.3.2 Vegetative Cover

Vegetative cover (Figure 2.4) plays an extremely important role in controlling erosion by the following:

- shielding the soil surface from the impact of falling rain;
- slowing the velocity of runoff, thereby permitting greater infiltration;
- maintaining the soil's capacity to absorb water; and
- holding soil particles in place.

By limiting the removal of existing vegetation, and by decreasing duration of exposure, soil erosion can be significantly reduced. Special consideration should be given to the maintenance of existing vegetative cover on areas of high erosion potential such as erodible soils, steep slopes, drainageways, and the banks of streams.

2.3.3 Topography

The size and shape of a watershed influences the amount and rate of runoff. Several control measures (described in Sections 3 and 6 of this appendix) deal with protecting vulnerable areas from high concentrations of runoff.

Slope length and steepness are key elements in determining the volume and velocity of runoff. As slope length and/or steepness increase, the rate of runoff increases and the potential for erosion is magnified.

Slope orientation is also a factor in determining erosion potential (Figure 2.5). For example, a slope that faces south and contains droughty soils may have such poor growing conditions that vegetative cover will be difficult to reestablish.

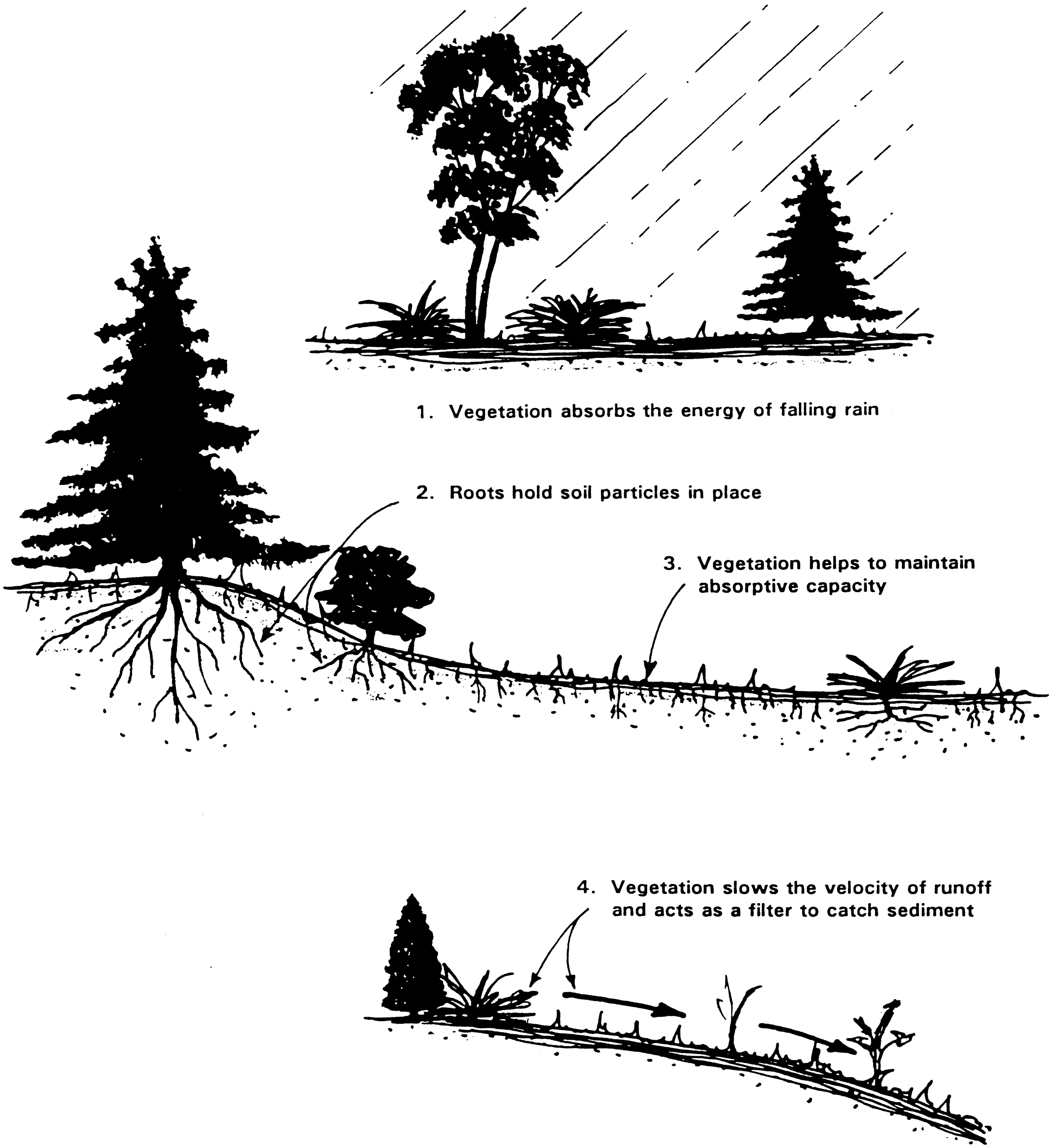


Figure 2.4 Effect of Vegetation on Stormwater Runoff

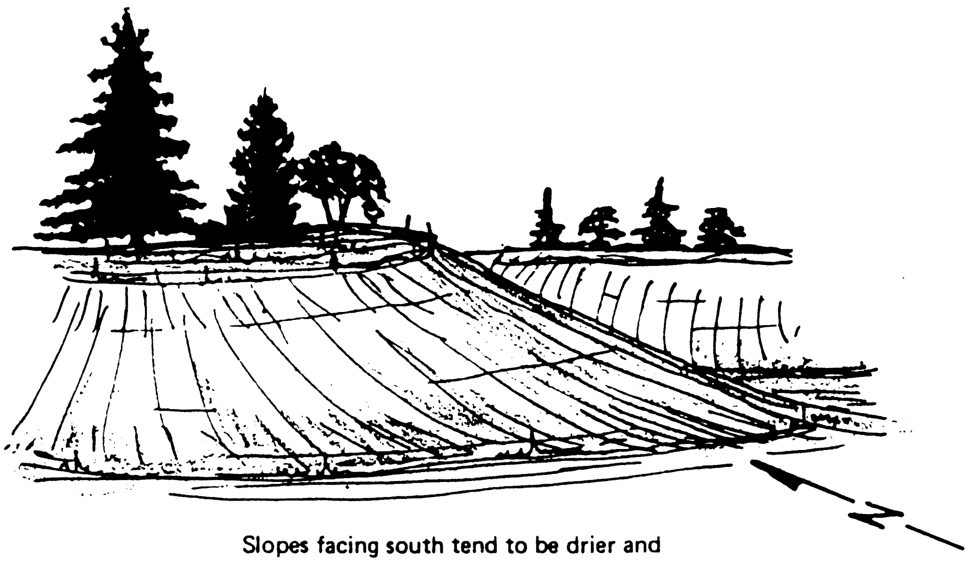


Figure 2.5 Slope Orientation Affects Erodibility

2.3.4 Climate

The frequency, intensity, and duration of rainfall and temperature are fundamental factors in determining the amounts of runoff produced. As the volume and/or the velocity of runoff increase, the capacity of runoff to detach and transport soil particles increases.

Where storms are frequent, intense, or of long duration, erosion risks are high (Figure 2.6). Seasonal changes in temperature, as well as variations in rainfall, help to define the high erosion risk period of the year. If precipitation falls as snow, no erosion will take place. In the spring, however, melting snow adds to the runoff, and erosion potential will be high. Because the ground is still partially frozen, its infiltration capacity is reduced.

The Lower Fraser Basin and adjacent areas vary significantly in storm intensity and duration from most of the rest of the country. This area is characterized in fall, winter and spring by storms that are mild in intensity and long-lasting in duration. Rainfall in the summer is sporadic and mild. These climatic differences are significant because storms in this area require the use of different management tools than do storms in other parts of the country.

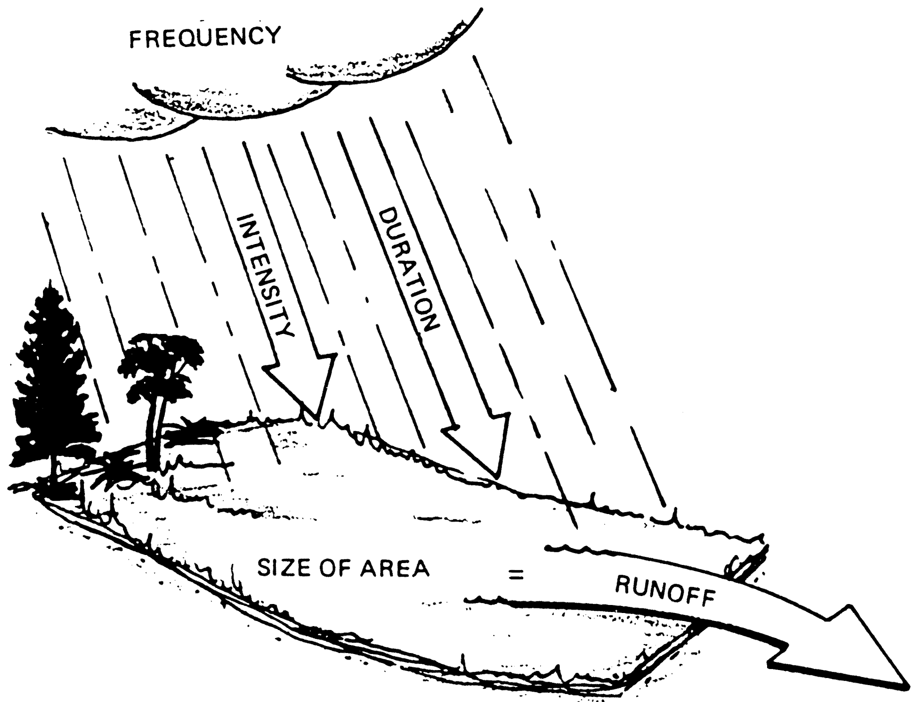


Figure 2.6 Rainfall Characteristics Help to Determine Amounts of Runoff

2.4 Basic Principles: A Summary

From this brief discussion of the erosion process and the factors that influence erosion, seven major principles of erosion and sedimentation control can be summarized.

1. Plan the development to fit the site.
2. Minimize the extent of the disturbed area and duration of exposure.
3. Stabilize and protect disturbed areas as soon as possible.
4. Keep runoff velocities low.
5. Protect disturbed areas from runoff.
6. Retain sediment within the corridor or site area.
7. Implement a thorough maintenance and follow-up program.

Each of these principles is discussed below in more detail.

2.4.1 Plan the Development to Fit the Particular Topography, Soils, Drainage Patterns, and Natural Vegetation of the Site

Detailed designing should be employed to assure that roadways, buildings, and other permanent features of the development conform to the natural characteristics of the site. Large graded areas should be located on the most level portion of the site. Areas subject to flooding should be avoided and floodplains should be kept free from filling and other development. Areas with steep slopes, erodible soils and soils with severe limitations for the intended uses should not be utilized without overcoming the limitations through sound engineering practices. For instance, long steep slopes can be broken by benching, terracing, or constructing diversion structures (see Section 3 of this appendix).

Erosion control, development, and maintenance costs can be minimized by selecting a site suitable by its nature for a specific proposed activity, rather than attempting to modify a site to conform to a proposed activity. This kind of planning can be more easily accomplished where there is a general land use plan based upon a comprehensive inventory of soils, water, and other related resources.

2.4.2 Minimize the Extent of the Area Exposed at One Time and the Duration of Exposure

When earth changes are required and the natural vegetation is removed, keep the area and the duration of exposure to a minimum. Plan the phases or stages of development so that only the areas which are actively being developed are exposed. All other areas should have a good cover of temporary or permanent vegetation or mulch. Grading should be completed as soon as possible after it is begun. Then immediately after grading is complete, permanent vegetative cover should be established in the area. As cut slopes are made and as fill slopes are brought up to grade, these areas should be revegetated as the work progresses. This is known as staged seeding. Minimizing grading of large or critical areas during the period October-April reduces the risk of erosion.

2.4.3 Stabilize and Protect Disturbed Areas as Soon as Possible

Two methods are available for stabilizing disturbed areas: mechanical (or structural) methods and vegetative methods. In some cases, these are combined in order to retard erosion. These control measures are discussed in Section 3 of this appendix.

2.4.4 Keep Runoff Velocities Low

The removal of existing vegetative cover and the resulting increase in impermeable surface area during development will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control. Slope changes should be designed to keep slope length and gradient to a minimum. Short slopes, low gradients, and the preservation of natural vegetative cover can keep runoff velocities low. This will limit erosion hazards.

2.4.5 Protect Disturbed Areas from Stormwater Runoff

Measures can be utilized to prevent off-site water from entering and running over the disturbed area. These protective measures are described in Section 3 of this appendix.

2.4.6 Retain Sediment Within the Corridor or Site Area

Sediment can be retained by two methods: (1) by filtering runoff as it flows and (2) by detaining sediment-laden runoff for a period of time so that soil particles settle out. The best way to control sediment, however, is to prevent erosion in the first place.

2.4.7 Implement a Thorough Maintenance and Follow-Up Program

This last principle is <u>vital</u> to the success of the six other principles. A site cannot be effectively controlled without thorough, periodic checking of the erosion and sediment control practices. These practices must be maintained just as construction equipment must be maintained and materials checked and inventoried. An example of applying this principle would be to start a routine "end of day check" to make sure that all control practices are working properly.

2.5 References

(1) Virginia Soil and Water Commission, Virginia Erosion and Sediment Control Handbook, Edition 2, Richmond, VA, 1980.

(2) M.G. Wolmon, and A. P. Schick, Water Resources Research, 3:451-464. 1967.

(3) Charles A. White and A. L. Franks, Demonstration of Erosion and Sediment Control Technology: Lake Tahoe Region of California, U.S. Environmental Protection Agency Publication EPA-600/2-78-208, 1978.

(4) Alex Sumari, Seattle District, U.S. Army Corps of Engineers, personal communication.

(5) PSSDA, Draft Report-Proposed Management Plan for Unconfined, Open-Water Disposal of Dredged Material Phase I (Central Puget Sound), U.S. Army Corps of Engineers, Seattle District; U.S. Environmental Protection Agency, Region X; Washington State Department of Natural Resources; Washington State Department of Ecology, January 1988, pp.2-4.

(6) W.H. Wischmeier and D.D. Smith, Predicting rainfall erosion losses from cropland east of the Rocky Mountains, Agricultural Handbook No. 282, U.S. Dept. of Agriculture, Washington D.C., 1965.

(7) Processes, Procedures and Methods to Control Pollution Resulting from all Construction Activity, U.S. EPA, Office of Air and Water Programs, EPA 430/9-73-007, 1973, p.41.

(8) Construction Site Erosion and Sediment Control Inspector Training Manual, Center for Urban Water Resources Management, University of Washington, prepared by Loren Reinelt, October, 1991.

3.0 BEST MANAGEMENT PRACTICES FOR PROBLEM AREAS ON CONSTRUCTION SITES

3.1 Best Management Practices

Understanding the basic processes of erosion and sedimentation and the basic principles of control provides the foundation for developing and implementing a successful erosion and sedimentation control approach. This section outlines the types of erosion and sediment control measures (Best Management Practices) that can be applied before, during and after the development process. Best Management Practices (BMPs) are defined as physical, structural, and/or managerial practices, that when used singly or in combination, prevent or reduce pollution of water.

The purpose of this chapter is to provide guidelines and background information that will assist in choosing the most suitable BMPs to control erosion and sediment from construction sites. This is done by describing the major problem areas and the appropriate BMPs that could be implemented to manage the problem. Complete guidelines and specifications for each BMP are provided in Section 6 of this appendix.

Best Management Practices are those practices that are currently believed to provide the most effective, practicable means of preventing or reducing pollution generated by non-point sources. They are used to implement the general principles presented in Section 2 of this appendix. Most importantly, they change with time, as we discover or become aware of other practices that better accomplish their purposes.

Most of the BMPs presented in this appendix either minimize erosion or control sedimentation. In any construction project, it is most important to do everything feasible to prevent erosion first. Stabilizing slopes, creating natural vegetation buffers, diverting runoff from exposed areas, controlling the volume & velocity of runoff and conveying that runoff away from the development area all serve to decrease erosion. Silt fences, sediment traps and diversions all trap sediment before it leaves the site. Sedimentation control should only deal with the sediment produced from unavoidable erosion.

Best Management Practices fall into a number of categories as shown in Table 3.1. Frequently they are split into cover BMPs, including grasses, mulches or other materials used to stabilize soil surfaces, or structural BMPs including check dams, sediment ponds (basins)[1], diversions and other structural techniques. Most sites require the use of several types of BMPs to adequately control erosion and sedimentation, so vegetative BMPs and structural BMPs are often used together to address a single problem. BMPs may be temporary or permanent. Soil that is exposed for a lengthy time is a large contributor to erosion and it

[1] The terms sediment pond and sediment basin are used interchangeably.

should be stabilized as soon as possible. Thus, a temporary control measure (vegetative or structural), may be used because more grading will be needed later in the project or because putting in a permanent control is not immediately feasible. Measures left in place for a year or less are generally considered temporary (Figure 3.1). In some cases temporary BMPs can be planned into a development in such a way that they may become permanent as completion of various phases of the development occurs. For example, sediment ponds can, with modification, function as permanent detention ponds (Figure 3.2).

Table 3.1
Categories, Examples and Effectiveness of BMPs adapted from (9)

Site Design and Construction Managemen	Preserving Natural Vegetation* Buffer Zones* Gradient Terraces* Dust Control
Site and Drainage Way Stabilization	Stabilized Construction Entrance* Riprap Construction Road Stabilization Vegetative Streambank Stabilization Bioengineering Protection of Very Steep Slopes Bioengineering Methods of Streambank Protection Structural Streambank Protection
Flow Diversion	Interceptor Dike and Swale* Level Spreader Pipe Slope Drains Subsurface Drains
Overland Flow Management	Biofilters (see Reference 10 at the end of Section 3) Temporary Seeding of Stripped Areas** Permanent Seeding** Mulching and Matting** Plastic Covering Sodding** Topsoiling Inlet Protection Outlet Protection Check Dams** Surface Roughening
Sediment Trapping	Filter Fence** Brush Barrier Straw Bale Barrier*** Gravel Filter Berm Sediment Trap*** Sediment Pond**

Effectiveness Ratings (from the King County Conservation District)

Most Effective * Moderately Effective ** Least Effective ***
Note: Effectiveness ratings are not available for all BMPs listed.

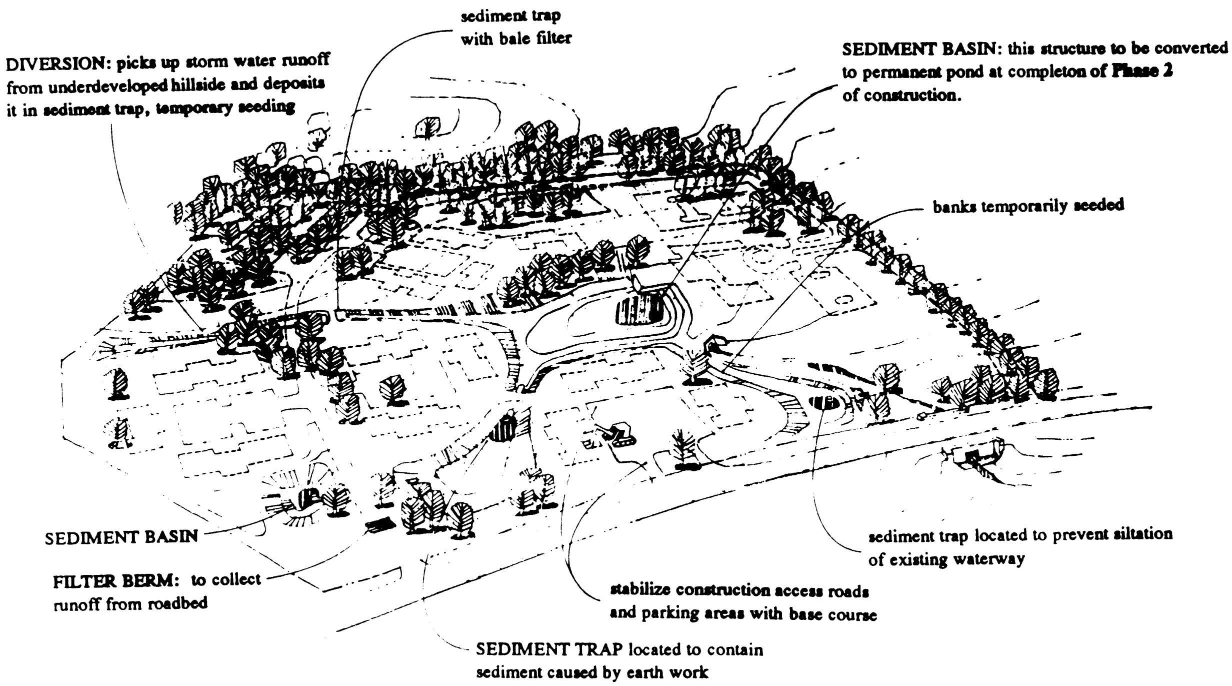


Figure 3.1 Temporary Control Measures Used During Construction

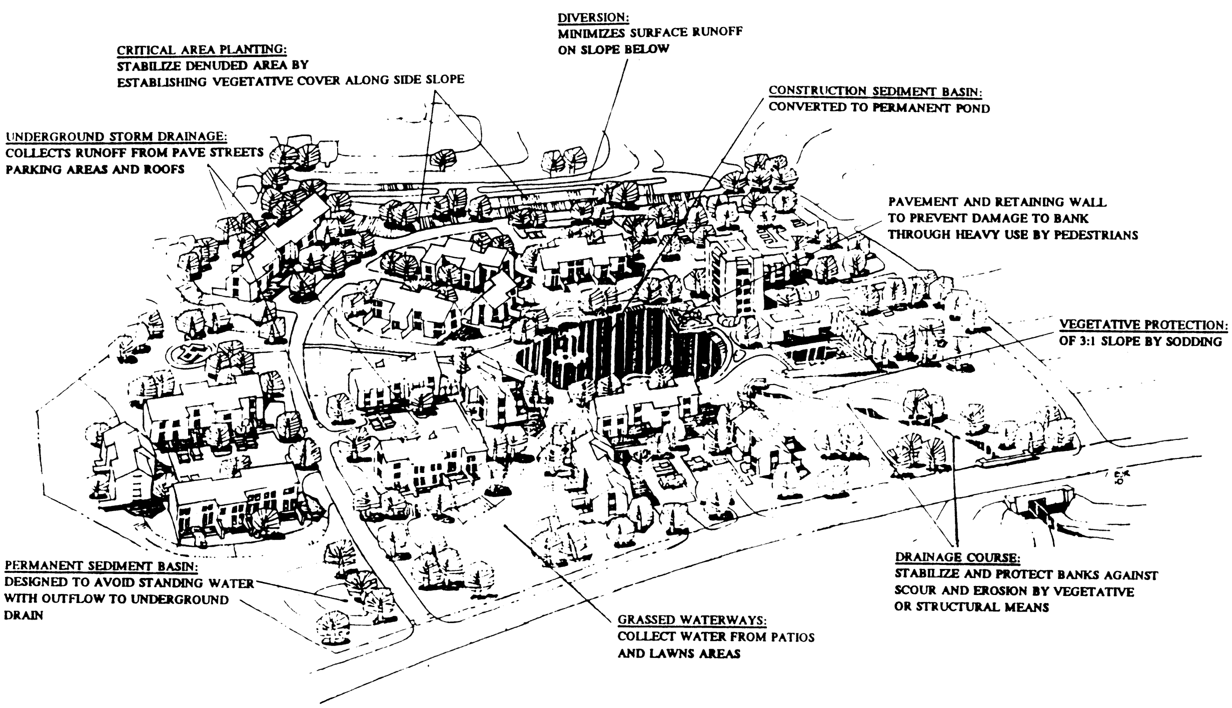


Figure 3.2 Many Temporary Measures can be Made Permanent

3.1.1 Monitoring and Maintenance

No matter whether BMPs are temporary or permanent, structural or vegetative, monitoring and maintenance of BMPs is vital. The importance of maintenance has been supported by a survey of BMPs by the King County Conservation District (1).

Preliminary results indicate that the major reason for BMP failure is poor maintenance. BMPs should be inspected regularly, particularly before, during, and after a major storm. Specific maintenance requirements of individual BMPs are dealt with in Section 6 of this appendix.

3.1.2 Problem Areas

The remainder of this section will examine particular problem areas of the construction site (such as slopes or surface drainageways) and will describe which BMPs best alleviate problems associated with each area. The areas are as follows:

1. slopes;
2. streams and waterways;
3. surface drainageways;
4. enclosed drainage inlets and outfalls;
5. large, flat surface areas;
6. borrow areas; and
7. adjacent properties.

A listing of the BMPs and the problem area, or areas, they are appropriate for, is presented as a uniform coding system in Table 3.2 at the end of Section 3. This has been introduced to promote uniformity in the specification and presentation of BMPs for erosion and sedimentation control (ESC) plans and strategies. Each BMP has been assigned a specific number, code and symbol.

Assigned numbers should be used to identify BMPs in written text, while the practice symbol should be used to identify practices on maps or site plans. The BMP can be further defined to indicate whether it is proposed as a temporary or permanent measure by using the notation "t" or "p". For example SOp = permanent sodding; STt = temporary sediment trap. The practice symbols are based upon systems used in the U.S. (e.g. Washington State, Virginia and Maryland).

Note: The American Society of Agricultural Engineers (ASAE) is proposing to standardize mapping symbols for erosion and sediment control structures and practices. These symbols differ somewhat from those now in this appendix, as they are based on another resource.

3.2 Slopes

Slopes greatly increase the potential for erosion. As slope length and steepness increase, runoff velocity increases. This increases the capacity of water to detach and transport soil particles. Steeper slopes usually have faster runoff velocities, less infiltration and more erosion than less steep slopes.

Modifying a slope by clearing existing vegetative cover also increases its vulnerability to erosion. Vegetation slows down runoff velocity and root systems hold soil particles in place. Vegetation maintains the soil's capacity to absorb precipitation. The following conditions indicate a need for special care when modifying or creating a slope:

- extensive length;[2]
- moderate to extreme steepness (greater than about 7%);
- high soil erodibility; and
- difficulty of reestablishing vegetative cover.

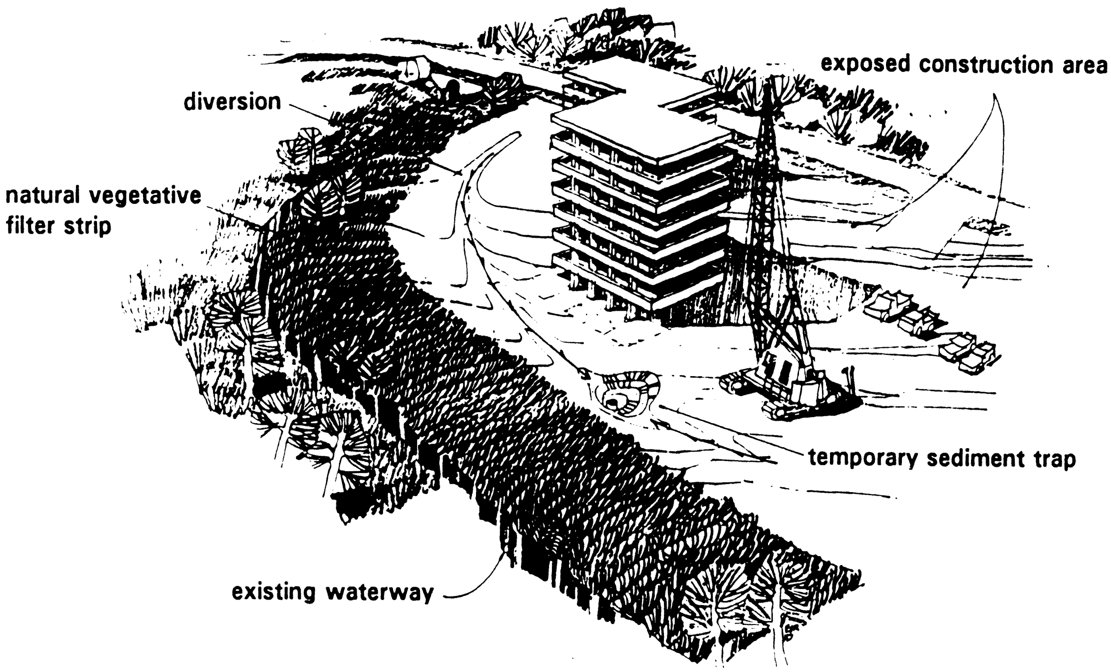
Vegetative stabilization, diversion measures, slope drains and slope stabilization measures may counteract problems created by modifying slopes.

3.2.1 Vegetative Stabilization Techniques (BMPs TC1, TC2, PC2, PC3, PC4)

Vegetative Buffer Strips

Maintaining a natural vegetative buffer or filter strip at the base of a slope retains sediment on site and is the preferred method for control of erosion. If the natural vegetative cover is left, other cover techniques such as mulch or plastic covering will not have to be used. Undisturbed vegetation is by far the best method to maintain unstable slopes. If the natural vegetative covering must be disturbed, methods such as placing sod strips at intervals along the face of the slope also help (Figure 3.3). These measures help slow runoff, trap sediment, and reduce the volume of runoff.

[2] As a general rule there will be a potential hazard if slope lengths exceed the following: 0-7% - 100 metres; 7-15% - 50 metres; >15% - 25 metres.



NATURAL VEGETATIVE FILTER STRIPS HELP TO MINIMIZE SEDIMENTATION

Figure 3.3 Natural Vegetative Filter Strips

Grass or grass and legumes are the most commonly used plant material for stabilizing slopes. Plants are usually established in one of three ways as described below (Figure 3.4):

1. *Hydro-seeding*: A mixture of seeds, fertilizer, and water is sprayed on the slope. A mulch and a mulch tacking agent can also be applied. This method is effective on large areas.

2. *Standard seeding*: Seed is drilled or broadcast either mechanically or by hand. A cultipacker or similar tool is used after seeding to make the seedbed firm and to provide seed covering. The proper timing of seeding, mulching, and watering is important for areas seeded in this manner.

3. *Sodding*: Sod strips are laid across the slope and in this way instant cover is provided. Sod should be placed on a prepared bed and pegged on steep slopes. Watering is important. This method is effective and is often used on steep slopes.

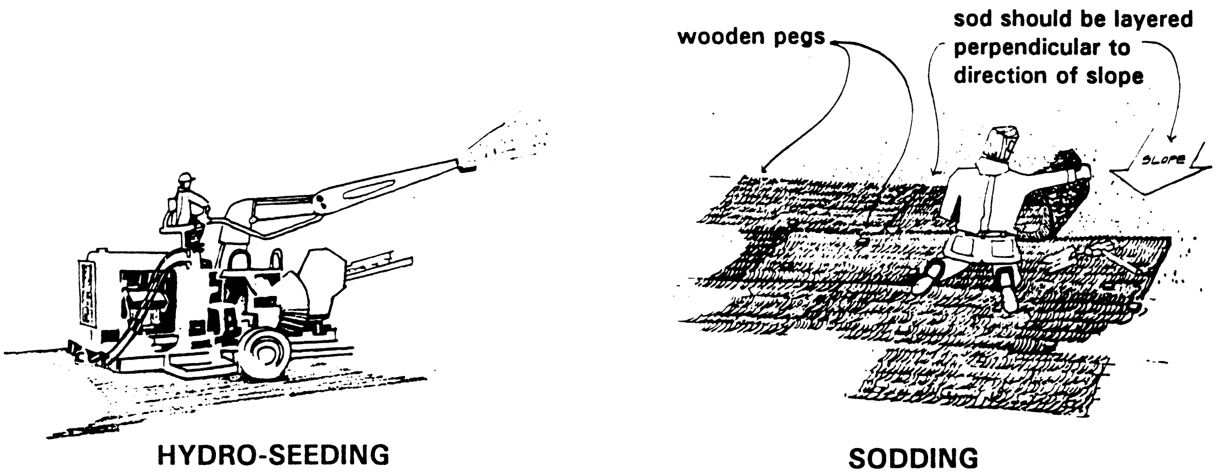


Figure 3.4 Seeding Methods

3.2.2 Diversion Measures Used to Control Erosion (BMP EC10)

A dike, ditch or a combination dike/ditch can divert runoff from the face of an exposed slope. For short slopes, placing these diversion measures at the top works well. For longer slopes, placing the dikes or ditches across the slope at intervals effectively reduces slope length. Temporary diversions must remain in place until slopes have been permanently restabilized.

Diversion ditches can be bare channels, vegetatively stabilized channels, or channels lined with a hard surface material (Figure 3.5). To determine what size and design is appropriate for each situation consider the following:

- the amount of runoff to be diverted;
- the velocity of runoff in the diversion;
- the erodibility of the soils on the slope; and
- the erodibility of the soils within the channel.

When properly constructed, diversions minimize runoff over disturbed slopes. They may also collect runoff and divert it to a sediment trap or pond.

Since diversions concentrate the volume of surface runoff, they increase its erosive force. The contractor should release runoff onto a stabilized area to reduce erosion potential. Gradually reducing the slope of the diversion channel is sometimes adequate. The contractor may also use level spreaders, or stormwater conveyance channels such as grassed waterways (Figure 3.6).

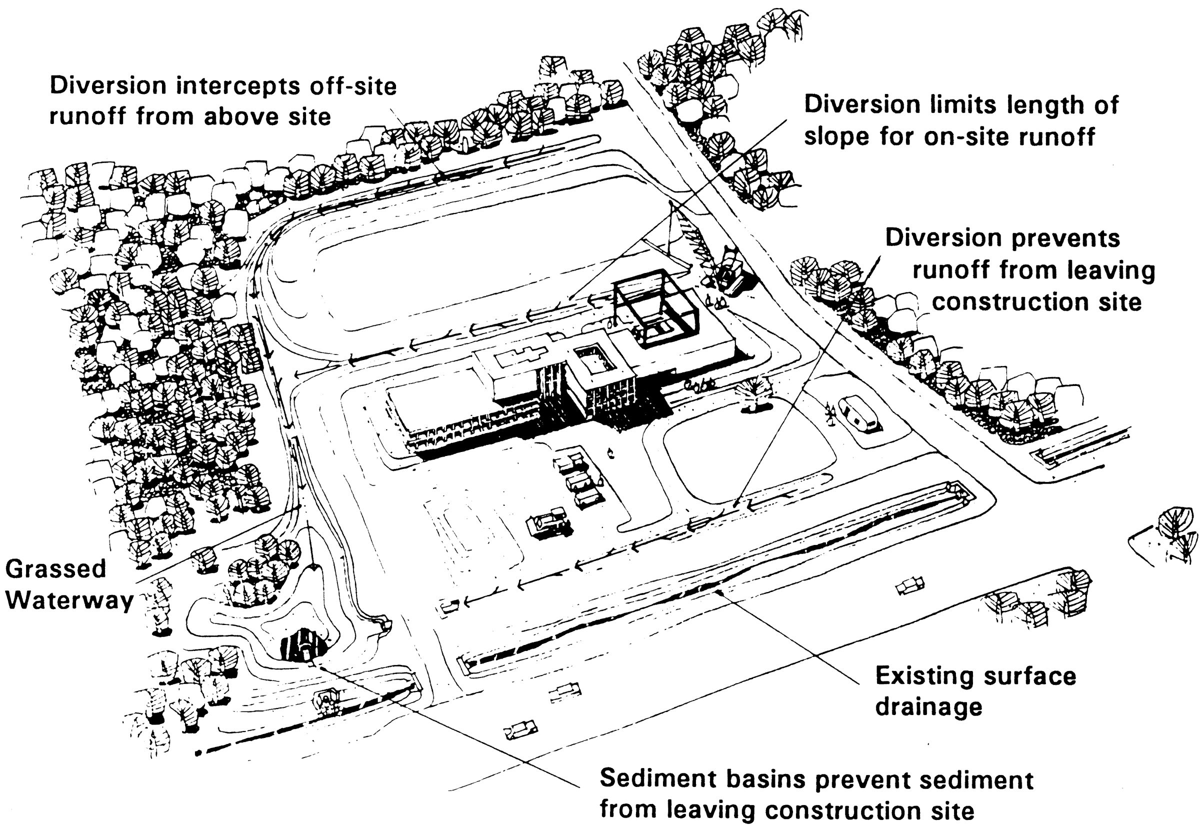
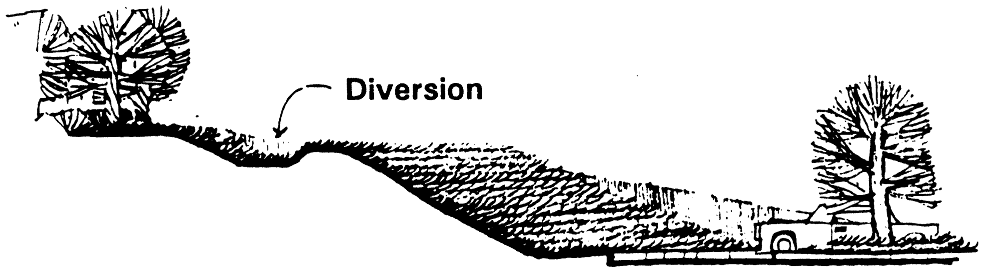
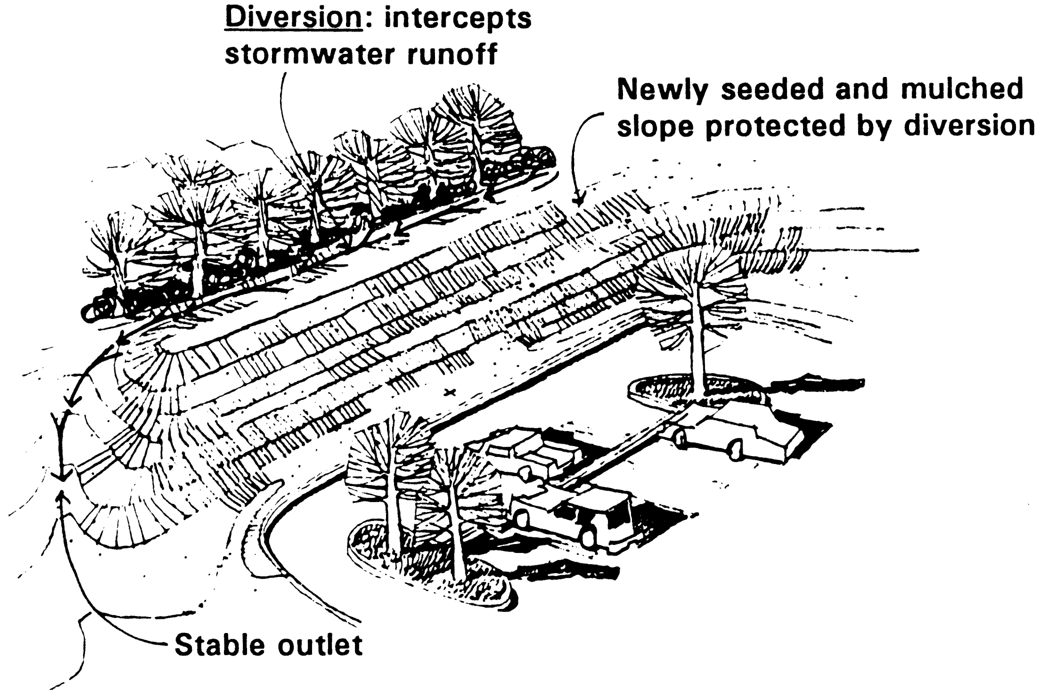


Figure 3.5 Diversion Control Measures



SECTION OF DIVERSION AT TOP OF SLOPE



DIVERSION OF CONTROL MEASURES CAN INTERCEPT STORMWATER RUNOFF BEFORE IT REACHES SLOPES

Figure 3.6 Diversion Control Measures

3.2.3 Slope Drains (BMPs EC4, EC12)

Where disposing of runoff laterally is unsatisfactory, the contractor may drain it over the slope face. Slope drains can run down the surface of the slope as sectional downdrains, paved chutes, or pipes placed beneath the ground surface (Figure 3.7).

On-surface sectional downdrains are usually pipes made of corrugated metal, bituminous fiber, or other material; these slope drains are temporary. Paved chutes covered with a surface of concrete or bituminous material are usually permanent. Subsurface pipes are also permanent.

The contractor should protect against erosion at the inlet; otherwise undercutting at the lip of the drain and piping under the drain frequently occur. Compacting the soil carefully at the mouth of the slope drain and anchoring it adequately can prevent this undercutting. Also, any areas cleared to construct the drain should be revegetated and stabilized.

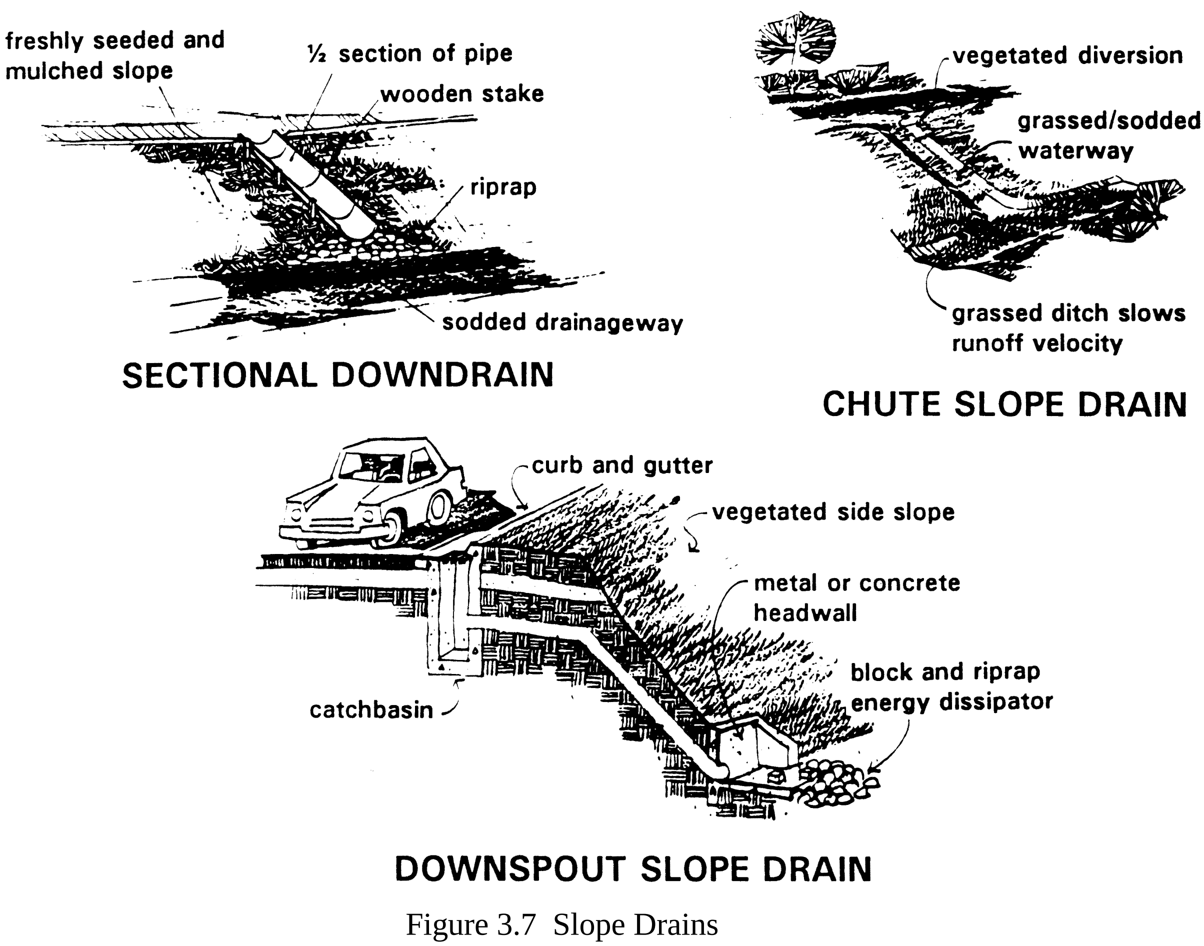


Figure 3.7 Slope Drains

At the slope drain outlet, energy dissipators (such as riprap) are frequently necessary. Not using a dissipator can result in serious erosion problems at the outflow end of the drain. The dissipator slows the velocity of the runoff to a nonerosive level. Riprap is one effective energy dissipator.

3.2.4 Structural Slope Stabilization Measures (BMPs EC6, EC7, EC8)

The most effective way to decrease erosion is to avoid modifying slopes. The angle of repose naturally achieved is the most stable for that soil type and situation. However, during construction it is often necessary to modify existing slopes or to create non-natural slopes. Cut and fill slopes are a good example.

One way to stabilize slopes is to reduce their steepness. To choose an appropriate slope ratio consider the soil's stability, drainage characteristics, and erodibility. The type of vegetative cover and the type of maintenance are also important.

To reduce extreme slope a developer may use retaining walls (Figure 3.8). Retaining walls are often used when a slope is too steep to establish and maintain vegetation. They obviate disturbance of the upper parts of natural slopes when lower parts are disturbed. Thus, trees or other naturally stable vegetation can be maintained. The cost of building retaining walls is significant but many areas are difficult or impossible to stabilize otherwise. Another way to protect slopes against erosion is to reduce length by using diversions or benches, as previously mentioned.

When slopes are disturbed, leaving them rough reduces velocity and increases infiltration rates. Rough slopes hold water, seed, and mulch better than smooth slopes.(2) Slope surfaces can be roughened by running wheeled construction equipment across the slope, or tracked equipment up and down the slope face. The grooves created by the construction equipment should run across the slope horizontally, and not up and down the slope. Slopes can also be scarified to produce the desired surface roughness (Figure 3.9).

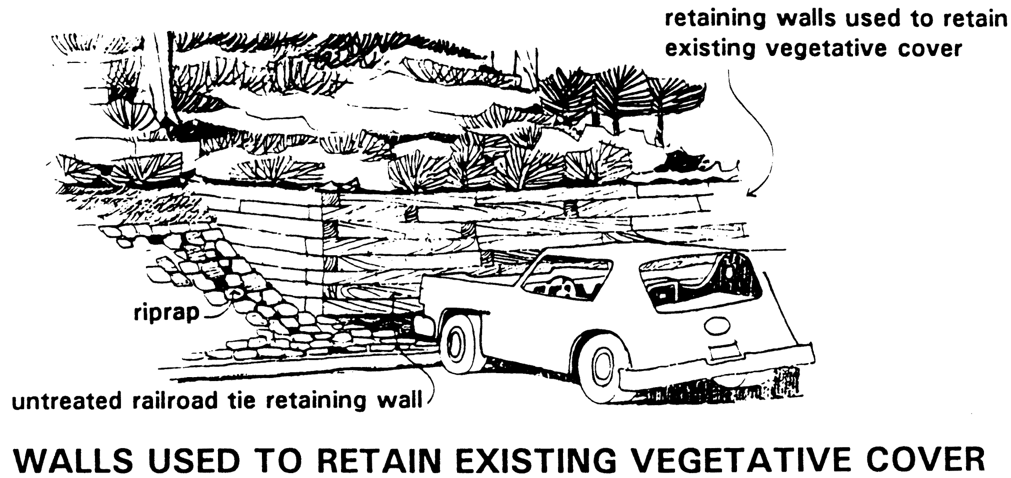


Figure 3.8 Use of Retaining Walls

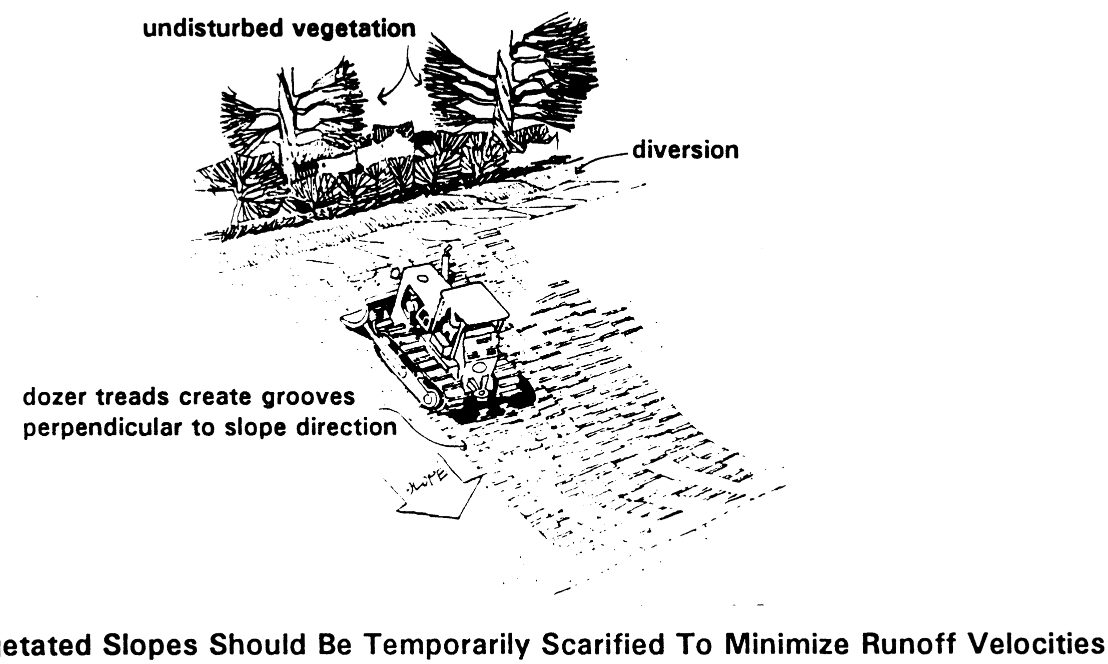


Figure 3.9 Slope Roughening

A suitable soil, good seedbed preparation, and adequate lime and fertilizer are required for all of these methods. However, special precautions need to be taken to avoid nutrients (especially phosphorus) from fertilizers being washed into waterways.

If final grading is delayed more than a few days, the contractor should stabilize exposed slopes immediately after completing rough grading. For short periods of protection either temporary mulching or temporary seeding and mulching together should be used.

When slopes are cut to final grade, permanent vegetative stabilization measures are implemented. Selecting appropriate plant materials depends on the following:

- soil and climate conditions;
- duration, quantity, and velocity of runoff;
- time required to establish cover;
- maintenance requirements; and
- site use.

Grass is the least expensive and most effective material for permanent protection of eroding soils.

Establishing grass successfully requires that contractors accomplish the following:

- select proper seeding mixture for the site;
- observe seeding dates;
- cover area to be seeded with topsoil;
- prepare seedbed and plant properly;
- apply the correct amount of fertilizer for the specific seed or plant type;
- protect slope from wind and water erosion during establishment; and
- ensure that adequate water is available during establishment and in dry periods, if necessary (by natural or other means);

Clear plastic covering provides immediate protection to slopes that cannot be prepared and seeded during the seeding period and/or during initial establishment of seeded areas. However, plastic covering also increases the quantity and velocity of runoff, requiring safe disposal of it onto stabilized areas. Additionally, plastic becomes a disposal problem once it is removed from the slopes it is protecting. Generally, mulches are a better solution for covering exposed areas.

Mulches

Mulching after permanent seeding as well as before seeding protects exposed areas for short periods. Mulches decrease the impact of falling rain, slow runoff velocity and increase the capacity of the soil to absorb water. Mulches hold seeds in place, preserve soil moisture, and insulate germinating seeds from the extremes of heat and cold. Many mulches are available: these include straw and woodchips.

Most mulches must be anchored. Another alternative is to disc the mulch just enough to anchor it. While tacking agents can be used, they are only effective under the right conditions and cannot be used to try and solve problems with unsuitable soils or excessively steep slopes.

Special Problems

On fill slopes, compaction can be a major factor in erosion control. Running heavy equipment over the fill usually compacts it adequately. Formal testing may not be required. On cut slopes, ground water seepage can cause erosion problems. Seepage causes piping and soil slippage. (4)

Slope is an important factor in the success of vegetative restabilization measures. On steep slopes (2:1 or steeper; 2 feet horizontal distance to 1 foot vertical rise) normal tillage equipment cannot be used to prepare a seedbed. Stormwater runoff will result in the loss of seeds, fertilizer, and soil. Sod can be used to stabilize steep slopes instead of seeding where grades are more than 2:1. Sod on steeper slopes must be anchored with pegs.

Sandy soils present a special problem for establishing vegetation, especially in areas where the sand is deep and droughty. Beach grass is one solution to this problem. This plant is established by hand planting live plants.

Steeply sloped areas such as lake shores and road banks involve three special considerations:

1. To ensure probability of successful stabilization, banks should consist of slopes that are 2:1 or flatter.

2. The toe of the slope must be protected from undercutting or other erosive forces by mechanical means where necessary.

3. Water seepage coming out on the face of the slope should be intercepted by a properly designed drainage system (Figure 3.10).

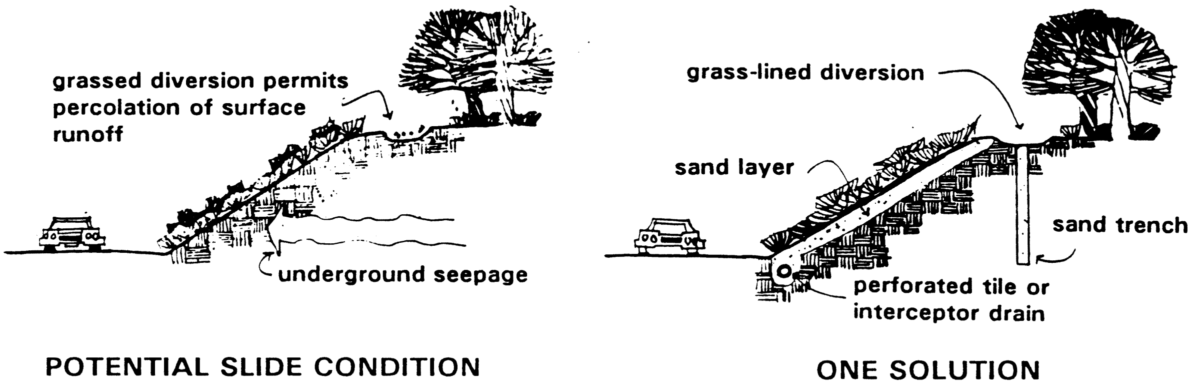


Figure 3.10 Slope Drain

3.2.5 <u>Summary</u>

This section reviewed a range of choices available for erosion control on slopes. These measures may protect other areas exposed during development. A summary is given below.

1. *Diversion measures*: Diversions can intercept stormwater runoff before it reaches disturbed slopes or other exposed areas. They can also collect runoff and convey it to a sediment basin or other suitable location.

2. *Vegetative buffer strips*: Natural vegetative filters retain sediment on-site. The contractor can significantly reduce erosion on slopes through proper application of these control measures.

3. *Slope stabilization control measures*: Slopes can be stabilized both mechanically and vegetatively. A slope exposed for longer than a few days should be stabilized by using temporary mulching and seeding. Retaining walls reduce slope and stabilization problems.

3.3 Streams and Waterways

Protecting streams and waterways on and near sites undergoing development and protecting areas downstream from development involves the three goals described below.

1. The increased sediment loads carried by surface runoff from areas under construction must not be allowed to enter streams.

2. Stream banks must be protected from erosion hazards caused by increases in runoff volume and velocity.

3. The rates of release of increased volumes of runoff into streams and waterways and the velocity of flow in stream channels must be controlled.

There are several characteristics that serve to identify streams that are particularly vulnerable to erosion. Streams which have a small channel capacity and steep banks are very susceptible to erosion. Streams which flow through areas of erodible soil and streams with sharp meanders or bends in the channel alignment are also prone to erosion (4). Before development begins, nearby streams should be analyzed to identify potential problem areas.

3.3.1 Streambank Stabilization Measures (BMPs EC13 to EC16)

The maintenance of existing vegetation on stream banks is a fundamental principle of erosion and sedimentation control. Streambank vegetation serves to stabilize the soil, slow runoff and dissipate its erosive energy, and to filter sediment from runoff. To prevent the destruction of streambank vegetation, stream crossing and construction traffic along the banks must be controlled. Culverts or temporary bridges for vehicle crossings should be constructed only where necessary (Figure 3.11).

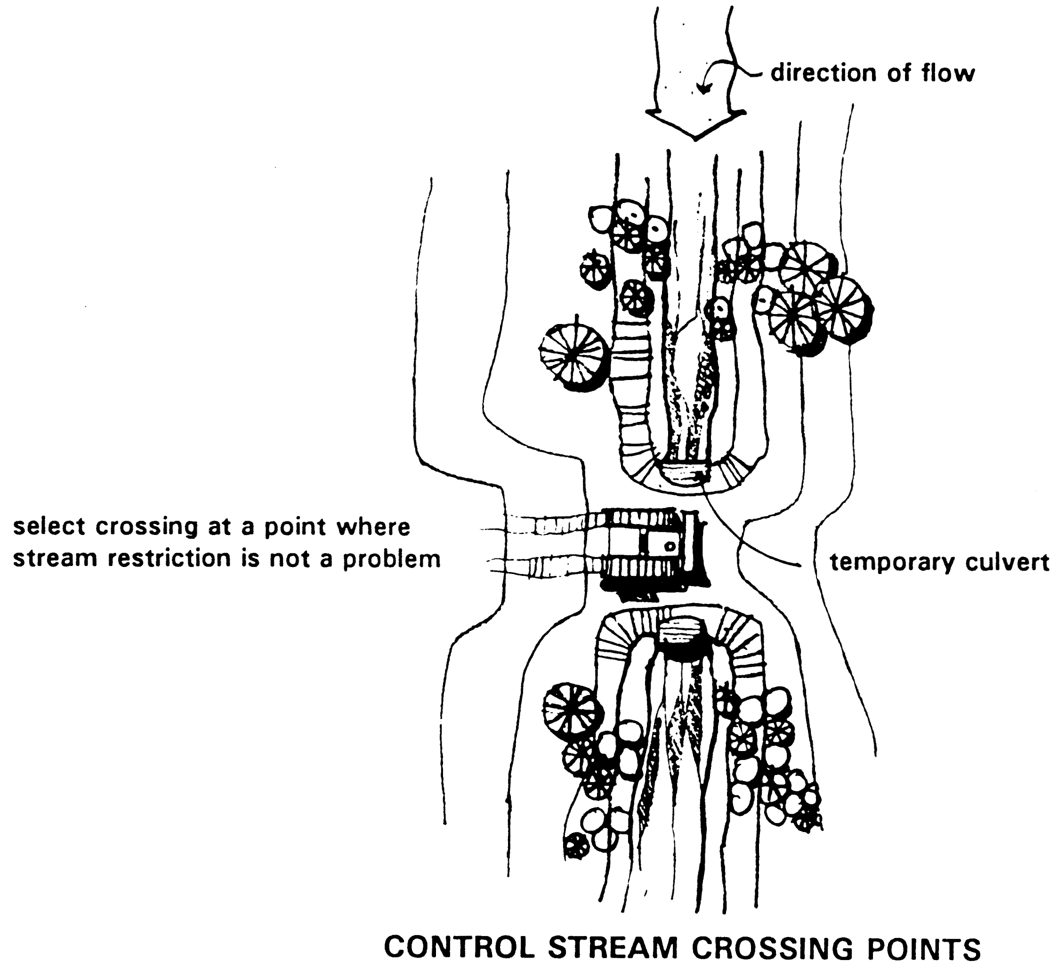


Figure 3.11 Stream Crossing

(Note: federal, provincial and local permits may all be required before streambank or near streambank work can commence).

Vegetative Measures

Where stream banks must be disturbed or where existing cover is inadequate, grass or grass-legume mixtures may be established. Immediately after grading on stream banks has been completed, vegetative restabilization measures must be initiated. Willows and other natural vegetation, as well as grass and legumes, are recommended for the protection of stream banks. Woody vegetation is used where ice damage may occur.(6)

Structural Measures

Stream banks can be protected from erosion by structural as well as vegetative measures. Where vegetation will not provide sufficient protection, banks can be protected with revetments and deflectors, as well as other mechanical measures. However, willows and other vegetation can also be used in conjunction with structural measures. This is a biomechanical approach. Biomechanical and vegetative methods are always preferred over purely structural measures, which only should be used when absolutely necessary.

Revetments, which cover the banks, are commonly used where sharp bends or constrictions in the stream channel (such as culverts, bridges, or grade control structures) occur. Riprap, gabions, sacked concrete, and concrete or asphalt paving are commonly used as revetment materials. Deflectors consist of jetties or pilings that angle outward from the bank in a downstream direction and deflect currents away from vulnerable bank areas (Figure 3.12).

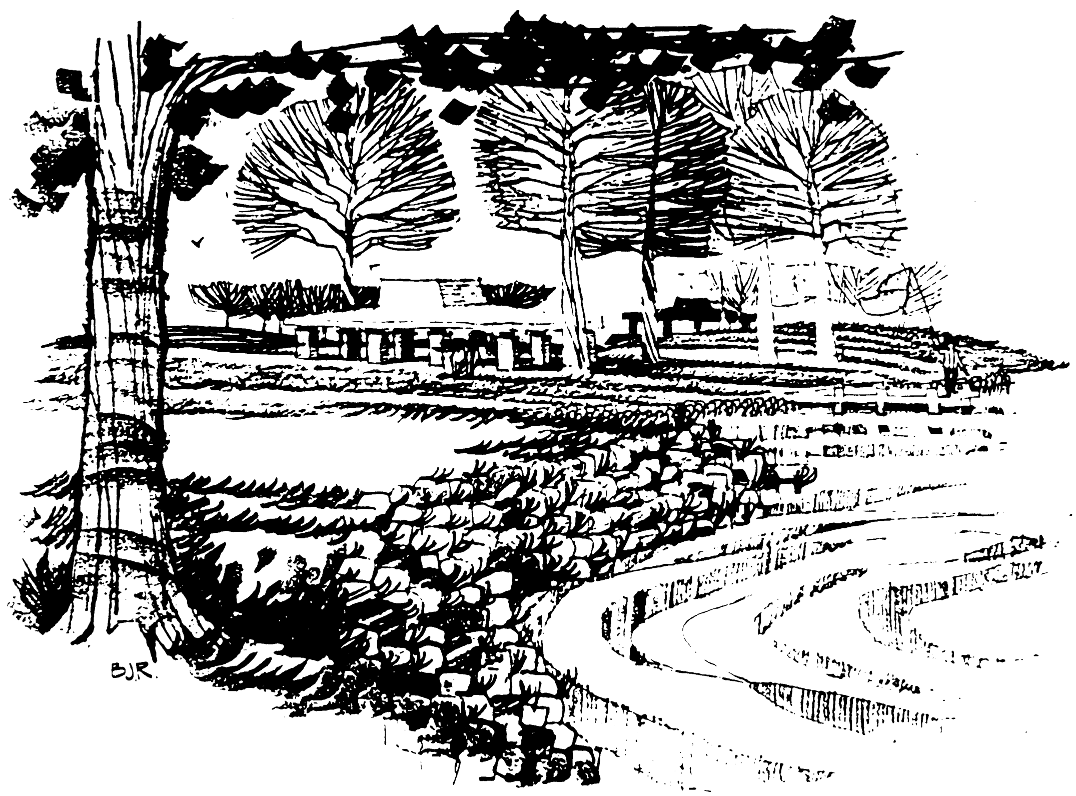


Figure 3.12 Riprap Revetment Can Help to Minimize Erosion

3.3.2 Sediment Control Measures (BMPs EC11, SR1 through SR7)

The first essential step in preventing sediment from entering streams and waterways is to control erosion on construction sites. A second necessary step in sediment control is to trap sediment that is transported by runoff before it reaches streams and waterways or leaves the construction site.

To trap sediment, the runoff must be detained for a sufficient period of time (up to 40 hours or longer) to allow the suspended soil particles to settle out. The amount of sediment which is deposited will depend on the speed at which runoff flows through the sediment trap, the length of time that runoff is detained, and the size and weight of the soil particles which are in suspension (6).

Several techniques are available for controlling the amount of sediment which reaches streams and waterways. Vegetative filter strips (preferably strips left in their natural state) between streams and development areas serve to slow runoff and filter out sediment. Check dams can also be constructed in drainageways. Check dams placed at regular intervals within a drainage channel are a temporary sediment control measure that is easy and economical to construct (Figure 3.13). Barriers are constructed of bags filled with peagravel or crushed rock and stacked in an interlocking manner which is designed to trap sediment and reduce the velocity of flow. Bags filled with peagravel tend to filter the water. They do not totally block the flow like sandfilled bags.

Piping, or undercutting, can be reduced by setting the bags at least 150 mm into the bottom of the drainageway and compacting excavated soil along the upstream side (Figure 3.14).

Streams may also be protected from increased sediment loads by trapping runoff in sediment basins or ponds before it is released into stream channels. In addition to trapping sediment, these basins are designed to release runoff at nonerosive rates. Such sediment basins can be constructed by excavating a pit or by construction of an impoundment (Figure 3.15).

Sediment basins often consist of an earthen dam, mechanical spillway (including a perforated riser pipe), and an emergency spillway. The construction of sediment basins should be completed before clearing and grading begin. They are generally located at or near the low point of the site. Points of discharge from sediment basins must be stabilized. In many developments these temporary sediment basins may be converted into permanent retention/detention basins (Figure 3.16).

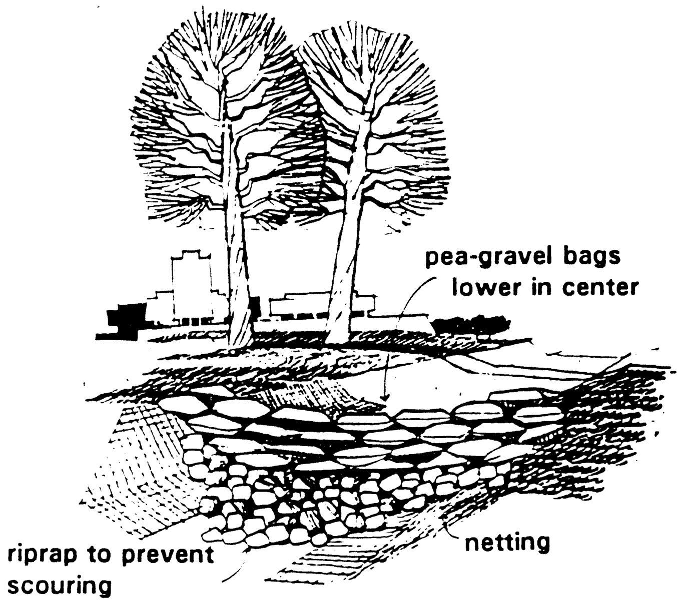
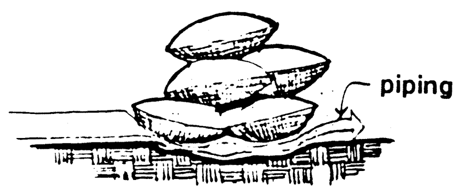


Figure 3.13 Check Dam



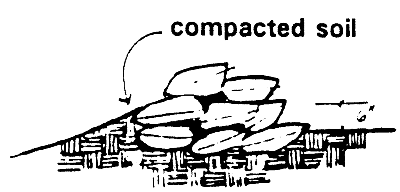
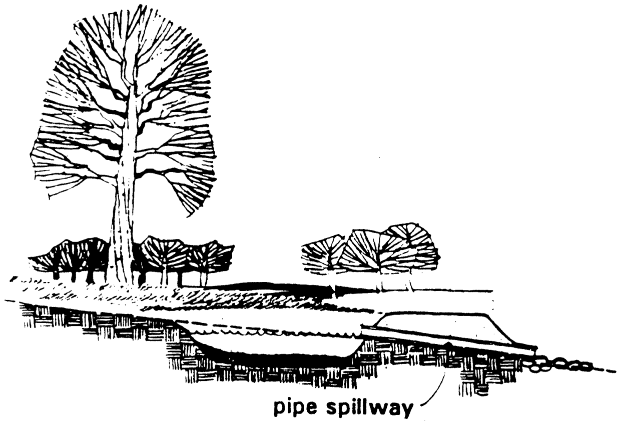
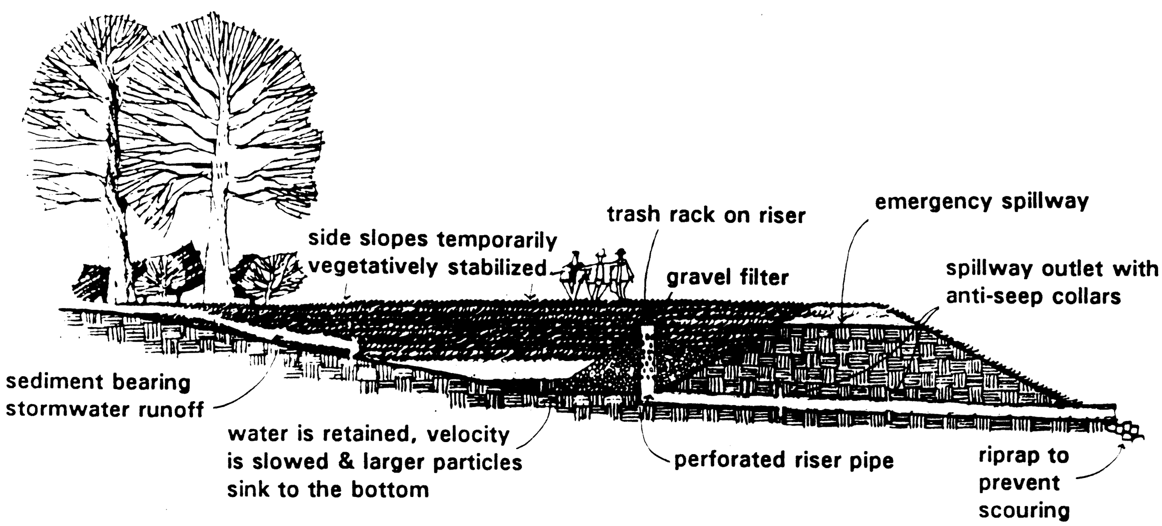


Figure 3.14 Proper Construction of Check Dam

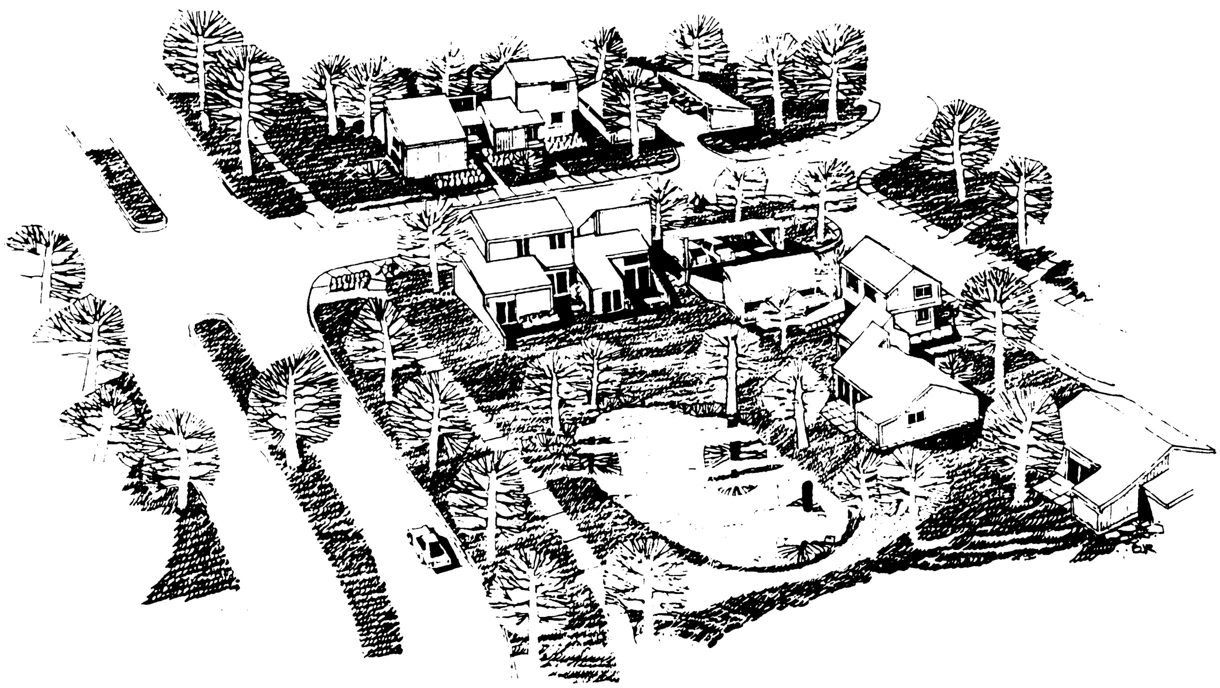


PROFILE THROUGH AN EXCAVATED SEDIMENT BASIN



PROFILE THROUGH TYPICAL EMBANKMENT SEDIMENT BASIN

Figure 3.15 Profile Through Typical Embankment Sediment Basin



PERMANENT RETENTION BASINS CAN BE INTEGRATED INTO A DEVELOPMENT

Figure 3.16 Detention Basin

3.3.3 Summary

The two categories of BMPs used to protect streams and waterways from erosion and sedimentation are described below.

1. *Streambank stabilization BMPs*: Streambanks can be stabilized by using vegetative or mechanical control techniques. Deciding which method is appropriate includes factors such as the volume and velocity of water in the stream, the gradient and shape of the stream, and maintenance of control measures.

2. *Sedimentation control BMPs*: It is necessary to prevent sediment from entering streams and waterways and this can be done by using vegetative filters and sediment traps or basins and check dams. Sediment traps and basins can be either temporary or permanent. Sediment traps are usually temporary and are removed and filled in after construction. Permanent sediment ponds may become a part of the final development in the form of ponds or small lakes. These ponds can be attractive after development is completed.

3.4 Surface Drainageways

Surface runoff, and runoff intercepted by erosion control measures such as diversions, must be collected by drainageways and let out in stabilized areas, storm sewers, or sediment basins. The design of these drainageways ensures that runoff is transported without risk of erosion or flooding. Unless surface drainageways are adequately designed, constructed, and maintained, they can become a major source of sediment pollution.

Development should be planned to maintain and utilize the naturally stabilized drainageways that exist on a site. Increases in runoff volume and velocity because of changes in soil and surface conditions during and after construction must be anticipated and controlled to the maximum extent possible. Where the capacity of the natural site drainage channels is exceeded, additional capacity, stabilizing vegetation, and/or structural measures may be needed.

Allowable design velocities vary with soil conditions, the character of the channel lining, and anticipated runoff volume.

3.4.1 Grade Control Structures

To reduce the velocity of runoff in drainageways, a variety of grade control structures can be used. These structures can be either temporary or permanent depending on the long-range requirements for the site. Pipe drops and drop spillways can be used.

3.4.2 Summary

Erosion and sedimentation from surface runoff can be minimized through the use of the techniques described below.

1. *Grassed waterways*: These channels may be stabilized through seeding and mulching or with sod, and are the preferred form of conveyance.

2. *Lined channels*: Lined channels should be used where water velocities are high, but are an undesirable alternative to grassed waterways.

3. *Grade control structures*: In some cases, grade control structures are necessary to reduce runoff velocity to non-erosive levels. Care should be taken to ensure the protection of channel sides and bottoms.

3.5 Enclosed Drainage: Inlet and Outfall Control

The capacity of vegetated drainage channels may be exceeded by the increases in runoff caused by construction activities. As a result, vegetatively-lined channels may scour and erode. Enclosed storm sewers can safely convey runoff of high concentrations and velocities; they can also serve to decrease the velocity of runoff and release it at preferred rates of flow. The following factors should be considered in determining when to use a storm sewer:

- whether or not existing enclosed storm sewers are available within reasonable proximity to the site or if there is a natural outlet available; and
- what the actual size of paved areas is and what the ratio of paved areas is to vegetated areas.

The installation of storm sewers, grassy swales, and other runoff control systems before major building construction begins can aid in controlling site runoff and in avoiding erosion hazards.

Diversions and surface drainageways are needed to intercept runoff and to convey runoff to storm sewers.

3.5.1 Drain Inlet Sediment Filters (BMPs SR5, SR6)

The capacity of the storm sewer system itself can be severely impaired by sediment deposits within the system. Sediment should be prevented from entering the enclosed storm sewer by the use of small sediment traps or sumps and filters at system inlets. Filters made of crushed rock, gravel, or sod, can be placed at inlets where sediment traps cannot be constructed (Figures 3.17 and 3.18). It is essential to regularly check and clean out these sediment traps and filters to insure that they function properly.

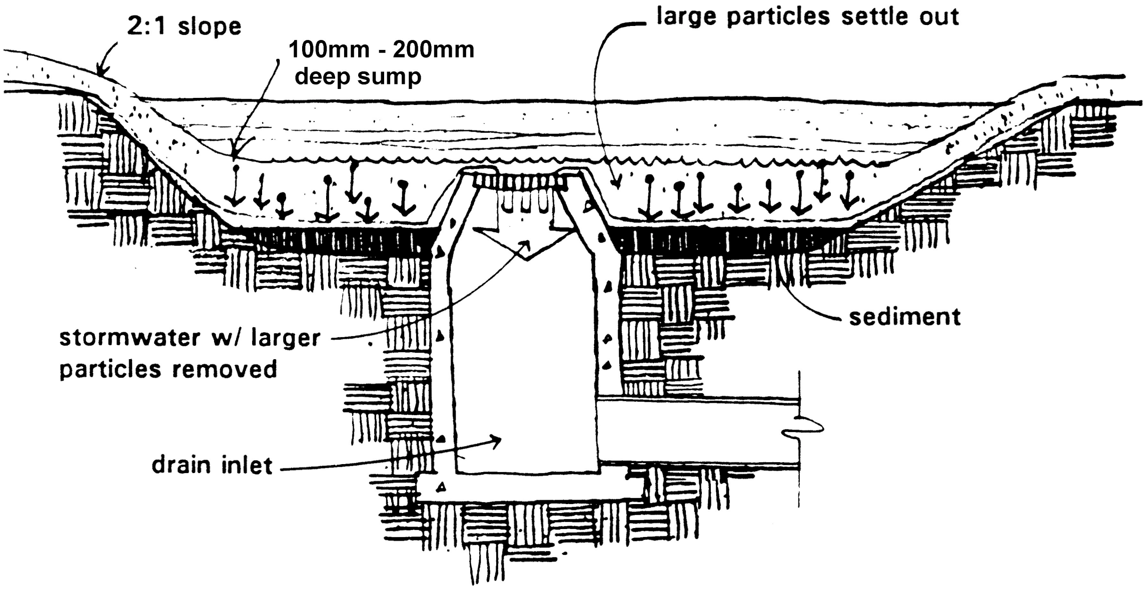


Figure 3.17 Inlet Sediment Trap

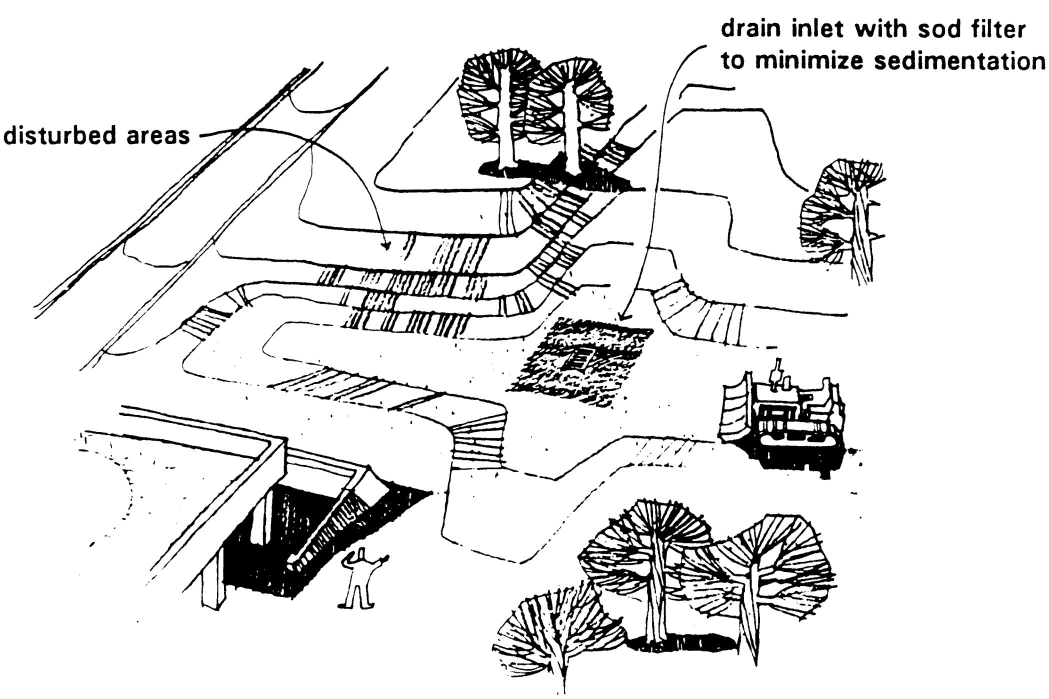


Figure 3.18 Sod Filter for Drain Inlet

3.5.2 Enclosed Drains and Sediment Basins (BMP SR7)

Where enclosed drainage systems do not tie into existing storm drainage mains, consideration should be given to the location and design of the enclosed drainage system outlet. These outlets should be resistant to erosion. The rate of release should be controlled and the energy of flow should be dissipated. It is essential that sediment be removed from runoff before it is released from the site or corridor. Sediment basins are frequently used at storm sewer outlets during construction.

3.5.3 Summary

Enclosed storm sewer systems can safely convey high velocities and large volumes of runoff as well as aid in preventing erosion during and after construction. Sediment should be prevented from entering the storm sewer system and it should be removed from runoff. The BMPs described below achieve these purposes.

1. Drain inlet sediment filters prevent sediment from entering the storm sewer system.

2. Enclosed drains and sediment basins should be carefully located and designed to:

    a. trap sediment that may be in storm water before it is released off the site or downstream; and
    b. control the volume and velocity of runoff.

The use of temporary control measures can reduce the accumulation of sediment in an enclosed drainage system.

3.6 Large, Flat Surface Areas

3.6.1 Exposed Surfaces (BMPs TC1, TC2, EC1, EC2, SR1, SR7)

Although erosion rates on steep exposed slopes are higher than on flat or gently sloping areas, all areas of exposed soil are vulnerable to erosion. If erosion control is ignored on large areas of nearly flat or gently sloping land, it will be possible for significant amounts of soil to be eroded. Clearing, grading, and vegetative restabilization in these areas can be timed so that the extent of exposed area and the duration of exposure is minimized. These areas require prompt vegetative restabilization. Temporary seeding or mulching is needed where large areas will not be permanently stabilized within recommended time limits. Diversions, sediment barriers, or traps constructed on the lower side of large disturbed areas should be used to intercept and collect sediment.

Rights-of-way and parking areas that are being prepared for paving should be protected from rainfall and runoff. Diversions should be constructed to protect these areas from runoff before clearing and grading begin.

Areas that are being prepared for paving should be properly compacted because compaction makes the exposed surface area less vulnerable to erosion. Cleared rights-of-way may be covered with crushed aggregate to reduce erosion. Where rights-of-way will not be used for construction traffic, they can be seeded with a temporary cover.

Gravel or stone filter berms should be used at intervals along the gradient right-of-way to intercept runoff and direct it to stabilized areas, drainageways, or enclosed drainage system inlets. Filter berms also serve to slow and filter runoff and collect sediment. These berms can be crossed by construction equipment.

3.6.2 Paved Surfaces (BMP SR4)

An increase in paved or compacted surface area on a site greatly increases the rate of site runoff. For example, a 20 percent increase in paved area can cause runoff to more than double during a heavy rainfall (8). In addition, the velocity of runoff moving across a paved surface is higher than the velocity of runoff moving across an area of exposed earth or vegetation. Pavement provides very little resistance to flow and does not allow any infiltration. Runoff draining from a paved surface area is also often highly concentrated.

The concentration of runoff leaving paved areas is highly erosive. After construction is complete, the paved roadway itself can serve as a drainageway with curbs and gutters conducting runoff to enclosed drainage system inlets. Where it is not economically feasible to install curbs and gutters, paved surfaces should be designed so that runoff will travel the shortest possible distance across the paved areas. This will prevent large accumulations of runoff from leaving paved areas at high velocities in any one area.

Well-stabilized drainageways will be necessary to receive and convey the increased volumes and velocities of runoff from paved surfaces. Where concentrated flows of runoff leave paved surface areas, outlet points should be especially well stabilized.

3.6.3 Summary

The amount of erosion on flat and gently sloping surface areas can be significant. Erosion on these areas can be minimized by the following techniques.

1. Scheduling development in phases: The extent of the exposed area and the duration of exposure should be kept to a minimum.
2. Vegetative restabilization: Prompt surface stabilization with either temporary or permanent vegetative cover minimizes erosion.
3. Sediment traps: These measures trap soil eroded from exposed surface areas before it is carried off the site or into waterways.

Areas being prepared for paving should be protected from erosion by the use of the following techniques.

1. Gravel or stone filter berms: Filter berms slow and filter runoff and divert runoff from the exposed right-of-way.
2. Compaction: Compaction reduces the vulnerability of the exposed right-of-way to erosion, but increases the velocity and amount of runoff.
3. Aggregate cover: Aggregate cover stabilizes the soil surface while allowing the movement of construction equipment on the right-of-way.

By implementing the control measures listed above, soil erosion on exposed surface areas and areas adjacent to paved surfaces can be minimized.

3.7 Borrow and Stockpile Area (BMPs E1.10, E1.20, E1.35, E1.50, E2.35, E2.55)

Borrow areas, especially those that are located off the development site, cannot be ignored in erosion and sedimentation control planning. Borrow areas, as well as stockpile and spoil areas, should be stabilized.

Borrow and stockpile areas present the same set of problems for the control of erosion and sedimentation as exposed cut and fill slopes. All areas are erodible. Runoff should be diverted from the face of the slopes which are exposed in the excavation process. The runoff must then be conveyed in stabilized channels to stable disposal points.

The BMPs used to control erosion on slopes, such as the top of dikes, diversions, slope drains, etc., should also be used in borrow areas. Only those sections of the borrow area which are currently needed to supply fill should be stripped. Immediately after the required fill has been taken, the exposed area should be stabilized. If practical, each phase of the borrow operation should be graded, covered with topsoil, seeded with permanent vegetation, and mulched.

If final grading is delayed for more than a few days, temporary seeding should be used. By properly timing the disturbance of the natural cover in the borrow area in carefully planned phases, the area of exposed soil and the duration of exposure are reduced and, therefore, erosion losses are reduced.

The topsoil from borrow areas is stripped and stockpiled for later redistribution on the disturbed area. These stockpiles should be located on the uphill side of the excavated area wherever possible so that they can act as diversions. Stockpiles should be shaped and seeded with temporary cover. They can also be covered with plastic and circled at the bottom with a ditch to catch the runoff.

Where borrow areas are off the development site, a separate system for trapping sediment from the borrow area is needed. After the excavation is complete, borrow areas should be restored. Regrading to ensure proper drainage and to blend the borrow area with the surrounding topography is required. Stockpiled topsoil is then redistributed and permanent vegetative cover established.

3.8 Adjacent Properties

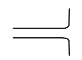
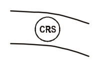
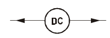
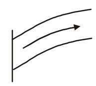
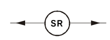
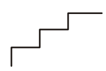
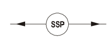
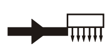
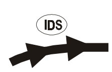
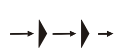
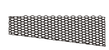
The protection of adjacent properties and waterways from accelerated erosion and sedimentation is an important concern. Relevant BMPs for protecting adjacent properties have already been discussed under the previous problem areas. The following list illustrates some of the BMPs which can be used.

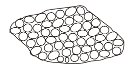
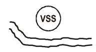
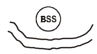
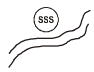
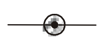
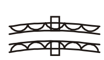
1. Sediment traps
2. Diversions
3. Grass waterways
4. Rock and washed gravel check dams
5. Vegetative filter strips
6. Filter fences

A more complete list of applicable BMPs is shown in The Unified Coding System in Table 3.2.

TABLE 3.2
UNIFIED CODING SYSTEM FOR EROSION AND SEDIMENT CONTROL BMPs
AND THEIR APPLICABILITY TO CONTROL VARIOUS PROBLEM AREAS

BMPs	**Code**	**Symbol**	Problem Areas: Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
I. Cover Practices									
TC1 Temporary Seeding	TS	◄ TS ►	X		X		X	X	X
TC2 Mulching & Matting	MU	◄ MU ►	X				X	X	
TC3 Clear Plastic Covering	CPC	◄ CPC ►	X					X	
PC1 Preserving Natural Vegetation	VEG	◄ VEG ►	X	X					
PC2 Buffer Zones	BZ	◄ BZ ►	X	X					X
PC3 Permanent Seeding & Planting	PS	◄ PS ►	X				X		
PC4 Sodding	SO	◄ SO ►	X		X		X	X	X
PC5 Topsoiling	TO	◄ TO ►	X				X	X	

BMPs	Code	Symbol	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
II. Erosion Control									
EC1 Stabilized Construction Entrance & Tire Wash	CE						X		
EC2 Construction Road Stabilization	CRS		X						
EC3 Dust Control	DC						X	X	X
EC4 Pipe Slope Drains	PSD		X						
EC5 Subsurface Drains	SD		X						
EC6 Surface Roughening	SR		X				X		
EC7 Gradient Terraces	GT		X					X	
EC8 Bioengineered Protection of Very Steep Slopes	SSP		X					X	
EC9 Level Spreader	LS				X				
EC10 Interceptor Dike & Swale	IDS		X					X	X
EC11 Check Dams	CD				X				X
EC12 Outlet Protection	OP			X	X				

BMPs	Code	Symbol	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
II. Erosion Control, con't.									
EC13 Riprap	RR		X	X	X				
EC14 Vegetative Streambank Stabilization	VSS			X					
EC15 Bioengineering Methods of Streambank Stabilization	BSS			X					
EC16 Structural Streambank Protection	SSS			X					
III. Sediment Detention									
SR1 Filter Fence	FF			X		X			X
SR2 Straw Bale Barrier	STB			X		X			X
SR3 Brush Barrier	BB		X	X					X
SR4 Gravel Filter Berm	GFB		X	X			X		X
SR5 Storm Drain Inlet Protection	IP		X			X			X
SR6 Sediment Trap (or Sump)	ST			X	X				X
SR7 Sediment Pond (or Basin)	SB			X	X	X			X

3.9 References

(1) Tiffany, Chris, Gary Minton and Rachel Friedman-Thomas, Erosion and Sediment Control: An Evaluation of Best Management Practices on Construction Sites in King County, Washington, King County Conservation District, Draft, April, 1990.

(2) Maryland Dept. of Water Resources, C. Becker, T.R. Mills and Hittman Associates, Inc., Guidelines for Erosion and Sediment Control Planning and Implementation, U.S. EPA, Washington D.C., 1972, p. 31.

(3) Washington State Dept. of Transportation, Standard Specifications for Road, Bridge and Municipal Construction, 1988.

(4) U.S. Dept. of Agriculture Soil Conservation Service and Milwaukee Co. Soil and Water Conservation District, Minimizing Erosion in Urbanizing Areas: Guidelines, Standards and Specifications, U.S.D.A. Soil Conservation Service, Madison, WI., 1973, p. 33.

(5) Maryland Dept. of Water Resources, C. Becker, T.R. Mills and Hittman Associates, Inc., Guidelines for Erosion and Sediment Control Planning and Implementation, U.S. EPA, Washington D.C., 1972, p. 15.

(6) Michigan Soil Conservation Service, Streambank Protection by Vegetative Measures, Soil Conservation Service, Lansing MI., 1971, p. 580B-2.

(7) Hittman Associates, Inc., Workbook: Control of Sediment Generated on Construction Sites, Columbia, MD., 1973, p. 2.

(8) Hittman Associates, Inc., Workbook: Control of Runoff During Construction, Columbia, MD., 1973, p.1.

(9) Reinelt, Loren E., Construction Site Erosion and Sediment Control Inspector Training Manual, University of Washington, November, 1991.

4.0 GUIDELINES FOR CONTROLLING POLLUTANTS OTHER THAN SEDIMENT ON CONSTRUCTION SITES

4.1 Introduction

Potential pollutants other than sediment associated with construction activity include numerous hazardous wastes as well as other solid and liquid wastes. Hazardous wastes include pesticides (insecticides, fungicides, herbicides, rodenticides etc.), petrochemicals (oils, gasoline, asphalt degreaser etc.) and other construction chemicals such as concrete products, sealer, paints, and wash water associated with these products. Other wastes include paper, wood, garbage, sanitary wastes, and fertilizer.

Practices should be used that prevent these potential pollutants from leaving the construction site. Good erosion and sediment control, coupled with stormwater management, will deter the movement of large amounts of sediment off the site. [It must be recognized, however, that pollutants carried in solution in runoff water, or fixed with sediment crystalline structures (e.g., crystalline clays), will be carried through the erosion and sediment control defenses.] Pollutants such as oils, waxes, and water-insoluble pesticides, form surface films on water and on solid particles, and also, oil films serve as a medium for concentrating water-soluble insecticides. Other than by use of very costly water-treatment facilities, or long runoff water detention periods, these pollutants become nearly impossible to control once present in the runoff.

The most economical and effective controls for pollutants other than sediment generated on construction sites, are the exercise of good "housekeeping" practices, and an awareness by construction workers, planners, engineers, and developers of the need and purpose of compliance with federal, provincial, and local regulations. For example, most pesticides can kill forms of life other than their pest targets. Certain insecticides can persist for months or years in soil and water, and many toxic chemicals can be passed along plant and animal food chains. Similarly, high levels of nutrients (principally phosphorus and nitrogen) from fertilizers used to revegetate exposed subsoils in graded areas may enter waterways and ponds, and increase the growth of algae at the surface to such an extent that light penetration in the water column is decreased. The end result is over-enrichment (or eutrophication). In confined water bodies, over-enrichment can lead to complete deoxygenation of the water and consequent death of fish and other organisms.

Ways must be found to protect ponds, wetlands, lakes, streams, and coastal and estuarine water bodies from damage by sediment and other pollutants generated during construction activities.

The variety of pollutants and the severity of the damage they cause depend upon a number of factors. The most significant of these include the following:

- the nature of the construction activity;
- the physical characteristics of the construction site, including such factors as weather, time of year for construction, topography, soil condition, drainage systems, etc.; and
- the proximity, quantity, and quality of the receiving waters (i.e., the amount and purity of the water receiving the contaminated runoff).

It is reasonable to expect, for example, that potential pollution resulting from fertilizers used during revegetation would be more severe on a highway or housing development than for a shopping center development. This is because highways and housing developments usually have far greater landscaping requirements than shopping centers which are composed mostly of rooftops and pavement.

The physical characteristics of the construction site have a major bearing on the potential severity of pollution from construction activities. As in the case of sediment, the vast majority of all pollutants are carried into the receiving waters via runoff. The amount of runoff coming from a construction site is dependent upon hydrologic factors. These include the amount, intensity, and frequency of rainfall; the infiltration rate of the soil; surface roughness; and the length and steepness of the ground slope. Large areas denuded or stripped of vegetation, long slopes, steep slopes, tight soils, and high intensity rainfall are all factors conducive to heavy runoff.

Another physical factor influencing the severity of pollution is the proximity of the pollutant, or potential pollutant, to the receiving water. For example, fertilizers applied to a streambank are more apt to cause water pollution than fertilizers applied to a slope well upland of the waterway.

The following sections deal with the nature and control of various construction-related pollutants, other than sediment.

4.2 BMP CP1: Pesticide Control

Although the word "pesticide" has come to mean only those chemicals which attack insect populations, here the word is used to include herbicides and rodenticides as well as chemicals commonly known as pesticides. Insecticides, rodenticides, and herbicides have historically been used on construction sites to increase health and safety, maintain a pleasant environment, and reduce maintenance and fire hazards. Often, rodents are attracted to construction sites and rodenticides are used.

Pesticides should only be used in conjunction with Integrated Pest Management (IPM). IPM utilizes a needs assessment which determines which method to use and the necessity of controlling a pest population. Pesticides should be the tool of last resort; methods which are the least disruptive to the environment and to human health should be used first (1).

If pesticides must be used, clearance for use of any of these chemicals is often required by restrictive regulations. All pesticides should be stored and applied in accordance with regulations. An awareness of the need to adhere to recommended dosages, type of application equipment, time of application, cleaning of application equipment, and safe disposal of these chemicals, will go far in limiting the pollution of waterways. Application rates should conform to registered label direction. Many of these compounds are considered "Hazardous Wastes" and must be disposed of properly. Disposal of excess pesticides and pesticide-related wastes should conform to registered label directions for the disposal and storage of pesticides and pesticide containers set forth in applicable regulations. General disposal procedures are as follows:

- dispose of through an appropriate waste management firm or treatment, storage and disposal company;
- use up, or give away to garden center, landscape service, etc.; and
- triple rinse containers before disposal, reuse rinse waters as product.

Pesticide storage areas on the construction site should be protected from the elements, from vandals, and from the curious. Warning signals should be placed in areas recently sprayed or treated with the most dangerous pesticides. Persons involved in the mixing and application of these chemicals, to be in compliance with regulations, must wear suitable protective clothing.

Other practices include the following:

- set aside a locked, weather-resistant storage area;
- lids should be tightly closed;
- keep in a cool, dry place – many pesticides rapidly lose their effectiveness if stored in areas exposed to heat;

- in case of a leak, put original container into a larger container and label it properly;
- check containers periodically for leaks or deterioration;
- keep a list of products in storage;
- use plastic sheeting to line the area;
- neighbors on properties adjacent to the one being sprayed should be notified prior to spraying; and
- all storage sheds, dumpsters or other storage facilities should be regularly monitored for leaks and repaired as necessary - remind workers during subcontractor or safety meetings about proper storage and handling of materials.

4.3 BMP CP2: Handling Of Petroleum Products

Petroleum products are widely used during construction activities. They are used as fuels and lubricants for vehicular operations, power tools, and general equipment maintenance. These pollutants include oils, fuels such as gasoline, diesel oil, kerosene, lubricating oils, and grease. Asphalt paving can be a pollutant source as it continues to release various oils for a considerable length of time. Most of these pollutants adhere to soil particles and other surfaces easily.

One of the best modes of control is to retain sediments containing oil on the construction site. Soil erosion and sediment control practices can effectively accomplish this. Improved maintenance and safe storage facilities will reduce their chances of contaminating construction sites. One of the greatest concerns confronting uses of these petroleum products is the method for waste disposal. Oil and oily wastes such as crankcase oil, cans, rags, and paper dropped in oils and lubricants, can be best disposed of in proper receptacles or recycled. Waste oil for recycling should not be mixed with degreasers, solvents, antifreeze, or brake fluid. The dumping of these wastes in sewers and other drainage channels is usually illegal and could result in fines or job shutdown. A further source of these pollutants is leaky vehicles. Proper maintenance of equipment and installation of proper stream crossings will further reduce pollution of water by these sources. Stream crossings should be minimized through proper planning of access roads.

Guidelines for storing petroleum products are as follows:

- store products in weather-resistant sheds where possible;
- create shelter around area with cover and wind protection;
- line the storage area with double layer of plastic sheeting; or similar material;
- create impervious berm around the perimeter;
- capacity of bermed area should be 110 percent of largest container;
- all products should be clearly labeled;
- keep tanks off the ground;
- keep lids securely fastened;
- post information for procedures in case of spills - persons trained in handling spills should be on-site or on call at all times;
- materials for cleaning up spills should be kept on-site and easily available - spills should be cleaned up <u>immediately</u> and the contaminated material properly disposed of;
- specify a staging area for all vehicle maintenance activities - this area should be located away from all drainage courses; and
- all storage sheds, dumpsters or other storage facilities should be regularly monitored for leaks and repaired as necessary - remind workers during subcontractor or safety meetings about proper storage and handling of materials.

4.4 BMP CP3: Nutrient Application And Control

Inorganic nutrient pollution is most often caused by fertilizers used in revegetating graded areas. The use of proper soil-stabilization measures, sediment control, and stormwater detention structures can be effective means of keeping these materials out of waterways. Only small amounts of inorganic nutrients are beneficial to the productivity of waterways, while excess amounts result in over-enrichment (eutrophication).

Nutrient pollution can be minimized by working fertilizers and liming materials into the soil to depths of 100 mm to 150 mm, and by proper timing of the application. Hydro-seeding operations, in which seed, fertilizers and lime are applied to the ground surface in a one-step operation, are more conducive to nutrient pollution than are conventional seedbed-preparation operations, where the fertilizers and lime are tilled into the soil. In the case of surface dressings, control can be achieved by applying the required quantity of fertilizer in more than one operation. For example, an area requiring an application of 560 kg per hectare of fertilizer could be dressed with about 140 kg per hectare at four separate times over the growing season.

Use of fertilizers containing little or no phosphorus may be required by local authorities if the development is near sensitive water bodies. In any event great care should be taken to use only the minimum amount of phosphorus needed, as determined by soil tests, or advice from qualified professionals.

Near sensitive surface waters, the addition of lime can affect the pH (or acidity) of runoff and receiving waters. Importation of topsoil is better than heavily liming and fertilizing exposed subsoil.

4.5 BMP CP4: Solid Waste Handling And Disposal

Solid waste is one of the major pollutants caused by construction. Solid waste is generated from trees and shrubs removed during land clearing for construction of streets and parking facilities, and during the installation of structures. Other wastes include wood and paper from packaging and building materials, scrap metals, sanitary wastes, rubber, plastic and glass pieces, masonry products, and others. Food containers such as beverage cans, coffee cups, lunch-wrapping paper and plastic, cigarette packages, leftover food, and aluminum foil contribute a substantial amount of solid waste to the construction site.

The major control mechanism for these pollutants is to provide adequate disposal facilities. Collected solid waste should be removed and disposed of at authorized disposal areas. Frequent garbage removal helps maintain construction sites in a clean and attractive manner. Waste containers should be labelled and located in a covered area. Lids should be kept closed at all times. Any useful materials should be salvaged and recycled. For instance, masonry waste can be used for filling borrow pits; trees and brush from land-clearing operations can be converted into woodchips through mechanical chippers and then used as mulch in graded areas. Sanitary facilities should be convenient and well maintained to avoid indiscriminate soiling of adjacent areas. Selective (rather than wholesale) removal of trees is helpful in conservation of soil and reduction of wood wastes. Indiscriminate removal of trees and other beneficial vegetation should be avoided.

Soil erosion and sediment control structures capture much of the solid waste from construction sites. Constant removal of litter from these structures will reduce the amount of solid waste despoiling the landscape. The extension of anti-litter bylaws to cover construction sites is also a viable control mechanism. Adherence to these regulations by construction personnel reduces unnecessary littering through carelessness and negligence.

4.6 BMP CP5: Use Of Chemicals and Other Pollutants During Construction

Many types of chemicals may be used during construction activities. These chemical pollutants include paints, acids for cleaning masonry surfaces, cleaning solvents, asphalt products, soil additives used for stabilization and other purposes, concrete-curing compounds, and many others. These materials are carried by sediment and runoff from construction sites.

A large percentage of these pollutants can be effectively controlled through implementation of source control soil erosion and sedimentation control practices. By using only the recommended amounts of these materials and applying them in a proper manner, pollution can be further reduced. As in the case of other pollutants, good housekeeping is the most important means of controlling pollution. The correct method of disposal of wastes varies with the material.

Other pollutants include concrete wash water from concrete mixers, acid and alkaline solutions from exposed soil or rock units high in acid, and alkaline-forming natural elements. The control of these pollutants involves good site planning and pre-construction geological surveys. Neutralization of these pollutants often provides the best treatment. Sealing of fractures in the bedrock with grout and bentonite will reduce the amount of acid or alkaline seepage from excavations. Adequate treatment and disposal of concrete further reduces pollution.

4.7 BMP CP6: Managing Hazardous Products

- Buy and use only what is needed. Leftovers need to be stored, re-used, given away, recycled or disposed of safely.
- Read labels and follow directions on the label. Hazardous products may be labeled as follows:

Danger	Poisonous	Volatile
Combustible	Caustic	Explosive
Warning	Corrosive	Flammable
Caution		

- Try to keep products in original containers and always keep them well- labeled. If the product must be transferred to smaller containers, use the proper size funnel and avoid spills. Label all containers.
- Labels can fall off with weathering. To prevent, cover with transparent tape. To relabel, use a metal tag attached to the container or use a stencil and spray paint.
- Do not mix chemical substances unless recommended by the manufacturer.
- Use in well-ventilated areas. Protect skin, eyes, nose, and mouth when necessary by wearing gloves, respirator, or other protective clothing.
- Keep corrosive liquids away from flammable liquids.
- Look for nontoxic or less toxic options.
- Use all of the product before disposing of the container.
- There are private firms that specialize in the cleanup of spills.

4.8 BMP CP7: Equipment Washing

Thinners or solvents should not be discharged into the sanitary or storm sewer systems when cleaning large machine parts where discharge of water is required. Use alternative methods for cleaning larger equipment parts such as high pressure, high temperature water washes, or steam cleaning. The water discharged into the sewer must not exceed the discharge limits set by applicable bylaws. Small parts can be cleaned with degreasing solvents which are reused after filtering or recycled. These solvents should not be discharged into any sewer.

4.9 BMP CP8 Spill Control Planning and Cleanup

Construction site supervisors should adopt a spill control plan and identify persons responsible for implementing the plan if a spill of a dangerous or hazardous waste should occur. Any spill that occurs, regardless of the size and/or type of spill, should be reported to the appropriate agencies:

Some of the important components of a spill control plan are as follows:

- establish who to notify in the event of a spill, particularly if it is hazardous;
- provide specific clean-up instructions for different products handled on site;
- assign a person to be in charge of clean-up assistance;
- prepare spill containment and clean-up lists that are easy to find and use;
- post a summary of the clean-up plan at appropriate locations;
- if a spill occurs, demobilize it as quickly as possible;
- if there is a chance that the spill could enter a storm drain or sewer, plug the inlet and turn off or divert any incoming water;
- cover the spill with absorbent material such as kitty litter or sawdust - do not use straw – properly dispose of the used absorbent - if the spill is flammable, dispose of as directed by the local fire department; and
- keep the area well ventilated.

4.10 BMP CP9: Treatment and Disposal of Contaminated Soils

Contaminated ground water or soil may be encountered during earthwork activities or by the spill or leak of a hazardous product. The contaminant may be known or unknown. Sampling and laboratory tests may be required to determine whether a landfill can accept the contaminated soil. In some cases it is possible to reduce the hazardous potential of the soil by aerating it, for example. Private firms can also be consulted for disposal.

4.11 BMP CP10: Concrete Trucks/Spray Washing of Exposed Aggregate Driveways and Walkways

The washout from a concrete truck should be disposed of into one of the following:

- a designated area which will later be backfilled or a slurry pit;
- an area where the concrete wash can harden, be broken up, and then put in the dumpster; or
- a location which is not subject to surface water runoff, and more than 15 metres away from a storm drain, open ditch, or receiving water.

<u>Never</u> dump into the following:

- sanitary sewer;
- storm drain; or
- soil or pavement which carries stormwater runoff.

When spray washing driveways or walkways to expose the aggregate, all wash water should be diverted or sprayed to the sides, not down the driveway. If water must run down the driveway towards the street or sidewalk, it should be diverted at the bottom to a sump or sediment trap.

4.12 BMP CP11: Use of Sandblasting Grits

If used to clean old buildings where lead, cadmium, or chrome-based paints were applied, the sandblasting grits may be a Hazardous Waste. They cannot be washed into any sewer system. Contact an appropriate waste management firm or authority (e.g., B.C. Ministry of Environment, Lands and Parks).

4.13 References

(1) Washington Toxics Coalition, letter dated January 31, 1990.

(2) Reinelt, Loren, Construction Site Erosion and Sediment Control Inspector Training Manual, Center for Urban Water Resources Management, University of Washington, October, 1991.

5.0 GUIDELINES FOR EROSION AND SEDIMENT CONTROL

5.1 Introduction

The manual developed for Puget Sound from which this appendix was derived contains minimum requirements and standards for developing Erosion and Sediment Control (ESC) Plans for small and large construction sites. The development of formal ESC Plans is a legal requirement in Washington State. In British Columbia, there are currently no provincial legal requirements or specifications aimed at developing formal ESC Plans for construction sites (other environmental regulations may apply in some cases – e.g., protection of fish habitat). Some B.C. municipalities have adopted bylaws for controlling erosion and sedimentation associated with construction activities (e.g., maximum allowable concentrations of suspended solids in site runoff water discharged to streams, stabilization of exposed areas, etc.).

For the purposes of this appendix to the GVS&DD BMP Guide for Stormwater, the requirements for ESC Plans laid out in the Puget Sound manual have been edited in the interests of clarity and simplicity, and the wording has been changed to present the information as guidelines, rather than as standards and requirements. Municipalities can adopt bylaws that specify requirements for developing formal ESC Plans by referring to this appendix or other manuals if they wish. A bylaw could adopt the approaches described in this appendix as a whole, or individual elements could be specified as required (see D&K et al., 1998 for guidance in developing bylaws). This appendix can also function as a resource/reference document for use by municipal staff, developers, and construction managers.