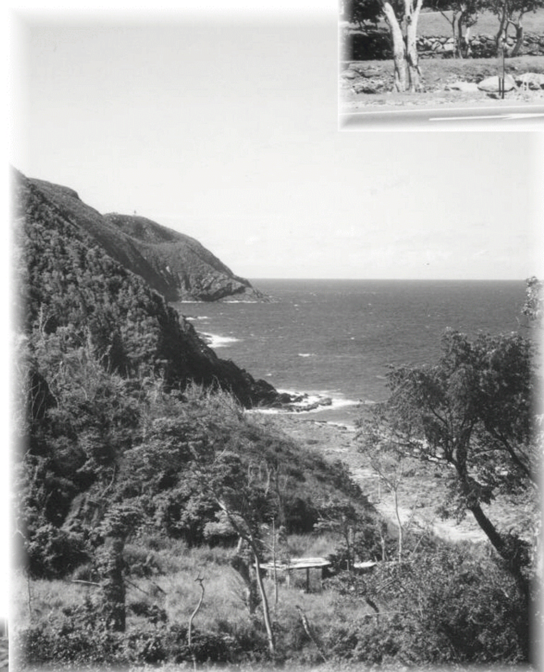
VIRGIN ISLANDS ENVIRONMENTAL PROTECTION HANDBOOK

2002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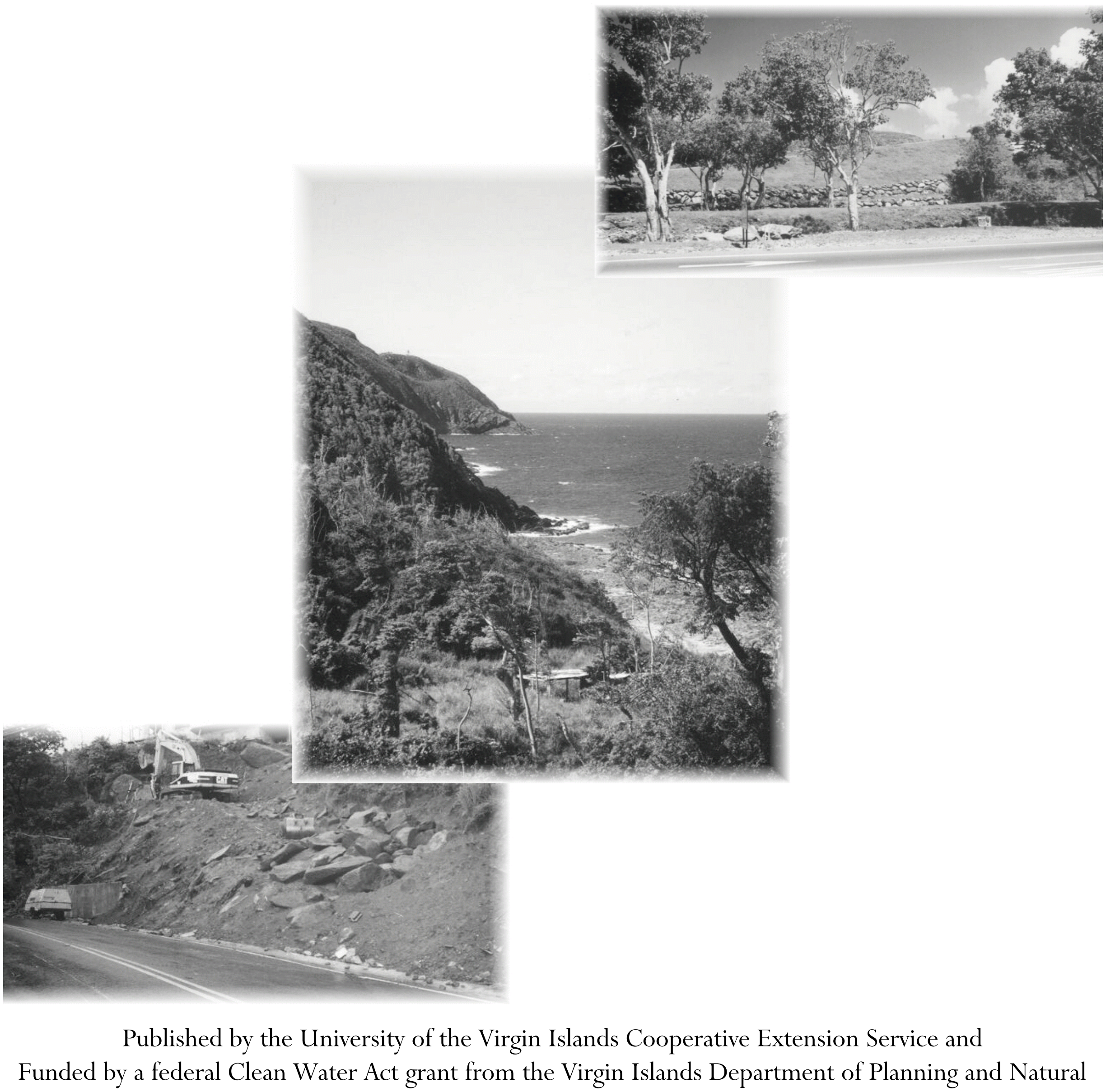

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VIRGIN ISLANDS ENVIRONMENTAL PROTECTION HANDBOOK

2002

A GUIDE TO ASSIST IN THE IMPLEMENTATION OF ENVIRONMENTAL PROTECTION LAWS OF THE UNITED STATES VIRGIN ISLANDS

Original Document by the
Virgin Islands Conservation District
1976

Virgin Islands Nonpoint Source Pollution Control Committee Second Revision – 1995

University of the Virgin Islands Cooperative Extension Service
Third Revision – 2002

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FOREWORD

The Virgin Islands Nonpoint Source (NPS) Pollution Control Committee was formed in the fall of 1992 to address nonpoint pollution problems in Virgin Islands' waters. Nonpoint source pollution of water resources comes from many sources and is caused by rainfall moving over and through the ground. As the rainwater moves, it picks up and carries away both natural and man-induced pollutants. These pollutants are then deposited onto roadways and downhill properties, and into guts, ponds wetlands, ground water, and coastal waters. Nonpoint source pollution in the Virgin Islands is commonly associated with land management practices involving construction, urban runoff, failing septic systems, marina operations, agriculture and hydrologic modification.

The NPS Committee receives funding from the U.S. Environmental Protection Agency through grants to implement the provisions of Section 319 of the U.S. Clean Water Act and Section 6217(g) of the U.S. Coastal Zone Act Reauthorization Amendments. Part of this federal funding was allocated to revise the Environmental Protection Handbook in order to conform with the intent of federal legislation.

The Environmental Protection Handbook is intended for use **only** as a **guide** to the reader, indicating what practices, standards, and procedures should be utilized in the development planning process in order to comply with the Virgin Islands Environmental Protection Law, Title 12, Chapter 13 of the Virgin Islands Code and the corresponding Virgin Islands Rules and Regulations. It is designed to assist contractors, developers, architects, and home builders implement a Stormwater, Erosion and Sediment Control Plan specifically designed for their construction site.

This handbook provides useful information on stormwater, erosion, and sediment control practices that can be used to prevent or reduce the discharge of sediment and other pollutants in stormwater runoff from your construction site. It also describes the practices and controls, and details how, when and where these practices are applicable. However, careful consideration must be given to selecting the most appropriate control measures based on site-specific conditions, and on properly installing the controls in a **timely** manner.

Lack of description or criteria for a specific practice does not suggest it should not be used, but only that consideration by the appropriate reviewing agency will be on the basis of information submitted with the design.

The term "shall" is used where the practice is sufficiently standardized to permit specific delineation of requirements or where safe-guarding of the public health or protection of water quality justifies such definite action. Other terms, such as "should" or "recommended" or "preferred" indicate desirable procedures or methods, with deviations subject to individual consideration.

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CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

Increasing amounts of forest and grass lands in the U.S. Virgin Islands are being converted to housing, roads, and commercial and industrial land uses each year. These construction activities take place on many different kinds of topography and soils, each having different properties and limitations. Such activities and land uses alter natural water flow paths and seepage of water into the soil (change hydrology) and increase erosion and sedimentation, damaging the environment. Ecosystem degradation also results from poor land clearing and landscaping practices that negatively impact plants, wildlife, soil, and water resources. Large-scale removal of vegetation reduces wildlife habitat, promotes soil erosion and sedimentation, and threatens biological diversity. Construction along ridge lines and in guts (intermittent streams) is rapidly depleting moist forest habitat and changing microclimates in the territory.

Increased runoff causes severe erosion and more frequent flooding and has created serious problems in many areas of the Virgin Islands. Eroding road beds and cut slopes (e.g. behind houses or next to roads) cause costly property damage. Sediment and other pollutants run off uphill construction sites, roads, parking lots and other land areas and are deposited along roadways, in guts, on lower-lying property, and in ponds and coastal waters, polluting surface and ground water.

Decreased water seepage into the ground (infiltration) also reduces the islands' critical fresh water supply. As paved areas increase, the amount of rainfall that seeps into the soil and into ground water is decreased. This reduces the water available for plant growth and as ground water for public consumption. In order to provide fresh water to the growing population of the Virgin Islands, and to ensure healthy terrestrial ecosystems, it is critical to retain as much rainwater as possible within the ground, in guts and in other surface water bodies.

The beauty and health of the Virgin Islands' environment is vital to the health and well being of all Virgin Islanders. Many residents enjoy the islands' beaches and coastal waters for swimming, bathing, snorkeling, diving, sailing, and fishing. The Virgin Islands fishing industry depends upon healthy coastal waters and reefs for its livelihood. Many residents also use native plants for cultural or medicinal purposes. However, these uses and environmental health, in general, are often considered to be secondary to the development process. Ugly raw excavation scars remain long after land development has been completed. Coastal water quality has been steadily deteriorating due to the influx of sediment, sewage and other pollutants. The health of the coral reefs is correspondingly declining. Many native plants and animals have become rare, threatened or endangered. This degradation is a long-term threat to the Virgin Islands economy, especially since that economy is dependent upon its environmental health and beauty to attract tourism, the largest industry.

Concern for the environment, including plant, soil and water resources, was made a matter of public policy through passage of the Soil and Water Conservation District Law and the Environmental Protection Law of 1971, as amended. The Environmental Protection Program, overseen by the Virgin Islands Department of Planning and Natural Resources (DPNR), promulgates rules and regulations in accordance with the Environmental Protection Law in order to "*...prevent improper development of land and harmful environmental changes*" (VIDCCA, 1979). This Program includes comprehensive erosion and sediment control measures applicable to both public and private developments, including the construction and maintenance of streets and roads. These rules and regulations are modified as necessary to meet the requirements of new Federal Programs.

1.2 STORMWATER RUNOFF, EROSION AND SEDIMENTATION PROCESSES

Stormwater runoff and ***erosion*** are natural processes that occur in the environment. However, as human activities alter the landscape, adverse impacts to receiving waters (guts, ponds, bays and other coastal areas) may result from changes in the quantity and quality of stormwater runoff. If left unmanaged, the ***hydraulic*** impacts (flooding, erosion, channelization) associated with increased stormwater runoff can be significantly higher than that of undisturbed areas. In addition to causing flooding, this stormwater is also a major ***nonpoint*** (diffuse) pollution source.

Nonpoint source pollution of water resources comes from many sources and is caused by rainfall moving over and through the ground. As the rainwater moves, it picks up and carries away pollutants such as sediment, excess nutrients, bacteria and other pathogens, oil and grease, and other toxic materials. These pollutants are then deposited onto roadways and downhill properties, and into guts, ponds wetlands, ground water, and coastal waters. Nonpoint source pollution in the Virgin Islands results from construction activities, urban runoff, failing septic systems, marina and recreational boating operations, and agriculture.

Urbanization (the conversion of rural areas or open spaces to suburban, commercial, or industrial land uses) typically results in changes to the physical, chemical, and biological characteristics of a ***watershed*** (or drainage basin). A watershed is the area of land that drains water, sediment, and other pollutants to a common outlet along the coastline (bay, lagoon or other coastal area, see Figure 1.1). The physical processes by which construction and other urban activities adversely affect water volumes and quality are ***stormwater runoff***, ***erosion*** and ***sedimentation***. Each of these processes has different impacts upon receiving waters.

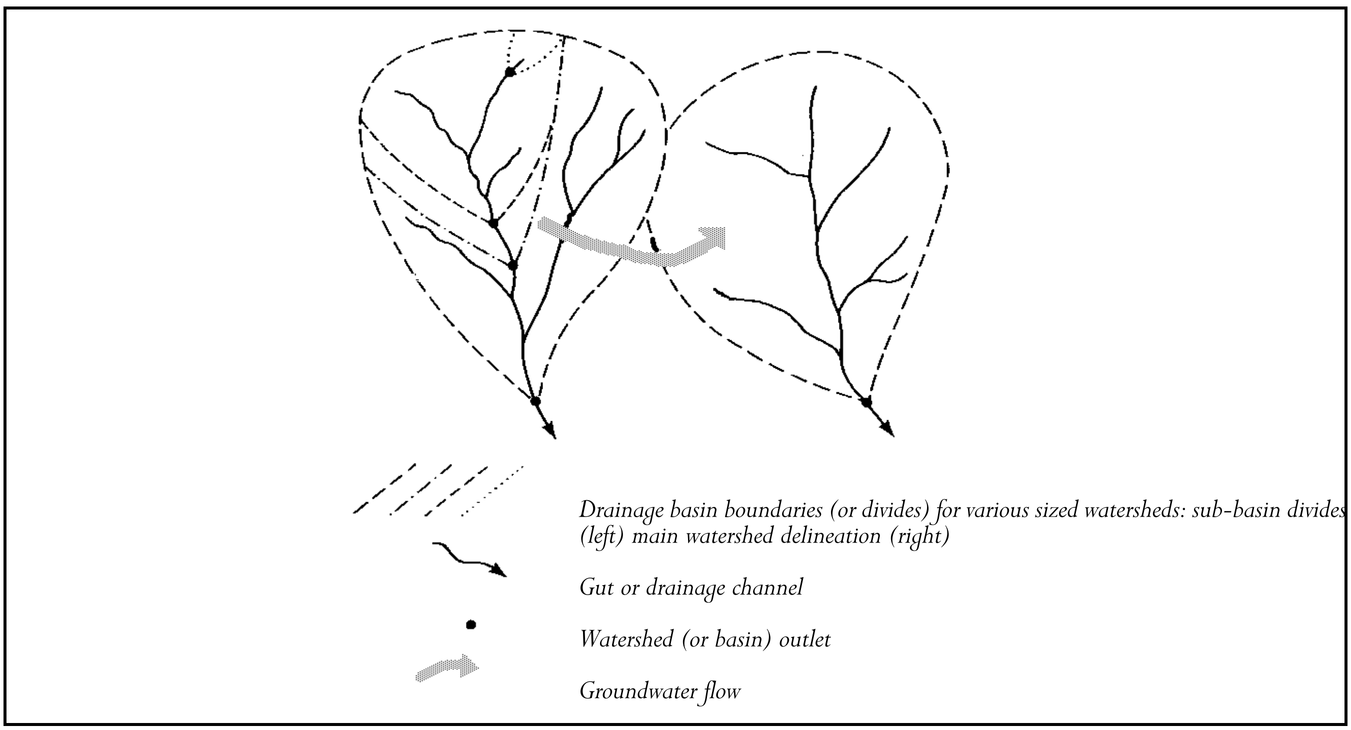

Figure 1.1. Watersheds (or drainage basins) and their boundaries (Dunne and Leopold, 1978).

1.2.1 Stormwater Runoff

Natural vegetated and open forest areas are ***pervious*** areas – under natural conditions, rainwater that falls on these areas seeps into the soil and does not run over the land surface. Vegetation (trees, grasses, bushes and other ground covers) slows rainfall, natural depressions temporarily hold water, and the humus layer of the forest floor absorbs rainfall. Plants also reduce raindrop impacts on the soil surface, reducing the detachment and erosion of soil particles through raindrop splashing (Donahue, Miller, and Shickluna, 1983). During development and urbanization, however, the soil's plant cover and humus layer are stripped from the land by clearing and grading. These activities increase the amount of rainwater that runs off the land surface as ***stormwater runoff***. When pervious areas are converted to ***impervious*** land uses (housing, roads, parking lots, or commercial areas) the amount of vegetation (and therefore the perviousness of the land) is decreased and stormwater runoff volume and velocity increases. Therefore, rain falling onto the surface of unmanaged, urbanizing watersheds results in a predictable increase in the quantity of runoff flowing to coastal waters (see Figure 1.2).

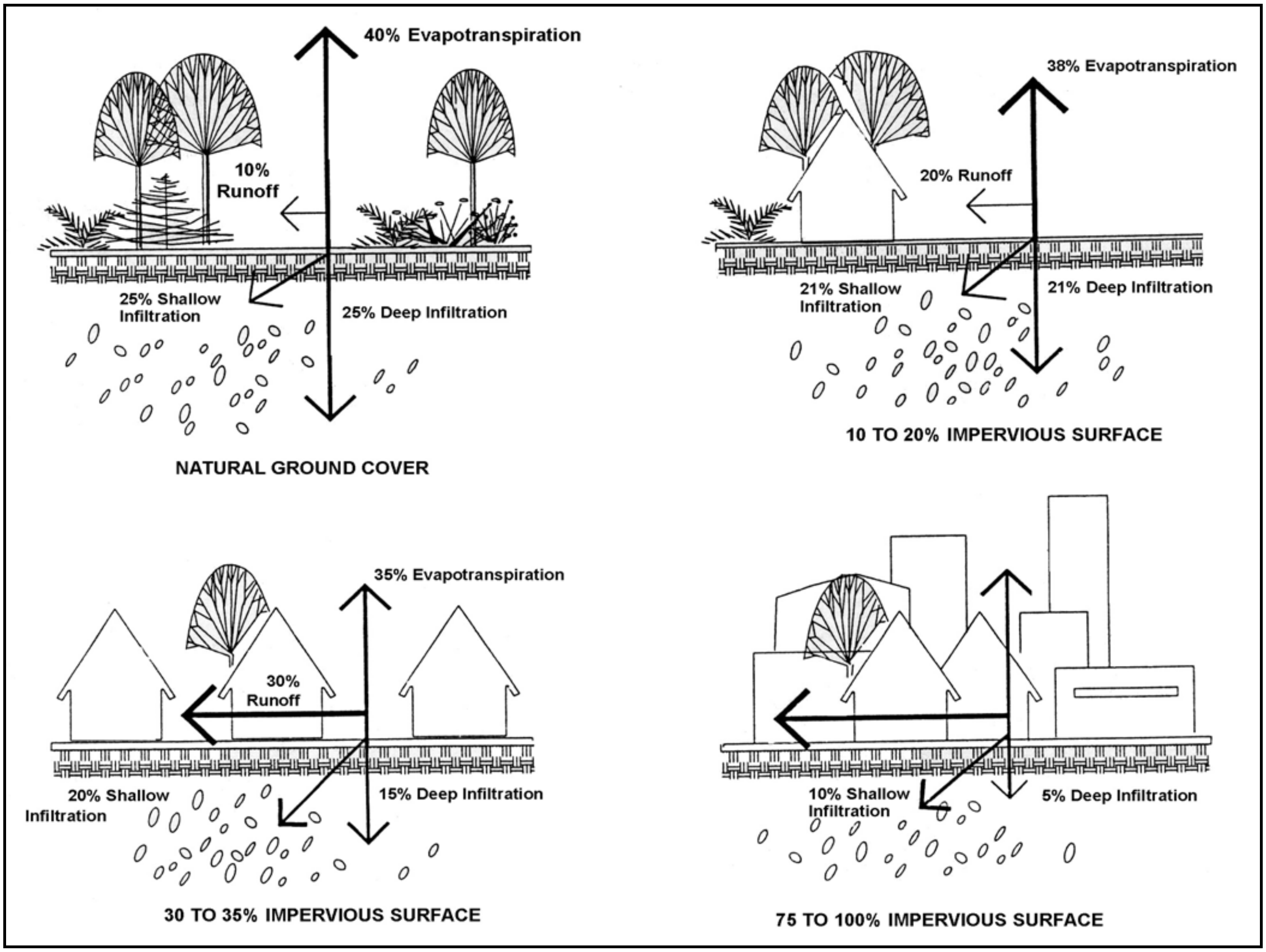

Figure 1.2. Water cycle changes associated with urbanization and resulting increases in impervious surfaces (*Arnold & Gibbons, 1998*).

1.2.2 Changes in Hydrology

The great increase in stormwater runoff due to urbanization changes the ***hydrology***, or the natural water movement, of the watershed. Hydrologic changes in a watershed are magnified after the completion of construction. Impervious surfaces prevent rain seepage into the soil, resulting in much increased volumes and speed (rate or velocity) of runoff. Control of higher stormwater flows requires the construction or "improvement" of runoff culverts, swales or other stormwater channels or the modification of existing drainage systems to avoid erosion of gut banks and steep slopes. The hydrologic changes in drainage channels or natural guts resulting from urbanization include:

- Increased peak runoff discharges two to five times pre-development levels;
- Increased volume of stormwater runoff produced by storms (a moderately developed watershed can produce 50% more runoff than a forested watershed during the same storm);
- Increased frequency and severity of flooding;
- Greater runoff velocity during storms; and
- Reduced water levels in soils, guts, and aquifers due to the reduced level of infiltration in the watershed. This change in the hydrologic cycle (Figure 1.3) can result in microclimate change in small, insular, tropical island ecosystems, such as the Virgin Islands.

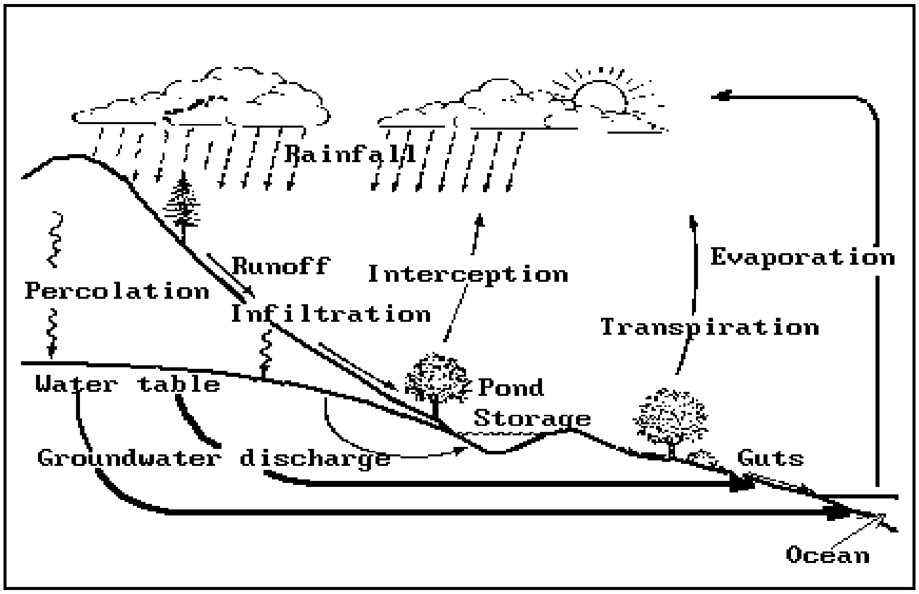

Figure 1.3. The hydrologic cycle (modified from Dunne and Leopold, 1978).

1.2.3 Erosion

Increased stormwater runoff volume and velocity results in increased ***erosion***. Water erosion is the loosening and removal of soil particles from the land surface by running water. The rate of erosion is directly related to stormwater runoff velocity and volume. There are many different types of erosion: raindrop, sheet, rill, gully, and stream channel erosion. Removal of vegetation from the land surface during construction and other land-clearing activities increases all these types of erosion. (Erosion can also be caused by wind – many wind erosion control practices are similar to water erosion control practices.)

The primary factors affecting erosion are rainfall intensity and frequency, soil characteristics, vegetative and other surface cover, topography (slope), climate, and aspect (i.e., degree of exposure to sun and tradewinds). Rainfall ***intensity*** (the volume of rainfall in a given time period) and slope steepness are the most significant factors affecting erosion. Soil physical factors (texture, structure) that affect infiltration capacity and soil detachment and transport are also important. Plants help to reduce erosion by intercepting rainfall and reducing raindrop energy, slowing runoff velocity, holding soil in place with roots, and improving soil porosity.

1.2.4 Sedimentation

Sedimentation occurs when eroded soil particles suspended in stormwater runoff are deposited onto flood plains, roadways or downhill properties, or into guts, ponds and coastal waters. Sediment can travel either suspended in runoff water or it can travel along the ground surface or the bottom of a channel or gut. Suspended sediment in stormwater runoff is the largest pollutant, by volume, in Virgin Islands' waters. Factors affecting sedimentation include runoff velocity, soil particle size, drainage channel roughness, and flow obstructions. Obstructions in the path of runoff water and rough channels slow runoff, causing sediment to settle to the bottom of the channel, gut or pond. Soil particle size and weight also affect sedimentation: finer particles (clays) will stay suspended in runoff water for a longer period of time and will travel farther than larger, heavier particles (like sands).

1.3 POLLUTANTS AND THEIR IMPACTS

As the population density of an area increases, there is a corresponding increase in pollutant loadings generated from human activities. Pollutant export increases dramatically both during and after development. During construction, soils are exposed and large amounts of sediment, along with attached soil nutrients and other pollutants, can run off into surface waters if proper erosion and sedimentation controls are not used. Once a construction site is stabilized, pollutants accumulate rapidly on impervious surfaces and are easily washed off. The primary pollutant carried by stormwater runoff is sediment. However, many other pollutants are transported to coastal waters by stormwater runoff: excess nutrients, harmful bacteria and viruses, oil and grease, and heavy metals and other toxic substances. The primary source of many of these pollutants is from the atmosphere (car and truck emissions), building surfaces and paving materials, and vehicles (Schueler, 1987). Some of these pollutants, such as nutrients, heavy metals, and hydrocarbons, also travel attached to sediments. Pollutants typically enter surface water through untreated stormwater runoff. The overall effect of development results in a 10-fold increase in the amount of pollutants entering surface waters (after Schueler, 1987).

1.3.1 Sediment

Sediment is the most prevalent pollutant, by volume, polluting surface waters in the U.S. Virgin Islands. Uncontrolled construction site sediment loads have been reported to average 35 to 45 tons/acre/year in the continental United States (Novotny and Chesters, 1981). However, a 1986 study of erosion rates on St. Thomas and St. Croix estimated erosion from a disturbed dirt road site to be 591 tons/acre/year (Wernicke, Seymour and Mangold, 1986). Studies of erosion rates in the Fish Bay watershed on St. John have soil loss from dirt roads of between 100 to 600 tons per year (MacDonald, et. al., 1997; Sampson, 1997).

Sediment has many short and long term harmful impacts on aquatic ecosystems. These include: increased turbidity, reduced light penetration (which inhibits coral and seagrass growth), reduced prey capture for sight-feeding fish, clogging of gills and filters in fish and shellfish, reduced spawning and juvenile fish survival, and decline of commercial and recreational fishing success (Schueler, 1987). Heavy sediment deposition in coastal waters smothers seagrass beds and coral reefs, increases sedimentation of channels and harbors (requiring more frequent dredging), changes bottom composition, and leads to loss of use for recreational purposes (such as swimming and snorkeling) (U.S. EPA, 1993). The primary cause of coral reef degradation in coastal areas is attributed to land disturbances and dredging activities due to development activities (Rogers, 1990). Additional chronic effects may occur where there are sediments rich in clay or organic matter (as is frequently the case in the Virgin Islands). Heavy metals and other toxic pollutants can tightly attach to soil particles. When these contaminated sediments settle to the bottoms of ponds, bays, channels and lagoons, they present a continued risk to aquatic and benthic life (organisms that live in the sediments at the bottom of bays, estuaries, and other waterbodies), especially when the sediments are disturbed and resuspended (U.S. EPA, 1993).

1.3.2 Nutrients

Excess levels of ***nutrients*** (particularly nitrogen and phosphorus) that runoff to coastal waters cause an imbalance in the natural nutrient cycle, leading to unwanted and excessive algae growth. This process is called ***eutrophication*** (Arms and Camp, 1988; Dunne and Leopold, 1978; Miller, 1982). Excessive algae growth uses up dissolved oxygen in the water and results in decreased fish, coral, and seagrass populations, and in extreme cases, can result in fish kills and widespread destruction of benthic habitats. Algal blooms can also cause discoloration and odors, cover water surfaces depriving aquatic organisms of light, and clog waterways. Surface algal scum and the release of toxins from sediment may also occur.

1.3.3 Bacteria, Viruses and Other Pathogens

Stormwater runoff from residential, commercial, and industrial areas usually contains levels of ***bacteria*** and other harmful (pathogenic) organisms (viruses, parasites) that exceed public health standards for water-contact recreation or seafood consumption. The presence of pathogens in runoff may result in beach closings for recreational uses due to public health hazards, as well as contaminated fish and shellfish catches. In the Virgin Islands, beach closures frequently occur due to sewage bypasses. However, as more stringent water quality monitoring is put in place, it is very likely that more beach closures will occur due to contamination by bacteria, viruses and other pathogens.

1.3.4 Petroleum Hydrocarbons (Oil and Grease)

Most of the oil, grease and other petroleum hydrocarbon pollutants found in stormwater runoff come from car and truck engines that leak oil and other fluids. Therefore, hydrocarbon levels are highest in stormwater runoff from parking lots, roads, and gas stations. Some do-it-yourself auto mechanics also dump used oil directly on the ground, in guts, or into storm drains. Petroleum-based hydrocarbon levels in surface waters are often high enough to kill aquatic organisms.

Oil and grease contain a wide variety of hydrocarbon compounds. Some of these are known to be toxic to aquatic life at low concentrations, and many are human carcinogens. Hydrocarbons also tend to collect in bottom sediments where they may persist for long periods of time and result in adverse impacts to benthic communities. Waterbodies with poor circulation (such as enclosed marinas) are particularly susceptible to this phenomenon.

1.3.5 Heavy Metals and Toxic Substances

Heavy metals and other toxic materials found in stormwater runoff are of concern because of their poisonous effects on aquatic life and their potential to contaminate ground water. Copper, lead, and zinc are the most common metals found in stormwater runoff (many come from trucks and cars). A large amount of the metals present in stormwater runoff are attached to sediment. Metals and toxic compounds that enter coastal waters can accumulate in the tissues of fish and shellfish, harming human health.

1.4 PROPER PLANNING

Proper planning recognizes that land is a limited resource and has many physical variations that need to be considered prior to development. Proper planning provides for the conservation and wise use of soil, water, plant and other natural resources. Use of this publication, along with the *Soil Survey of the Virgin Islands* (USDA-NRCS, 1995; USDA-SCS, 1970, http://www.statlab.iastate.edu/soils/soildiv/surveys/virgnis.pdf) to get information about the particular site, including soils and erosion and sediment control information, is one of the first steps to proper planning.

1.4.1 Land is a Limited Resource

Primary consideration must be given to critical habitats and environmentally-sensitive areas (coastal areas and wetlands such as guts, salt ponds, and mangrove lagoons) when planning for development. Available farmland must also be considered in the process. Developments that result in irreversible land use changes represent a loss of valuable resources. The long-term impacts of land conversion on the quality of the Virgin Islands' remaining natural ecosystems and coastal water resources, as well as to the productive capacity of our farmland, should be evaluated.

Most of the land in the Virgin Islands (St. John, St. Thomas and the North Shore of St. Croix) is steep and very susceptible to soil erosion and sediment loss. Since constant development pressures are making this resource more and more valuable, it becomes increasingly evident that future developmental pressure is going to be on steeper, more erodible soils. Therefore, careful assessment of the land as a natural resource base is a necessary first step toward planning the future development of an area. Development must be carefully adjusted to that base if serious environmental problems are to be avoided.

1.4.2 Know Your Soil

One of the first steps in sound development planning is to know the soils and select the best possible site for the use intended. Soil properties have a strong influence on the way that people use and should use the land. With the limited flat land in the Virgin Islands, and much of that subject to flooding, development will increase on the steeper upland areas. Soil properties of each parcel need to be determined prior to development to prevent costly mistakes.

The use of the *Soil Survey of the Virgin Islands* is a necessity in planning for development. The Soil Survey is a basic inventory of the soil resources of the islands. The survey includes soil maps, soil descriptions, and soil interpretations. It can be used as a tool in determining soil limitations for many suburban and urban uses and in selecting sites and designing structures to minimize environmental and soil-related problems. Digital copies of the text of the *Soil Survey of the Virgin Islands* revised in 1995 can be found and downloaded from: http://www.statlab.iastate.edu/soils/soildiv/surveys/virgnis.pdf. Maps can be obtained digitally from the UVI Conservation Data Center, or the USDA-NRCS Caribbean Office in Puerto Rico.

1.5 ORGANIZATION OF THIS HANDBOOK

Chapter 2 discusses planning strategies and practices that can be used during development planning phases. Before development occurs, land in a watershed is available for a number of pollution prevention options, such as setbacks, buffers, or open space requirements. Siting requirements or restrictions and other land use ordinances, which are highly effective in reducing pollution, are also more easily implemented during this period. If development has started before these practices can be implemented, then these options may not be practicable or cost-effective.

Chapter 3 presents practices to control construction-related erosion and soil loss (sedimentation). The implementation of proper erosion and sediment control practices during construction can significantly reduce erosion of valuable topsoil and damage associated with sedimentation.

Chapter 4 presents practices to control stormwater runoff from new and existing development. Practices such as detention ponds or constructed wetlands that treat stormwater runoff are most easily implemented in new projects where their design can be incorporated into the overall development plan. After development has occurred, the lack of available land severely limits the implementation of cost-effective treatment options. This chapter also presents information on improving pollution prevention through controls that reduce stormwater runoff and pollution generated from ongoing residential and commercial activities.

Chapter 5 provides information and examples for estimating soil erosion from proposed construction activities using the Revised Universal Soil Loss Equation (RUSLE) developed by the USDA Natural Resources Conservation Service (USDA-NRCS Caribbean Area, 1995).

Chapter 6 provides information on use of TR55, a computer model that uses the USDA-SCS Curve Number method to predict stormwater runoff from development sites.

The Handbook also includes a number of appendices. Appendix A provides a Glossary of terms used in this handbook. Appendices B and C provide design and construction specifications for erosion and sediment control practices and stormwater practices, respectively, that are presented in the Handbook. Appendix D contains existing Territorial legislation for the control of erosion, sedimentation, and stormwater runoff from development. This legislation is modified, as necessary, to meet the requirements of any new Federal Programs. Finally, Appendix E is a list of References used to develop this Handbook.

1.6 PURPOSE OF THIS HANDBOOK

The prevention and control of nonpoint pollution from construction activities and other sources in coastal areas require comprehensive solutions to protect and enhance coastal water quality. This handbook will supersede the Virgin Islands Environmental Protection Handbook printed in 1976 (VICD, 1996) and updates the 1995 Revised Handbook (Wright, 1995). You will find many new practices in this handbook that reflect the growing body of knowledge regarding stormwater, runoff and sedimentation control. Many studies conducted following the development of the 1976 Handbook have refined the information available regarding the impacts of nonpoint pollutants from construction sites and other developing areas and the effectiveness and limitations of control practices. The U.S. Environmental Protection Agency has also promulgated new rules, regulations and guidance governing stormwater discharges from construction and urban areas, including the NPDES (National Pollution Discharge Elimination System) Stormwater Rules of 1990 and the 1993 Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters that may apply under certain conditions. This handbook was developed using the most current information available regarding practices to control or prevent nonpoint pollution from urbanizing areas.

The Environmental Protection Handbook is intended for use **only** as a **guide** to the reader, indicating what practices, standards, and procedures should be utilized in the development planning process in order to comply with the Virgin Islands Environmental Protection Legislation, Title 12, Chapter 13 of the Virgin Islands Code and the corresponding Virgin Islands Rules and Regulations. It is designed to assist contractors, developers, architects, engineers, draftsmen and home builders implement a Stormwater, Erosion and Sediment Control Plan specifically designed for their construction site.

The handbook provides useful information on stormwater, erosion, and sediment control practices that can be used to prevent or reduce the discharge of sediment and other pollutants in stormwater runoff from your construction site. It also describes the practices and controls, and details how, when and where these practices are applicable. However, careful consideration must be given to selecting the most appropriate control measures based on site-specific conditions, and on properly installing the controls in a **timely** manner.

The drawings presented in this Handbook are samples derived from publications developed by Federal, state and local agencies regulating erosion and sediment control. These drawings are used for example purposes **only**, they are not intended to be extracted for Erosion and Sediment Control Plans without prior review by a licensed engineer and/or architect before construction.

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CHAPTER 2: PLANNING PRACTICES

2.1 PLANNING - THE BASIS OF SMART DEVELOPMENT

Avoiding the adverse effects of development requires comprehensive planning. Studies by the USGS National Water Quality Assessment (NAWQA) program in the last decade have shown that the water quality and aquatic health of any given area reflect a complex combination of land and chemical use, land management practices, population density, watershed development and natural features such as soils, geology, hydrology and climate. Contaminant concentrations vary from rainy to dry season and watershed to watershed - even among seemingly similar land uses and pollution sources, different areas can have very different degrees of vulnerability (Southeast Watershed Forum, 2001).

Better site design reduces impervious cover, conserves natural areas and prevents stormwater pollution. Fitting the new home or development into the natural topography and existing landscape is an important part of the overall planning process. By following natural contours and features you can minimize clearing, reduce pollution potential, and provide more open space to enhance property values and aesthetics. In addition to structural and non-structural best management practices (BMPs), planning elements also include growth management, land use planning, long-term operation and maintenance, and public education (CH2MHill, 1998). This chapter presents planning strategies and practices that can be used during the initial phases of development to reduce nonpoint source pollution while enhancing land values.

2.2 KNOW YOUR SOILS

The first step to minimize problems involving land use and development is to know the soils and select the best possible site for the intended use. Soil properties have a strong effect on the way that people use and should use the land. With the limited flat land in the Virgin Islands (much of that subject to flooding), development will increase on steeper upland areas. Soil properties of this land need to be determined prior to development to prevent costly mistakes.

The *Soil Survey of the Virgin Islands* (USDA-NRCS, 1995) provides vital information necessary to plan development. It is a basic inventory of the soil resources of the islands. The survey includes soil maps, soil descriptions, and soil interpretations. Soil maps depict soil boundaries and other features, such as guts and roads. The Soil Survey describes the characteristics and properties of each kind of soil in the Virgin Islands, including soil texture (sand, silt or clay), slope, depth, erodibility, permeability, degree of wetness, and other information useful to land developers. It can be used as a tool in determining soil limitations for many rural and suburban uses and in selecting sites and designing structures to minimize soil related problems.

Soils are rated according to their limitations for a given use. These limitations are described as either slight, moderate, or severe. Soils with slight limitations have few problems that limit their use for a given purpose. Moderate limitations can be overcome with careful planning and design of structures. Severe limitations indicate the need for very careful consideration of a site prior to development. In some instances, the cost of overcoming a limitation may be excessive.

Some of the common soil-related limitations in the Virgin Islands are flooding, high shrink-swell potential, high erodibility, very steep slopes, shallow or stony soils, and excessively dry climate. Examples of problems resulting from these limitations include collapsing roadbeds, flooded buildings, cracking and failing building foundations, malfunctioning septic systems, excessive erosion, and sedimentation damage. Measures necessary to help overcome these problems are much easier to identify in the planning phase by using the Soil Survey. The Soil Survey can also be used to map sensitive areas, such as steep slopes and highly erodible soils, wetlands, and gut corridors. Further information on the soils of the Virgin Islands can be obtained from the USDA Natural Resources Conservation Service, the UVI Cooperative Extension Service, or the V.I. Department of Agriculture.

2.3 WATERSHED PLANNING

A ***watershed*** is the area of land that drains water, soil, and pollutants to a common outlet along the coastline (bay, lagoon or other coastal area). Watersheds are of different sizes and can be subdivided to the smallest area with an outlet. Large watersheds, like Coral Bay or Benner Bay, have many outlets into common nearshore areas. Since all land within a watershed drains to a common outlet, any activity on that land will affect downstream areas of the watershed and the bays or coastal areas the watershed drains into. Pollutants found in stormwater runoff can be easily carried from the land into a watershed's guts and drainage ways, eventually finding their way to salt ponds, and coastal and ground waters.

Pollution due to stormwater runoff (a ***nonpoint source***) from urbanizing watersheds differs from point source pollution (discharge of pollutants from a single outlet such as a sewer pipe or a wastewater pipe) in many ways:

The Basics of Watershed-Smart Development

1. Design residential streets for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance and service vehicle access (widths should be based on traffic volume).
2. Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.
3. Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.
4. Create a variable-width, naturally vegetated buffer system along all guts that includes critical features like floodplains, steep slopes, and wetlands .
5. Limit clearing and grading of forests and native vegetation to the minimum amount needed to build lots, allow access and provide fire protection. Manage a fixed portion of any community open space as protected green space.
6. Encourage incentives such as density compensation, buffer averaging property tax reduction, stormwater credits, and by-right open space development to promote conservation of gut buffers, forests, grass-lands, and other valuable areas.
7. Do not discharge unmanaged stormwater from new stormwater outfalls into jurisdictional wetlands, sole-source aquifers or other water bodies.

(From Southeast Watershed Forum, 2001)

- Nonpoint sources generally cannot be monitored at their point of origin because their exact source is difficult or impossible to trace.
- Nonpoint source pollution is cumulative: it results from many actions by many different people, animals and/or businesses, and is often spread over wide areas.
- The extent of nonpoint source pollution may vary from place to place and from year to year, depending on geography, geology, weather and human activities.
- Nonpoint source pollution control requires more than structural solutions. Effective control requires the use of comprehensive planning and best management practices, combined with public education, economic incentives, and, in some cases, regulations.

Comprehensive planning is an effective nonstructural tool that can control ***nonpoint source pollution*** from urbanizing areas. Poorly planned growth and development have the potential to degrade and destroy entire watersheds and coastal ecosystems (Mantel et al., 1990). Where possible, growth should be directed to areas where it can be sustained with a minimal impact on the natural environment. While stormwater runoff treatment practices (those that remove or reduce pollutants in stormwater) are an important method of reducing water pollution, a combination of pollution prevention and treatment practices is most effective. Planning, design, and education practices in combination with treatment practices are generally more effective, require less maintenance, and are more cost-effective in the long-term than treatment practices alone (U.S. EPA, 1993).

The primary opportunities to control pollutants in stormwater runoff occur during the siting and design phase; the construction phase; and the post-construction phase. Before construction occurs, a number of pollution prevention options, such as setbacks, buffers, or open space requirements, are available to the property owner. Siting requirements, restrictions and other land use ordinances, such as zoning, are also more easily implemented during this period. These practices protect environmentally sensitive areas such as wetlands and vegetative buffers that filter and trap sediments, nutrients, and chemical pollutants. After construction has occurred, these options may no longer be practicable or cost-effective. Table 2.1 describes the general steps to take in developing a watershed management plan.

Table 2.1. Watershed Management: A Step-by Step Guide (Livingston and McCarron, 1992).

1. **Delineate and map watershed boundary and sub-basins within the watershed.**

2. **Inventory and map natural stormwater conveyances and storage systems.**
(Guts, ponds, salt ponds, etc.)

3. **Inventory and map existing man-made stormwater conveyances and storage systems.**
This includes all ditches, swales, storm sewers, detention ponds, and retention areas and includes information such as size, storage capacity and age.

4. **Inventory and map existing land uses by sub-basin.**

5. **Inventory and map detailed soils by sub-basin.**

6. **Establish a clear understanding of water resources in the watershed.**
Analyze water quality, sediment, and biological data. Analyze subjective information on problems (such as citizen complaints). Evaluate waterbody use impairment — frequency, timing, seasonality of problem. Conduct water quality assessment — low flows, seasonality.

7. **Inventory pollution sources in the watershed.**
Point sources — location, pollutants, loadings, flow, capacity, etc. Nonpoint sources — type, location, pollutants, loadings, etc.
    - land use/loading rate analysis for stormwater;
    - sanitary survey for septic systems; and
    - dry flow monitoring to locate illicit discharges.

8. **Identify and map future land uses by sub-basin.**
Conduct land use loading rate analyses to assess potential effects of various land use scenarios.

9. **Identify planned infrastructure improvements — 5-year, 20-year.**
Stormwater management deficiencies should be coordinated and scheduled with other infrastructure development projects.

10. **Analysis.**
Determine infrastructure and natural resources management needs within each watershed.

11. **Set resource management goals and objectives.**
Before corrective actions can be taken, a resource management target must be set. The target can be defined in terms of water quality standards; attainment and preservation of beneficial uses; or other resource management objectives.

12. **Determine pollutant reduction (for existing and future land uses) needed to achieve water quality goals.**

13. **Select appropriate management practices (point source, nonpoint source) that can be used to achieve the goal.**
Evaluate pollutant removal effectiveness, land owner acceptance, financial incentives and costs, availability of land, operation and maintenance needs, feasibility, and availability of technical assistance.

14. **Develop watershed management plan.**
Develop watershed management plan specific to the area, including such elements as:
- existing and future land use plan;
- master stormwater management plan that addresses existing and future needs;
- wastewater management plan including septic system maintenance programs; and
- infrastructure and capital improvements plan.

The Center for Watershed Development has developed a manual of **better site design principles** (CWP, 1998) for the national Site Planning Roundtable that proscribes innovative and effective resource management techniques to protect waterways, estuaries and coastal habitats. The principles revolve around the theory that the suburban landscape consists of three habitats: the car habitat (roads, driveways, and parking lots), the human habitat (where we live and work, including our homes and yards), and open spaces and natural areas that are relatively undeveloped (CWP, 1998). Table 2.2 describes the 22 site design principles by habitat category.

2.4 SITE PLANNING PRACTICES

Site planning practices apply to individual sites rather than watersheds or regional drainage basins. The goal of site planning is to reduce pollution generation and to minimize the impacts of stormwater runoff and associated pollutants. The basic premise is that effective site layouts and designs can reduce the need for conventional structural BMPs, reducing development costs (CH2MHill, 1998). Tables 2.3-2.6 (pages 2.7 - 2.9) contain checklists developed by EPA for use in designing stormwater pollution prevention plans for construction sites greater than 1 acre, pursuant to EPA stormwater regulations. These checklists can be used by Virgin Islands developers and contractors to design pollution prevention plans.

Table 2.2. Model development principles for better site design (CWP, 1998).

Residential Streets and Parking Lots

1. Design residential streets for the minimum required pavement width needed to support travel lands; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on traffic volume.
2. Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.
3. Wherever possible, residential street right-of-way widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels (swales).
4. Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should be considered.
5. Where density, topography, soils, and slope permit, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.
6. The required parking ratio governing a particular land use or activity should be enforced as both a maximum and a minimum in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance taking into account local and national experience to see if lower ratios are warranted and feasible.
7. Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.
8. Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in spillover parking areas.
9. Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.
10. Wherever possible, provide stormwater treatment for parking lot runoff using bioretention areas, filter/buffer strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

Lot Development

11. Advocate open space development that incorporates smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.
12. Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.
13. Promote more flexible design standards for residential subdivision sidewalks. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.
14. Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.
15. Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space.
16. Direct rooftop runoff (any not captured by cisterns) to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.

Conservation of Natural Areas

17. Create a variable width, naturally vegetated buffer system along all guts that also encompasses critical environmental features such as the 100-year floodplain, steep slopes and wetlands.
18. The riparian buffer (around guts) should be preserved or restored with native vegetation that can be maintained throughout the delineation, plan review, construction, and occupancy stages of development.
19. Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to built lots, allow access, and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.
20. Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open spaces, street rights-of-way, parking lot islands, and other landscaped areas to promote natural vegetation.
21. Incentives and flexibility in the form of density compensation, buffer averaging, property tax reduction, stormwater credits, and by-right open space development should be encouraged to promote conservation of stream/gut buffers, forests, grass lands, and other areas of environmental value. In addition, off-site mitigation consistent with locally adopted watershed plans should be encouraged.
22. New stormwater outfalls should not discharge unmanaged stormwater into jurisdictional wetlands, sole-source aquifers, or sensitive areas.

Objectives of site planning practices

The following objectives should be incorporated into the site development process:

- Disturb the smallest area necessary for current construction activities in order to reduce erosion and soil loss;
- Avoid disturbing unstable soils or soils especially susceptible to erosion and soil loss, and favor sites where development will minimize erosion and soil loss;
- Protect and retain native plants as much as possible in order to decrease stormwater runoff, filter and/or absorb pollutants, and maintain site hydrology;
- Minimize the percentage of impervious area on the site;
- Avoid alteration, modification or destruction of guts and other natural drainage features on the site (V.I. Code (V.I. DCCA, 1979) requires a permit to cut any tree within 25 feet of the edge of a gut);
- Design sites to preserve natural buffers adjacent to guts, salt ponds and coastal waters; and
- Minimize water quality impacts from landscaping activities by applying chemicals properly (see Good Housekeeping Practices, section 2.6).

Site planning and evaluation are extremely important – they can significantly reduce sediment control practice costs by minimizing erosion and keeping sediment on the construction site. Long-term maintenance efforts and costs can also be significantly reduced. While designing the site, planners should identify sensitive areas and land forms that can provide water quality protection, target these areas for preservation or conservation, and incorporate them into the site design. Highly erodible soils should not be disturbed. By locating development away from highly erodible soils, erosion and sedimentation can be significantly reduced. Sediment loads from developing areas where new construction is occurring can be 5 to 500 times greater than loads from undeveloped areas (Gray and Leiser, 1982). Because of the adverse effects of sedimentation (as described in Chapter 1) and the many nonpoint source pollutants (including heavy metals and nutrients) that can be attached to sediment, it is important to limit the volume of sediment entering coastal waters.

What are site planning practices that can be used to reduce runoff, erosion and sedimentation?

- **Phasing and Limiting Areas of Disturbance –** Erosion potential can be reduced by **not** clearing and grading all post-development buffer zones, configuring the site plan to retain large areas of open space, and phasing construction to limit the amount of disturbed area at any given time.
- **Low Disturbance/Low Maintenance –** This site development approach allows clearing and site grading only within a carefully defined building area, preserving and protecting the surrounding natural vegetation. Landscape designs should avoid exotic plants that need large amounts of water, fertilizers and pesticides. Rare, threatened, and endangered species should be preserved. Retaining existing vegetation holds the soil in place and helps to reduce runoff volume and rate, reducing erosion. Low disturbance/low maintenance strategies also minimize fertilizers and pesticide applications that can pollute coastal waters and harm fish and reef habitats.
- **Cluster Development –** Concentrate development and construction activity on a limited area of a site, leaving the remaining area undisturbed. Clustering promotes the design of more effective stormwater runoff, erosion and sediment control practices, helps preserve environmentally sensitive areas, and reduces impervious area.
- **Site Fingerprinting –** Fingerprinting reduces the total amount of disturbed area within a site by placing development away from environmentally sensitive areas (wetlands, guts, floodplains, steep slopes, etc.). At a subdivision or lot level, ground disturbance is confined to areas where structures (buildings, septic system), driveways and roads will exist after construction is complete.

- **Setbacks and Buffers –** Setbacks provide an area between buildings, parking lots and roads and protected areas such as salt ponds, guts, shorelines, or wetlands. A buffer strip is the transitional vegetated area closest to the water body or wetland. Buffers are designed to minimize erosion, stabilize gut banks or shorelines, filter runoff pollutants from adjacent developments, preserve fish and wildlife habitat, provide privacy screening and preserve aesthetic value, and provide access for maintenance or trails (CH2MHill, 1998).
- **Preserving Natural Drainage Channels –** Natural drainage features (guts) should be preserved during development because of their ability to absorb and reduce stormwater runoff flows and to filter pollutants. V.I. Code (V.I. DCCA, 1979) requires a permit to cut any trees within 25 feet of the edge of a gut. Cluster development can be used to preserve guts and allow for incorporation of these features into a site design.
- **Minimizing Impervious Areas –** Impervious areas prevent the infiltration of rainfall into the soil, leading to increased volumes and rates of stormwater runoff. Some practices to minimize impervious areas include: reducing street and sidewalk widths; reducing the use of storm sewers, using permeable materials for sidewalk and driveway construction; requiring open spaces; and/or using porous or cellular pavement.
- **Encourage Xeriscaping –** Xeriscaping is a landscaping method that maximizes water conservation by using drought-tolerant native species. Xeriscaping can reduce landscape maintenance by as much as 50% by reducing watering requirements and fertilizer and pesticide applications (U.S. EPA, 1993). (Contact the USDA Natural Resources Conservation Service or the UVI Cooperative Extension Service for more information on xeriscaping with native plants.)
- **Development Designed to Fit Site Topography –** Creating a design that avoids the need for major grading changes will reduce project expense, soil compaction, destruction of natural drainage ways, and loss of site diversity. By varying lot sizes and building styles and by using at least limited clustering, the need for mass grading can be significantly reduced.

2.5 DEVELOPMENT PLANNING PRACTICES

Planning practices are used to avoid impacting areas that are particularly susceptible to erosion and soil loss; to preserve areas that provide important water quality benefits and/or are necessary to maintain wetland or aquatic ecosystems; and to locate development, including roads, highways, and bridges, to protect the natural integrity of water bodies and natural drainage systems. All of these practices will minimize runoff, erosion and sedimentation.

2.5.1 Pollution Prevention Management Plan

The most effective way to minimize runoff, erosion and sedimentation before and after construction is to implement a ***pollution prevention management plan***. A pollution prevention management plan is a comprehensive approach that addresses the needs of a site or watershed, including land use, stormwater, erosion and sediment control practices, pollutant reduction strategies, and pollution prevention techniques. Before developing a pollution prevention management plan you must first define site, sub-watershed and/or watershed boundaries, target sensitive areas, identify pollutants of concern, and conduct a resource inventory and information analysis. Once environmentally-sensitive areas are identified, areas essential to safeguard coastal waters and prevent nonpoint source pollution can be protected.

The components of a pollution prevention management plan

A pollution prevention management plan must have defined, measurable goals (for example, maintaining runoff volumes at a calculated level relative to undeveloped conditions) in order to be effective. Design and implementation specifications for runoff, erosion and sediment control practices are then incorporated into the plan as methods to achieve the goal. This type of planning is especially necessary when designing larger developments requiring a major permit (i.e., developments greater than 1 acre).

Pollution prevention management plan implementation

Once critical areas, land use designations and goals have been identified, defined and established, management plan implementation strategies can be developed (i.e., once you have followed the steps in Table 2.1). The following are examples of implementation tools that have been successful at controlling nonpoint source pollution:

- Infrastructure planning;
- Limits on impervious surfaces, encouragement of open space and cluster development;
- Setbacks (buffer zones);
- Slope restrictions;
- Site plan reviews;
- Mapping; and
- Environmental impact assessment statements (U.S. EPA, 1993).

Table 2.3. EPA Baseline Construction General Permit Requirements: Pre-Construction Checklist (U.S. EPA, 1992).

STORMWATER POLLUTION PREVENTION PLANS

1. A site description, including:
- ☐ The nature of the activity
- ☐ Intended sequence of major construction activities
- ☐ The total area of the site
- ☐ The area of the site that is expected to undergo excavation
- ☐ The runoff coefficient of the site after construction is complete
- ☐ Existing soil or stormwater data
- ☐ A site map with:
  - ☐ Drainage patterns
  - ☐ Approximate slopes after major grading
  - ☐ Area of soil disturbance
  - ☐ Outline of areas that won't be disturbed
  - ☐ Location of major structural and non-structural controls
  - ☐ Areas where stabilization practices are expected to occur
  - ☐ Surface waters
  - ☐ Stormwater discharge locations
- ☐ The name of the receiving water(s)

2. A description of controls:
- 2.1 Erosion and sediment controls, including:
  - ☐ Stabilization practices for all areas disturbed by construction
  - ☐ Structural practices for all drainage/discharge locations
- 2.2 Stormwater management controls, including:
  - ☐ Practices used to control pollutants occurring in stormwater discharges after construction activities are complete
  - ☐ Velocity dissipation devices to provide non-erosive flow conditions from the discharge point along the length of any outfall
- 2.3 Other controls including:
  - ☐ Waste disposal practices that prevent discharge of solid materials to waters of the U.S.
  - ☐ Practices to minimize offsite tracking of sediments by construction vehicles
  - ☐ Practices to ensure compliance with Federal and Territorial waste disposal, sanitary sewer, and septic system regulations
- 2.4 ☐ Description of the timing during construction when practices will be implemented

3. ☐ Are Federal and Territorial requirements incorporated into the plans?

4. ☐ Are Maintenance procedures for control measures identified in the plan?

5. ☐ Identification of allowable non-stormwater discharges and pollution prevention practices

6. ☐ Contractor certification

7. ☐ Plan certification

Table 2.4. Stormwater Pollution Prevention Plan: Construction/Implementation Checklist (U.S. EPA, 1992).

1. Maintain records of construction activities, including:
- ☐ **Dates when major grading activities occur**
- ☐ **Dates when construction activities temporarily cease on a portion of the site**
- ☐ **Dates when construction activities permanently cease on a portion of the site**
- ☐ **Dates when stabilization measures are initiated on the site**

2. Prepare inspection reports summarizing:
- ☐ **Name of inspector**
- ☐ **Qualifications of inspector**
- ☐ **Practices/areas inspected**
- ☐ **Observed conditions**
- ☐ **Changes necessary to the Stormwater Pollution Prevention Plan**

3. Report releases of reportable quantities of oil or hazardous materials (if they occur):
- ☐ **Notify the National Response Center 1-800-424-8802 immediately**
- ☐ **Notify DPNR in writing within 14 days**
- ☐ **Modify the pollution prevention plan to include:**
  - **- the date of release**
  - **- circumstances leading to the release**
  - **- steps taken to prevent re-occurrence of the release**

4. Modify pollution prevention plan as necessary to:
- ☐ **Comply with minimum permit requirements when notified by EPA that the plan does not comply**
- ☐ **Address a change in design, construction, operation or maintenance that has an effect on the potential for discharge of pollutants**
- ☐ **Prevent re-occurrence of reportable quantity releases of a hazardous material or oil**

Table 2.5. Pollution Prevention Plan for Stormwater Discharge Associated with Construction Activities: Erosion and Sediment Control Checklist (U.S. EPA, 1992).

INSTRUCTIONS: THIS CHECKLIST LISTS THE MINIMUM SEDIMENT EROSION CONTROL REQUIREMENTS UNDER THE US EPA GENERAL PERMIT. CHECK EACH ITEM AND FILL IN THE BLANKS BELOW TO EVALUATE COMPLIANCE FOR EACH DRAINAGE AREA AND LOCATION.

STABILIZATION PRACTICES

☐ Stabilization will be initiated on all disturbed areas where construction activity will not occur for a period of more than 21 calendar days by the 14th day after construction activity has permanently or temporarily ceased.

Stabilization practices to be used include:

☐ Temporary Seeding	☐ Sod Stabilization	☐ Filter Fabrics
☐ Permanent Seeding	☐ Mulching	☐ Other ___________

STRUCTURAL PRACTICES

☐ Flows from upstream areas will be diverted from exposed soils. Practices to be used include:

☐ Drainage Swale	☐ Diversion Dike/Swale	☐ Other ___________

Drainage areas less than 10 disturbed acres	Drainage areas of 10 or more disturbed acres
☐ Sediment controls will be installed Sediment controls include: ☐ Sediment Basin ☐ Sediment Trap ☐ Silt Fence or equivalent controls along all sideslope and downslope boundaries	☐ A sediment basin will be installed ☐ A sediment basin is not attainable on the site; therefore, the following sediment controls will be installed: ☐ Sediment Trap ☐ Silt Fence or equivalent controls along the sideslope and downslope boundaries

Sediment Basin Storage Calculation

_____ acres area draining to the sediment basin

X

3,600 cubic feet of storage per acre*

=

_____ cubic feet of storage required for the basin

* *For further discussion of storage requirements, refer to Chapter 3 and Appendix B,* ***Sediment Basins****.*

Table 2.6. Stormwater Pollution Prevention Plan: Final Stabilization/Termination Checklist (U.S. EPA, 1992).

1.	☐	**All soil disturbing activities are complete**
2.	☐	**Temporary erosion and sedimentation control Practices have been removed or will be removed at an appropriate time**
3.	☐	**All areas of the construction site not otherwise covered by a permanent pavement or a structure have been stabilized with a uniform perennial vegetative cover with a density of at least 70%, or equivalent measures have been employed**

2.6 GOOD HOUSEKEEPING PRACTICES

Good housekeeping refers to keeping a clean and orderly construction site. Good housekeeping practices and common sense prevent contamination of stormwater runoff from construction site chemicals. Good housekeeping practices can reduce accidental spills, improve spill response times, and reduce safety hazards. These practices are inexpensive, relatively easy to implement, and are often effective in preventing stormwater contamination. They can also reduce costs by preventing unnecessary loss of products.

Different types of good housekeeping practices

There are three areas related to good housekeeping on a construction site that should be addressed in each watershed or site development plan. These areas are: proper disposal of building material wastes; proper storage and handling of chemicals used on the construction site; and implementation of a spill prevention and control plan.

2.6.1 Waste Disposal

Proper management and disposal of building materials and other construction site wastes is an important part of pollution prevention. Sources of pollution include surplus or refuse building materials as well as hazardous wastes. All controls and practices must meet the requirements of your Earth Change or CZM Permit and other Federal and Territorial requirements your site is subject to.

This section discusses some of the waste materials encountered at construction sites and, in general, how they should be stored and handled to minimize their exposure to stormwater. However, you should contact the Department of Public Works (DPW) to find out more about waste disposal regulations, or the Department of Planning and Natural Resources (DPNR) to find out how to safely handle, store and dispose of hazardous and toxic chemicals.

2.6.1.a Construction Wastes

Construction projects tend to generate large amounts of solid waste materials that are unique to this activity. These wastes may include, but are not limited to:

- Trees and shrubs removed during clearing and other phases of construction;
- Packaging materials (wood, paper, plastic, cardboard, etc.);
- Scrap or surplus building materials (scrap metals, rubber, plastic and glass pieces, masonry products, etc.);
- Paints and paint thinners; and
- Materials generated by structure demolition (rubble).

Steps to be taken to properly dispose of construction wastes

- Select a designated waste collection area onsite;
- Provide an adequate number of containers with covers;
- Locate containers in a covered area, when possible;
- Arrange for waste collection before containers overflow;
- Provide immediate clean-up in the event of a spill;
- Plan for additional containers and more frequent pick-ups during demolition phases;
- Make sure that construction waste is collected, removed and disposed of only at authorized disposal areas; and
- Check with DPW or DPNR for specific guidance.

2.6.1.b Hazardous Products

Many materials found at construction sites may be hazardous either to personnel or to the environment. Always read the labels of the materials and products present onsite--they may contain warning information that will help you be aware of potential problems. Hazardous products at a construction site include, but are not limited to:

- Paints;
- Acids for cleaning masonry surfaces;
- Cleaning solvents;
- Chemical additives used for soil stabilization;
- Concrete curing compounds and additives; and
- Pesticides, herbicides, fungicides, and rodenticides.

Basic management practices that can minimize or prevent contamination of stormwater from hazardous products on construction sites

Most problems involving hazardous materials result from carelessness or from not using common sense. The practices listed below will help avoid problems associated with hazardous material disposal. Section 2.6.2 contains further information on hazardous material handling and storage and section 2.6.3 discusses spill prevention plans.

- Check with DPNR to determine the requirements for hazardous material disposal.
- Use all of the product before properly disposing of the container – if you must dispose of surplus products, do not mix products together unless specifically recommended by the manufacturer.
- Do not remove the original product label from the container, it contains important information.
- Follow the manufacturer's recommended method of disposal for the product and the empty container (often found on the label).

2.6.2 Material Management

Material management is important as the best way to avoid a problem is to prevent it at its source. On a construction site, the material storage area can become a major source of pollution due to the mishandling of materials or accidental spills. An inventory of the material storage area and of the site should be made. Special care should be taken to identify any materials that have the potential to come into contact with stormwater.

There are a number of risks (other than stormwater contamination) to consider in the management of materials on a construction site, including health and safety of employees and groundwater contamination. However, this section only addresses stormwater contamination risks. Contact DPNR for information about measures to minimize other risks.

Materials to be considered when evaluating potential risks

- Pesticides;
- Petroleum products;
- Fertilizers and detergents (nutrient sources);
- Construction chemicals;
- Other pollutants; and
- Hazardous products (see previous section).

Information to be evaluated for onsite risk assessment

- What types of materials are stored onsite?
- How long will the materials be stored before they are used?
- Are you storing more than is needed?
- How are the materials stored and distributed?
- How can potential contact with stormwater be avoided?

2.6.2.a Pesticides

Pesticides include insecticides, rodenticides, and herbicides commonly used on construction sites.

How to reduce the risks of using pesticides

- Handle the materials as infrequently as possible; and
- Observe all applicable Federal and Territorial regulations when using, handling or disposing of these materials.

Management practices that can be used to reduce risks from pesticide use

Management practices that can reduce the amount of pesticides coming into contact with stormwater include the following:

- Store pesticides in a dry covered area;
- Provide curbs, dikes or berms to contain potential pesticide spills;
- Have measures on site to contain and clean up pesticide spills; and
- Strictly follow recommended application rates and methods.

2.6.2.b Petroleum Products

Petroleum products include oil, gasoline, lubricants, and asphaltic substances such as paving materials. These materials should be carefully handled to minimize their exposure to stormwater. Petroleum products usually occur in two areas:

areas where road construction of some type is occurring and vehicle storage areas or areas of onsite fueling or equipment maintenance.

Practices that can be used to reduce the risks of using petroleum products

- Provide equipment to contain and clean up petroleum spills in fuel storage areas or on maintenance and fueling vehicles;
- Store petroleum products and fuel vehicles in covered areas;
- Contain and clean up petroleum spills immediately;
- Perform preventative maintenance of equipment used onsite to prevent leakage (e.g., check for and fix gas or oil leaks in construction vehicles on a regular basis); and
- Properly apply asphaltic substances (see manufacturer's instructions) to reduce spill risks;
- Build impervious dikes or berms to contain any spills; and
- Install oil/grease separators in stormwater inlets (see Chapter 4).

2.6.2.c Fertilizers/Detergents

The proper landscaping or revegetation of construction sites often requires using fertilizers and detergents that contain nutrients such as nitrogen and phosphorus. Excess quantities of these nutrients can be washed away by stormwater runoff and become a major pollution problem. Excess nutrients in wetlands and coastal waters can cause eutrophication and other pollution problems.

Practices that can be used to reduce the risks of nutrient pollution

- Only apply fertilizers when absolutely necessary to revegetate disturbed areas;
- Apply fertilizers to a minimum area and at the minimum recommended amount and rate (time-released fertilizers can be used);
- Work fertilizers into the soil to reduce exposure of nutrients to stormwater runoff;
- Seed and fertilize in one application (see section on Hydroseeding in Chapter 3); and
- Implement good erosion and sediment control practices to help reduce the amount of sediment and fertilizers that leave the site (see Chapter 3).

2.6.3 Spills

Spills of pesticides, petroleum products, or other toxic or hazardous products can contaminate soil, water and waste materials resulting in potential health risks. Preparations should be made to deal quickly and effectively with accidental spills. A spill control plan can help you be prepared. This section discusses your additional responsibilities if there is a reportable quantity spill.

A spill control plan should include methods to:

- Stop the source of the spill;
- Contain the spill (i.e., utilizing impervious liners and collection containment systems);
- Clean up the spill (i.e., filtration systems);
- Dispose of all materials contaminated by the spill; and
- Contact qualified personnel responsible for spill prevention and control.

Specific spill prevention methods and responses that can be used

- Store and handle materials to prevent spills.
  - Tightly seal containers.
  - Make sure all containers are clearly labeled.
  - Stack containers neatly and securely.
- Reduce stormwater contact if there is a spill.
  - Have cleanup procedures clearly posted.
  - Have cleanup materials readily available.
  - Contain any liquid.
  - Stop the source of the spill.
  - Cover the spill with absorbent material such as kitty litter or sawdust.
- Discard contaminated materials according to manufacturer's instructions or according to Federal or Territorial requirements.
- Identify personnel responsible for responding to a spill of toxic or hazardous materials.
  - Provide personnel spill response training.
  - Post names of spill response personnel.
- Keep the spill area well ventilated.
- If necessary, use a private firm that specializes in spill cleanup.

2.7 CONCLUSION

The importance of proper development planning and the use of good housekeeping practices cannot be overstated. It is cheaper in the long run, for both the developer and the community, to effectively plan a development to minimize pollution than to clean-up the effects of poor planning and management after the fact.

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CHAPTER 3: EROSION AND SEDIMENTATION CONTROL PRACTICES TABLE OF CONTENTS

CHAPTER 3: EROSION AND SEDIMENTATION CONTROL PRACTICES

3.1 INTRODUCTION

Erosion from construction sites, dirt roads and other disturbed lands are a source of sediment, toxic chemicals, and excess nutrients that can pollute coastal waters. Runoff from construction sites is by far the largest source of sediment in urbanizing areas (U.S. EPA, 1993; U.S. EPA, 1992). Sediment eroded from dirt roads, construction sites and other cleared areas is the primary pollutant impairing V.I. water quality (DPNR-DEP and USDA-NRCS, 1998). A 1986 study of erosion rates on St. Thomas and St. Croix estimated erosion from a disturbed dirt road site to be 591 tons/acre/year (Wernicke, Seymour and Mangold, 1986). Studies of erosion rates in the Fish Bay watershed on St. John have soil loss from dirt roads of between 100 to 600 tons per year (MacDonald, et. al., 1997; Sampson, 1997).

Erosion control practices reduce the amount of soil that erodes from construction sites. ***Sediment control practices*** remove eroded soil from stormwater before it leaves the construction site and is deposited onto roadways and down-slope properties and into guts, ponds and coastal waters. Using erosion and sediment control practices is an important part of stormwater pollution prevention. These practices have been developed by the USDA Soil Conservation Service/Natural Resources Conservation Service, various local and state government agencies, and erosion control professionals and product manufacturers.

The selection of the best soil erosion and sediment control practices for construction sites should be based upon the nature of the construction activity and the conditions that exist at the construction site. A properly designed erosion and sediment control plan should:

- **Minimize the amount of disturbed soil** on the construction site. This will decrease the potential amount of soil that erodes from the site, reducing the number and complexity of practices needed to remove sediment from site runoff.

- **Prevent runoff from off-site areas from flowing across disturbed areas.** This will reduce the amount of stormwater that comes into contact with bare soils. Reducing runoff flow over bare soils decreases soil erosion and reduces the volume of stormwater needing treatment to remove sediment.

- **Slow the runoff flowing across the site.** High runoff velocities reduce water seepage into the soil, increase runoff volume, and cause soil particles to detach from the soil surface. High runoff velocities can cause severe gully erosion, especially on steep slopes. Make grades as gradual as possible without excessively modifying existing site conditions.

- **Remove sediment from on-site runoff before it leaves the site.** Because vegetation used for soil stabilization may not establish itself before a severe storm occurs, on most construction sites it will be necessary to install practices that can remove sediment from runoff before it leaves the site.

- **Plan soil disturbance activities for the dry season.** This will help to minimize erosion by scheduling site disturbance activities to occur during times of little or no rainfall.

EROSION CONTROL KEYS

The keys to controlling erosion and soil loss on construction sites are to:

- **Protect the soil surface from rain drop impact,**
- **Maintain soil's water holding capacity,**
- **Slow storm water runoff speed,**
- **Minimize slope lengths,**
- **Plan to control storm water runoff,**
- **Match practices to individual site conditions, and**
- **Maintain erosion, sediment and stormwater control practices.**

How these objectives are met depend upon site characteristics and the type of construction activity. The following sections describe stabilization and structural practices for erosion and sediment control. Construction specifications and design procedures for each practice are provided in Appendix B.

3.2 STABILIZATION PRACTICES

Preserving existing vegetation and re-planting cleared/bare soils as soon as possible after earth change is the most effective way to control erosion. Plant cover reduces erosion potential by:

- Protecting the soil surface from the impact of falling rain drops (reducing erosion);
- Slowing runoff velocity (or speed) and allowing sediment to settle out (reducing off-site sediment loss);
- Physically holding the soil in place with plant roots (erosion control); and
- Increasing infiltration (or seepage) rates by improving the soil's structure and porosity.

Vegetative cover can be grass, trees, shrubs, ground covers, other types of plants, or any combination of these. Grasses are used most commonly because they grow quickly and have fibrous root systems that can rapidly stabilize soils. Other soil stabilization practices such as mulching or matting may be used during the dry season when seeds have difficulty establishing themselves. Newly planted shrubs and trees establish root systems more slowly, so keeping existing ones is a more effective practice. Existing vegetation is adapted to the area, whereas many exotic plant species that are planted after construction may prove to be less successful.

Vegetative and other stabilization practices can be either temporary or permanent. Temporary practices provide cover for exposed or disturbed areas for short time periods or until permanent erosion controls are in place. Permanent vegetative practices are used when soil-disturbing activities are completed or when erosion is occurring on a site that is otherwise stabilized. It is generally preferable to permanently stabilize disturbed soils as soon as possible. The stabilization practices presented in this chapter include:

- Preservation and Protection of Natural Vegetation
- Filter Strips
- Land Grading
- Surface Roughening
- Temporary Seeding
- Permanent Seeding and Planting
- Mulch, Mats and Geotextiles
- Soil Binders/Tackifiers
- Soil Retaining Walls
- Soil Bioengineering

Stabilization practices should be initiated as soon as practicable in sections of the site where construction activities have temporarily or permanently ceased, but in no case more than 14 days after the construction activity in that part of the site has temporarily or permanently stopped.

Preservation and Protection of Natural Vegetation

The preservation of natural vegetation (existing trees, vines, bushes, and grasses) provides natural buffer zones to slow runoff and filter sediment. Often areas of a construction site are unnecessarily cleared. Only those areas essential for construction activities should be cleared (building footprints, road/drive ways, cistern and septic system areas). Other areas should remain undisturbed, particularly critical areas such as those with steep slopes and/or highly erodible soils, or areas around guts, ponds or coastal waters.

Preserving natural vegetation on the site by clearing only the area where structures will be built minimizes erosion potential, protects water quality, provides aesthetic benefits, and is cost-effective in the long term. This practice is a permanent control practice.

When and Where to Use Natural Vegetation Preservation

This practice applies to all construction sites. Natural vegetation preservation is particularly beneficial in or near floodplains, wetlands, guts, steep slopes, and other areas where erosion controls would be difficult to establish, install, and/or maintain. Virgin Islands Law (V.I. Code Annot. Title 12, sections 121 to 125) prohibits ***"...the cutting or injury of any tree or vegetation within 30 feet of the center of any natural watercourse, or within 25 feet of the edge of such watercourse, whichever is greater."*** This chapter goes further to define a natural watercourse as ***"...any stream with a reasonably well-defined channel, and includes streams which have a permanent flow, as well as those which result from the accumulation of water after rainfalls and which regularly flow through channels formed by the force of the waters,"*** i.e., guts. In many instances, guts may flow for only a few days or weeks during the year. However, the vegetation within or bordering these guts is very important for maintaining water quality and may contain rare, endangered or threatened plant and animal species.

What to Consider

On-site vegetation preservation should be planned before any site disturbance begins (Figure 3.1). Preservation requires good site management to minimize the impact of construction activities on existing vegetation. Heavy equipment can ruin the topsoil through compaction and kill desirable plants. **The proposed limits of land disturbance should be physically marked off to ensure that only the required land area is cleared.** Clearing promotes unwanted weed growth because of increased exposure to sunlight. Hard-to-control plants like guinea grass, vines, tan-tan and casha can rapidly take over cleared areas. Hand-clearing preserves existing vegetation while removing unwanted plants.

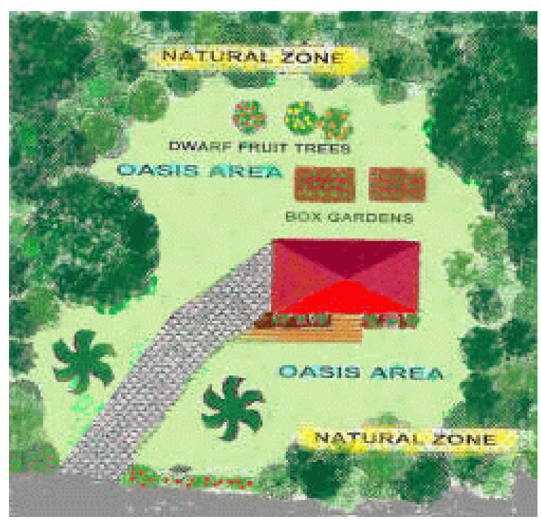

Figure 3.1. Diagram showing site where natural vegetation is preserved around the perimeter (*Toni Thomas, UVI-CES*).

Trees to be preserved should be clearly marked and protected from ground disturbances around the base of the tree. Trees should be protected with tree armoring, fencing, or a tree well (Figure 3.2). Limit soil placement over existing tree and shrub roots to a maximum of 3 inches. Retaining walls or terraces should be used to protect roots of trees and shrubs when grades are lowered. Lowered grades should start no closer than the tree's dripline. Care should be taken to minimize damage to tree limbs and root systems. Contact the

Department of Planning and Natural Resources (DPNR), the DPNR Division of Fish & Wildlife, the UVI Cooperative Extension Service (CES), or the V.I. National Park for information on rare or endangered species before removing trees or other vegetation.

Since soils are so shallow in the Virgin Islands, topsoil is a rare commodity and should be conserved. As little existing topsoil should be removed as possible. Where topsoil has been removed, soil should be stockpiled on the site so that it can be re-applied. **Soil stockpiles must be temporarily seeded or covered with a tarp, mat or geotextile to prevent erosion.** Compatibility of existing and imported topsoils should be checked to ensure maximum growth potential for the desired vegetation.

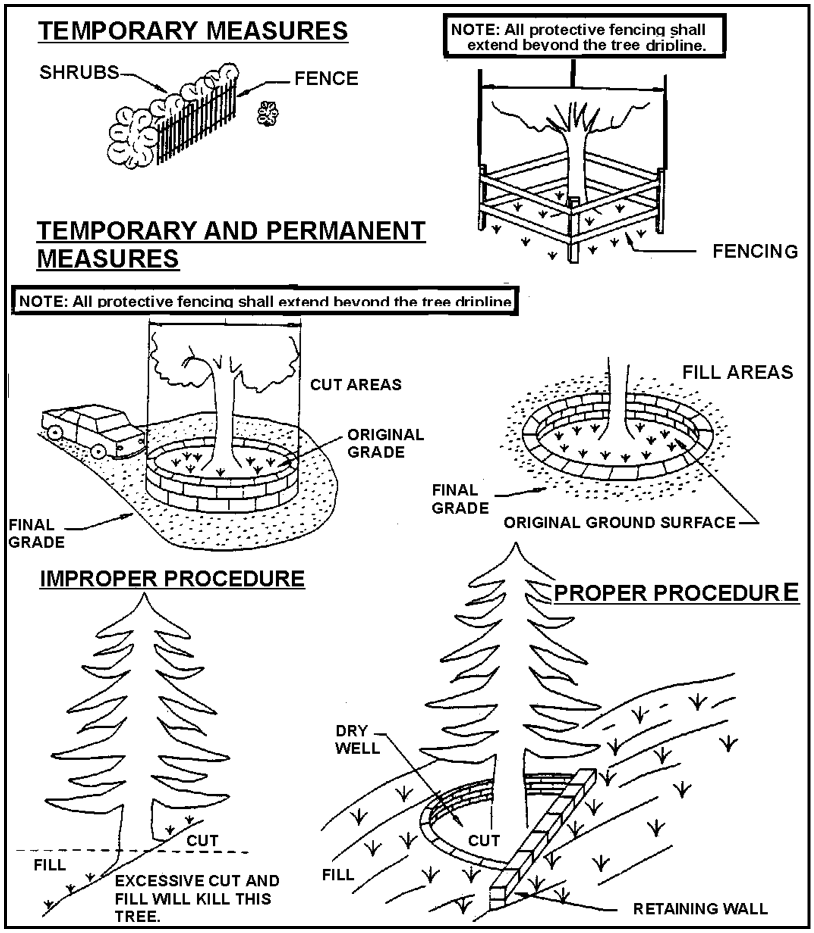

Figure 3.2. Tree protection practices (*Maryland Department of the Environment, 1994*).

How Effective is Natural Vegetation Preservation?

Preservation and enhancement of natural vegetation is the most effective erosion and sediment control practice. Any ground disturbance on a site results in increased erosion from that site. By minimizing land clearing to the areas where final structures will be located (building footprints, driveways, septic systems, etc.), overall site erosion is minimized. The vegetation remaining on the site also works as a filter to trap sediments and other pollutants (see ***Filter Strips***). A natural vegetation zone around the building area will also provide a windbreak, shade, privacy barrier, noise buffer, dust filter, and wildlife habitat. However, other practices may also be needed to control erosion and sediment loss, especially from roadways or driveways.

ADVANTAGES OF NATURAL VEGETATION PRESERVATION/PROTECTION

- Is inexpensive and already established.
- Can handle higher quantities of stormwater runoff than newly seeded areas.
- Is already established, therefore is immediately effective.
- Has good pollutant filtering capacity since preserved natural vegetation and root structure are usually denser than in newly seeded areas.
- Provides areas for infiltration, reducing stormwater runoff volume and velocity.
- Requires less maintenance than planting new vegetation and is more likely to successfully control erosion and sedimentation.
- Holds existing topsoil on ground so that new soil does not have to be brought in.
- Provides noise buffers and screens for onsite operations.
- Provides a windbreak, shade, privacy barrier, dust filter, and wildlife habitat.
- Enhances aesthetics and property values.

Filter Strips

Filter strips are vegetated strips of land used to remove sediment and other pollutants from stormwater runoff by slowing runoff speeds, filtering out sediment and other pollutants, and providing some infiltration. Filter strips are different from buffer strips (as described in Chapter 4) because their effectiveness is not measured by their ability to improve stormwater infiltration. A filter strip can be an area of vegetation that is left undisturbed during construction, or it can be newly planted. Filter strips can be either temporary or permanent practices.

When and Where to Use Filter Strips

Filter strips can be used at any site that can support vegetation. Filter strips are best suited for treating runoff from roads and highways, small parking lots, construction sites and pervious surfaces (CWP, 2000a). Filter strips are used at the lower edge of cleared or disturbed areas, small parking lots or home sites, or above structural practices such as swales or diversions. They are particularly effective on flood plains, next to wetlands, ponds and guts, and on steep unstable slopes. **Filter strips should always be used around guts and other drainage ways, ponds, and coastal waters, and are most effective if they are buffers (see Chapter 4) consisting of native vegetation left undisturbed during construction.** If native vegetation does not provide enough ground cover, it can be supplemented with native grass seed, such as bahia or hurricane grass.

What to Consider

The type and quantity of pollution that filter strips will be treating must be determined. Slopes, soils, plant species, construction timing, watering needs, and operation and maintenance methods should be considered in designing a filter strip. If the filter has outlet flow, it must be non-erosive.

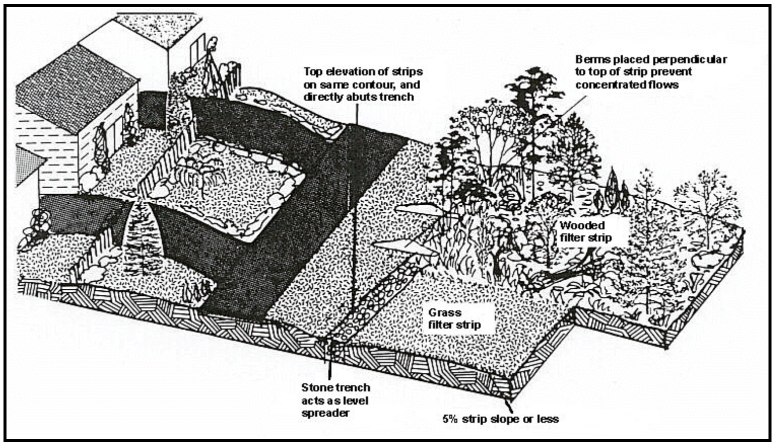

Figure 3.3. Vegetated buffer strip design (*Schueler, 1987*).

Filter strips are typically used to treat very small drainage areas. The limiting design factor is the length of flow contributing to the filter strip. The slope length contributing runoff to a filter strip should not exceed 75 feet for impervious areas (including compacted soil) or 150 feet for pervious areas (CWP, 2000a). Filter strips are most effective on slopes of 5% or less, and grassed filter strips should be at least 15 feet wide, forested filter strips should be at least 50 feet wide. Steeper slopes require wider widths (for example, a 20 - 30% slope requires a grassed strip at least 25 feet wide, (USDA-SCS, 1993a).

If filter strips are composed of preserved existing vegetation, good planning and site management are needed to protect them against disturbances such as grade changes, excavation, equipment damage, and other activities. Establishing new filter strips requires the establishment of good grass cover, trees and shrubs (see ***Preservation and Protection of Natural Vegetation*** (page 3-3) or ***Permanent Seeding and Planting*** (page 3-10)). Careful maintenance is important to ensure healthy vegetation. The need for routine maintenance like mowing, pruning, irrigation, and weed and pest control will depend on the species of plants and trees used. Native plant species will require minimum maintenance while exotic species may require significant inputs (irrigation, pesticides, nutrients). Maintaining planted areas may require debris removal and protection against unintended uses or traffic.

How Effective Are Filter Strips?

Filter strips can be very effective in removing sediment from stormwater if dense plant growth is present (i.e., if existing vegetation is preserved or newly planted vegetation grows quickly and thickly). Filter strips can also slow and reduce stormwater flow through infiltration of excess water so that downstream erosion is greatly reduced.

ADVANTAGES OF FILTER STRIPS
• Filter sediment and other pollutants from stormwater runoff before it reaches drainage channels, guts, ponds, and/or coastal waters.
• Prevent erosion on the vegetated area of the site.
• Provide areas for infiltration, reducing the volume and speed of stormwater runoff.
• Native (or existing growth) filter strips have lower maintenance requirements.
• Are very low cost if using existing vegetation.
• Provide screens and buffers for noise and privacy, provide areas for wildlife habitat and improve site appearance.
DISADVANTAGES OF FILTER STRIPS
• Limit the amount of land area to be used for construction and other activities.
• Require plant growth before they are effective (for newly planted filter strips).
• May not be feasible for small lots.

Land Grading

Land grading is the reshaping or alteration of the existing land surface to provide for better utilization, improvement of drainage, and erosion control (Figure 3.4). Land grading requires a well-developed plan using an engineering survey and layout. The land grading specification is used to provide for erosion control and vegetation establishment on those areas of the construction site where the existing land surface will be disturbed by grading activities.

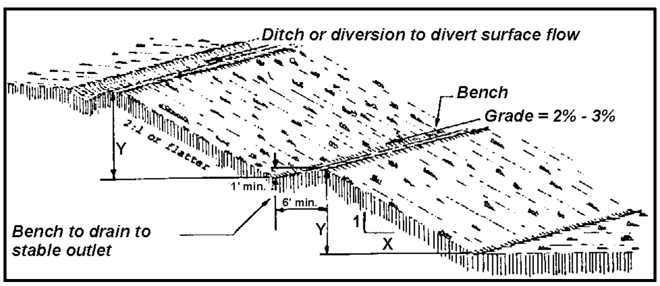

Figure 3.4. Land grading details (*Empire State Chapter, Soil and Water Conservation Society, 1991*).

When and Where to Use Land Grading

Proper land grading practices should be used in all land disturbing activities, and particularly on sites where surface irregularities, slopes, soil type, obstructions, or wetness interfere with planned uses; or where the desired land use requires designed land surfaces. **Serrated cut slopes (Figure 3.5) should be used for steep cuts behind buildings or adjacent to driveways or roads to prevent landslides.** These slopes can then be planted with temporary or permanent vegetation (see ***Seeding & Planting*** section). Special attention should be given to maintaining or improving habitat for rare, threatened or endangered species, where applicable (contact the DPNR Division of Fish and Wildlife for information on Virgin Islands habitat requirements).

What to Consider

The grading plan should incorporate building designs and street layouts that fit into and utilize the existing topography, vegetation and other desirable natural features to avoid extreme grade modifications. The effect of grading on runoff quantity and surface storage should be considered. Stormwater runoff will be increased by removal of vegetation and surface storage areas (depressions).

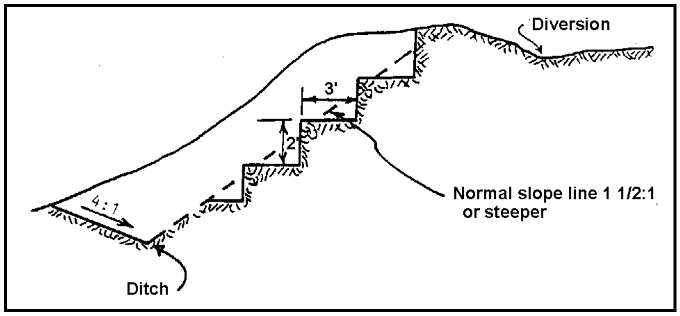

Figure 3.5. Typical section of serrated cut slope *(Empire State Chapter Soil and Water Conservation Society, 1991)*.

Water quality will be affected by an increased rate of erosion during construction. Sediment loss will vary with changes in runoff. Factors determining potential sediment loss (and appropriate control practices) include slope before and after grading, results of the construction process, and the amount of vegetation re-established on the graded or shaped site. **All disturbed areas MUST be stabilized structurally or vegetatively upon completion of construction activities**.

ADVANTAGES OF LAND GRADING
• Minimizes the amount of erosion from graded areas and cut and/or fill slopes.
• Prepares land for construction purposes.
DISADVANTAGES OF LAND GRADING
• May be difficult on small lots and/or lots with steep slopes.

Surface Roughening

Surface roughening roughens a bare soil surface with horizontal grooves running across the slope, stair-stepping, or tracking with construction equipment (Figure 3.6). This practice is used to ease establishment of vegetation by seed, to reduce stormwater runoff velocity, increase infiltration, reduce erosion, and trap sediment.

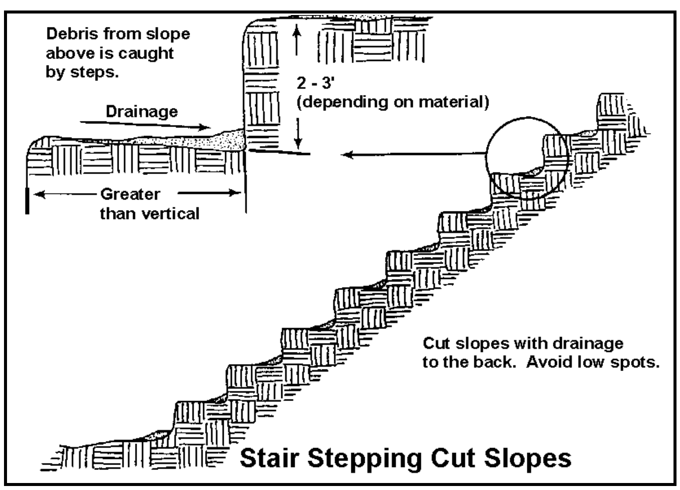

Figure 3.6. Surface roughening details - stair-stepping *(Empire State Chapter Soil & Water Conservation Society, 1991)*.

When and Where to Use Surface Roughening

All slopes, especially those steeper than 3:1 (33%), require surface roughening to facilitate vegetative stabilization.

What to Consider

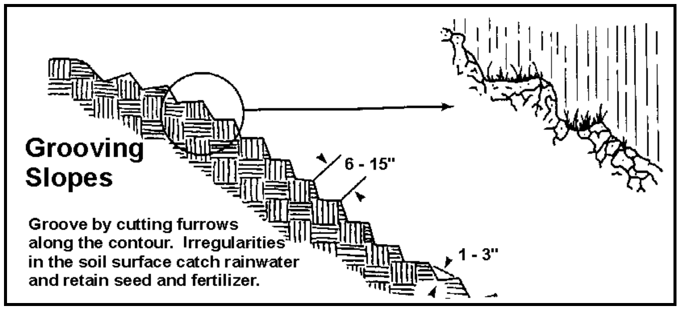

Figure 3.7. Surface roughening details - grooving *(Empire State Chapter Soil & Water Conservation Society, 1991).*

There are many different ways to roughen soil surfaces. Selecting the best method depends on the type of slope. Steepness, mowing requirements (if any), and a cut or fill slope operation are all factors that need to be considered in selecting a roughening method. A common roughening method on moderate slopes is to run the bulldozer/backhoe up and down the slope so that the treads create horizontal indentations (grooving, Figure 3.7).

ADVANTAGES OF SURFACE ROUGHENING
• Reduce runoff speed and decrease the distance of overland runoff flow.
• Hold moisture better than do smooth slopes and minimize sheet and rill erosion.
DISADVANTAGES OF SURFACE ROUGHENING
• May increase cut and fill costs and cause sloughing if excessive water infiltrates the soil.

Temporary Seeding

Temporary seeding is used to reduce erosion and sedimentation on areas that will not be stabilized for a long time or where permanent plant growth is not necessary or appropriate. A short-term cover of fast-growing grasses is seeded on a cleared or disturbed site to keep soils from being carried offsite by stormwater runoff or wind. Seeding can be performed by hydroseeding, hand broadcasting, or installing seeded erosion control mats. Seeded areas can also be covered with erosion control mats to conserve moisture, prevent wash out, and protect seeds from birds and insects (see ***Mulch, Mats & Geotextiles***, page 3-11).

When and Where to Use Temporary Seeding

Temporary seeding should be performed no later than 14 days after the halt of construction activities on all disturbed areas that are likely to be re-disturbed, but not for several weeks or more. This includes denuded areas, cuts, fills, soil stockpiles, sides of sediment basins, and temporary roadbanks. **Temporary seeding should take place as soon as possible after the last land disturbing activity in an area.** It is especially important on critical areas such as dams, dikes, levees, cuts, fills, and denuded or gullied areas.

What to Consider

Proper seed bed preparation and the use of high-quality seed are needed to grow grass for effective erosion control. Soil that has been compacted by heavy equipment may need to be loosened with a rake or tiller. Top-soiling is not necessary for temporary seeding, but it may improve chances for vegetation establishment. Seed bed preparation may also require fertilizer application to make conditions more favorable to plant growth. Proper fertilizer application, seeding mixtures and seeding rates vary depending on site location, soil type, slope, and weather.

It is very important to select appropriate grass species and to time seeding. Seeding native or naturalized grass species will increase the odds for success in establishing vegetation. Native species also tend to have lower maintenance needs because they are adapted to the environmental conditions in the area. The UVI Cooperative Extension Service or USDA Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) can supply information on suitable native grasses. Local suppliers, the Cooperative Extension Service, or USDA-NRCS can supply information on best seed mixes and fertilizer and irrigation needs.

Seeded areas on slopes steeper than 4:1 or in sandy, clayey or caliche soils should be covered with mulch or erosion control mats (see ***Mulch, Mats & Geotextiles***, page 3-11) to provide protection from rainfall and to prevent birds from eating the seed. Seeded areas should also be mulched and matted if the weather is excessively dry or if heavy rain is expected before the seed sprouts. Frequent inspections are necessary to ensure that the grass is growing properly and to determine if irrigation is needed. If grass does not grow quickly or thick enough to prevent erosion, the area should be reseeded as soon as possible.

Hydroseeding is an erosion control practice used to rapidly stabilize disturbed soils with grasses (Figure 3.8). Hydroseeding equipment is used to uniformly apply a combination of grass seed, water, fertilizer, mulch and tackifier to an area to be seeded. Grass seed, paper fiber mulch, water, and even fertilizer are mixed together in the hydroseeder tank and then sprayed out over the disturbed soil area. This equipment allows rapid stabilization of a site with a minimum amount of labor. DPNR-CZM owns two hydroseeders maintained by the UVI Cooperative Extension Service (CES) that are leased to government agencies and the general public upon completion of an equipment certification workshop. For more information on the DPNR/UVI-CES hydroseeding program, contact CES at (340) 693-1080.

Figure 3.8. Hydroseeding side slopes and outside rim of a sediment basin (*Estate New Hernhut, St. Thomas, 1998*).

How Effective is Temporary Seeding?

This practice, along with ***Preservation and Protection of Natural Vegetation*** (page 3-3) and ***Permanent Seeding and Planting*** (page 3-10), is most effective in reducing erosion and sedimentation from a construction site, especially in areas where soils are unstable because of their slope, texture, structure, a high water table, or high winds. However, seeding with non-native grasses not adapted to the Virgin Islands climate and soil conditions may not be as effective due to low survival rate and higher maintenance requirements.

Once vegetation is established, its roots hold the soil in place and the vegetation also slows down runoff, increases infiltration, and filters sediments from runoff. However, temporary seeding may not be effective in arid and semi-arid regions (eastern portions of the islands) or during dry seasons (where/when climate prevents fast plant growth). In those areas, mulch, erosion control mats or geotextiles may be more appropriate for the short term.

ADVANTAGES OF TEMPORARY SEEDING
• Is generally inexpensive and easy to do.
• Quickly establishes grass cover when conditions are adequate.
• Provides excellent soil stabilization, provides sediment filtering capability, and is visually pleasing.
• May help reduce costs of maintenance of other erosion controls (i.e., silt fences, sediment traps/basins may need to be cleaned out less often).
• Reduces stormwater runoff rates and volume.
• Hydroseeding has lower labor costs than hand application methods – one person can operate a hydroseeder to apply seed, mulch and fertilizer simultaneously.
• Hydroseeding also applies grass seed more evenly, results in faster germination, produces better grass stands, and provides for easier transportation and storage.
• Improves the appearance of the site.
DISADVANTAGES OF TEMPORARY SEEDING
• Depends on adequate rainfall or irrigation for success, especially prior to establishment.
• May require fertilizing of plants grown on some soils (particularly caliche), which can be more expensive and cause downstream water quality problems.
• Temporary vegetation requires protection from equipment and heavy use once seeded.

Permanent Seeding and Planting

Permanent seeding and planting is the planting of permanent plant cover such as trees, shrubs, vines, grasses or legumes on highly erodible or critically eroding areas, or on disturbed soils at the completion of earth change activities. This practice provides soil stabilization and reduces stormwater runoff and sediment loads to guts and coastal waters by slowing runoff velocity and increasing runoff infiltration. Vegetation also filters sediment and other pollutants, improves wildlife habitat, and enhances the appearance of a site and its property value.

When and Where to Use Permanent Seeding & Planting

Permanent seeding and planting should be used to stabilize all disturbed areas once construction has been completed in that area. Permanent vegetation establishment is especially important on steep slopes and grades, in filter strips, buffer areas, and vegetated swales, and along guts, ponds and coastal areas.

Figure 3.9. A low-maintenance, natural landscape in a dry area (*Estate Nazareth, St. Thomas, 1995*).

What to Consider

It is very important to select appropriate plant species and to carefully time planting. Planting native or naturalized species will increase the odds for success in establishing vegetation. Native species also tend to have lower maintenance needs because they are adapted to local environmental conditions. Many low-maintenance, native plants can be added to the site's landscaping (Figure 3.9). Some good native plants available in local nurseries include wild frangipani, orange man jack, pink cedar, sea grape, lignum vitae, turpentine tree, teyer palm, sabal palm, wild ferns, wild anthurium, and spider lily.


Figure 3.10. Newly planted vetiver hedge *(UVI St. Thomas, 1999)*.

Some exotic plants can also be incorporated into the landscape. Be careful to choose species that won't escape into natural areas and crowd out native plants. Vetiver grass (*Vetiveria zizanioides*) hedges can be planted across slopes (along the contour) to form a living terrace (Figure 3.10). Vetiver is a non-native, non-invasive, clumping grass species. It is used in Africa, India and Southeast Asia to stabilize slopes and channels by trapping sediment behind the grass. Some exotic ornamental plant species that can be used around the home include hibiscus, bougainvillea, oleander, croton, heliconia, ginger, isora, aralia, agave, and non-native palms. Fruit trees and vegetable gardens can also be planted once construction is completed. The UVI Cooperative Extension Service (CES) or USDA Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service, SCS) can supply information on suitable native and exotic plant species. Local suppliers, CES or USDA-NRCS can supply information on best seed mixes and fertilizer and irrigation needs.

ADVANTAGES OF PERMANENT SEEDING & PLANTING
• Quickly establishes vegetative cover when conditions are adequate.
• Provides excellent soil stabilization and sediment filtering capability.
• Improves stormwater infiltration, reducing stormwater runoff speed and volume.
• Provides a windbreak, shade, privacy barrier, dust filter, and wildlife habitat.
• Improves site appearance and property values.
DISADVANTAGES OF PERMANENT SEEDING & PLANTING
• Depends on adequate rainfall or irrigation for success.
• May require fertilizing of plants grown on some soils (particularly caliche), which can be more expensive and cause downstream water quality problems.
• Permanent vegetation requires protection from equipment and heavy use once seeded.

Mulch, Mats and Geotextiles

Mulching is a temporary soil stabilization or erosion control practice. Mulching uses materials such as cut grass, woodchips, wood fibers, straw, or gravel to cover the soil surface to temporarily stabilize disturbed areas until vegetation is established or construction is completed. Mulching also reduces the speed of stormwater runoff over bare soils. When used together with seeding and planting, mulching can aid in plant establishment by holding seed, fertilizer, and topsoil in place; by helping to retain moisture; by insulating against high temperature, and by protecting seed from birds.

Erosion control mats are materials (straw, coconut, wood, or synthetic fiber) that have been woven into a mat or blanket and are backed with plastic or jute netting. Erosion control mats offer the same benefits as mulch but are more stable and can withstand much higher stormwater velocities than loose mulch. They are used to temporarily stabilize bare soils or slopes during construction when it is difficult to establish temporary vegetation (due to dry, stony, or steep soil conditions). Mats are also used with permanent seeding and planting to help hold soils in place until grass or other plants can become established. Figure 3.10 shows how erosion control mats are used for erosion control in a drainage swale.

Netting is typically made from jute, coconut or other wood fiber, plastic, paper or cotton and can be used to hold mulch onto the ground. Netting can also be used alone to stabilize soils while plants, such as ground covers, become established. However, it does not retain moisture or temperature well.

Other materials, called filter fabrics or ***geotextiles***, are also used for erosion control. These materials are made by weaving or bonding fibers made from synthetic materials such as polyester, nylon, polyvinyl chloride (PVC), or other material. Mats, netting and other filter fabrics are used in areas with steep slopes where loose mulch and seed are vulnerable to being washed away, or where vegetation is difficult to establish.

When and Where to Use Mulch, Mats and Geotextiles

Loose mulch should only be used on fairly level slopes, or in areas that only need short-term stabilization. Erosion control mats or geotextiles are often used alone in areas where temporary seeding cannot be used because of season or soil/slope conditions. Mats can provide immediate, effective erosion control. In critical areas such as drainage swales , channels, or along shorelines, mats or geotextiles can be used to provide channel stabilization. There are many different types of erosion control mats. Erosion control mats can be used for a wide range of slopes and stormwater flow rates. For example, 100% straw mats can be used on slopes up to 3:1 in steepness and 75 feet in length or in low-flow swales (Figure 3.11). Straw/coconut mats can be used on steeper slopes (2:1 - 1:1, depending on length) and medium flow discharge channels. Coconut fiber or synthetic mats provide long term protection on steeper slopes or in high discharge channels. Check the manufacturer's specifications to determine which material is appropriate for a given application.

Figure 3.11. Straw mat used to stabilize seeded slope (*UVI St. Thomas, 1999*).

Geotextiles can be used alone as matting to stabilize flow in channels and swales, to protect seedlings on recently planted slopes, or to protect tidal or drainage banks where moving water may wash out new plantings. When properly anchored, geotextiles can provide stabilization on slopes up to 30-40% (depending upon material type). Geotextiles are also used as separators. For example, filter fabric can be placed between gravel or rip-rap and soil. This "sandwiching" prevents the gravel from being compacted into the underlying soil and prevents the soil underneath the rip-rap from being eroded.

What to Consider

Mulch should be applied to moderate slopes ($<$ 10%) and soils that are not highly erodible. On steep slopes, highly erodible soils, or in swales (see sections on ***Drainage Swales*** and ***Grassed Swales***) erosion control mats or geotextiles should be used and anchored into place with staples (anchoring patterns depend on slope steepness and length and flow rate, see Figure 3.12). On extremely arid sites where grasses cannot survive, native ground covers or shrubs can be planted in jute or coir (coconut fiber) netting. Filter fabric or erosion control mats can also be used for this purpose. Before stabilizing an area, it is important to have all sediment controls installed and for runoff to be diverted away from the area to be planted.

Final grading is not necessary before mulching. Mulched areas should be inspected often to find where mulch has been loosened or removed. These areas should be reseeded, if necessary, and the mulch cover replaced immediately.

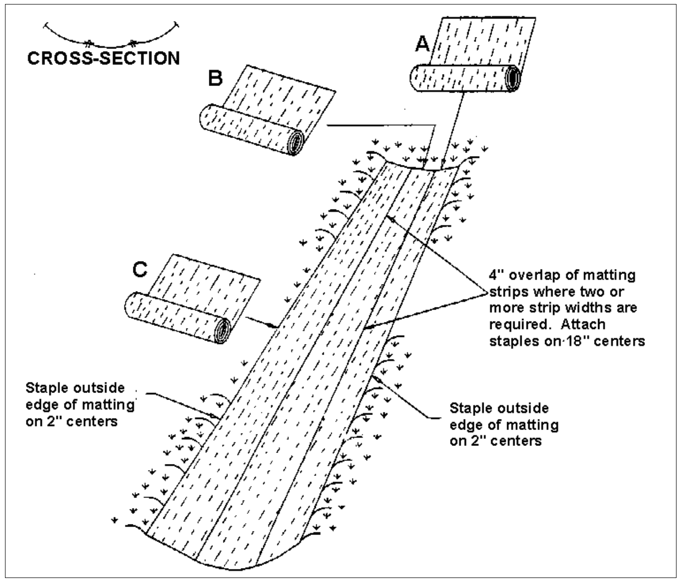

Figure 3.12. An example of erosion control matting of a drainage swale (*Maryland Department of the Environment, 1994*).

When selecting erosion control mats or geotextiles, choose an appropriate type for the intended use. Follow manufacturer recommendations or seek advice from the USDA Natural Resources Conservation Service or the UVI Cooperative Extension Service. Areas covered with mats or geotextiles should be inspected regularly to determine if cracks, tears, or breaches have occurred. If so, repairs should be made immediately.

Effective netting and matting requires firm and continuous contact between the fabric and the soil. If there is no contact, the material will not hold the soil in place and erosion will occur underneath it. Matting should be able to withstand stormwater runoff speeds of up to 5 feet per second.

How Effective are Mulch, Mats, and Geotextiles?

Mulch, mats and geotextiles are very effective in reducing erosion and are very cost-effective, as compared to retaining walls or purchasing new top soil. Mulch alone should only be used for temporary protection of the soil surface on fairly level slopes. The useful life of mulch, mats and geotextiles varies according to the material and amount of rainfall, from a minimum of 1 month for mulch to 3 years for geotextiles.

ADVANTAGES OF MULCH, MATS AND GEOTEXTILES
C Provide immediate, effective protection of exposed and/or eroding soils.
C Mulch, mats and geotextiles retain moisture, minimizing the need for watering.
C Organic mulch, mats and netting do not need to be removed because they are biodegradable.
C Mats protect seeds from birds and other animals.
C Mats and geotextiles are less expensive than structural practices and a wide variety are available to match specific needs.
C Are convenient to install.
DISADVANTAGES OF MULCH, MATS AND GEOTEXTILES

- Mulch and/or mats may delay seed germination in some species.
- Mulch can be easily blown or washed away by runoff if not secured.
- Mats are difficult to anchor into stony or compacted clay soils.
- Mats may inadvertently contribute to weed growth, since they hold in moisture.
- Geotextile effectiveness may be reduced significantly if the fabric is not properly selected or installed.
- Many geotextiles are photodegradable and must be protected prior to installation.

Soil Binders/Tackifiers

Soil binders or tackifiers are chemical polymers or emulsions sprayed onto the soil surface to provide soil stabilization. There are many different types of chemical polymers on the market that provide varying degrees of stabilization. Soil polymers are used for temporary erosion control, and are typically applied using hydroseeding equipment, with or with out seed and/or mulch.

When and Where to Use Soil Binders/Tackifiers

Soil binders are often used on extreme slopes and droughty (very dry) soils where it is difficult to establish vegetation. Tackifiers are typically used in conjunction with hydroseeding (see ***Temporary Seeding*** page 3-8) to stabilize soils and hold grass seed and mulch in place until germination and root establishment occurs. Binders and/or tackifiers can also be used to hold loose mulch in place on soils. Some tackifiers and binders can also help to conserve moisture in soils. These chemicals are also effectively used on construction sites for dust suppression.

What to Consider

There are many different types of soil binders and tackifiers available. Some materials are more toxic than others, and some may or may not be biodegradable. The type of material chosen depends on the site's slope and soils, the season and geographic area of the site (for example, whether the site is on the dry east end or wetter north side of an island), the longevity of the material, whether or not seed and/or mulch will be applied with the material, and whether or not it is an acceptable material to be used in the hydroseeding equipment. Products should be carefully investigated. Practice application/installation varies by manufacturer; see manufacturer guidelines for specific installation specifications. The International Erosion Control Association (IECA) website provides a partial list of erosion control product vendors at: www.ieca.org.

ADVANTAGES OF SOIL BINDERS/TACKIFIERS

- Provide short-term stabilization of severe, dry and/or stony slopes that are difficult to vegetate.
- Can provide stabilization for 2 to 18 months, depending on the material and site conditions.
- Are useful for holding seed, mulch and fertilizer in place on steep slopes.
- Aid in conserving soil moisture.
- Provide excellent dust control.
- Some are non-toxic and/or biodegradable.

DISADVANTAGES OF SOIL BINDERS/TACKIFIERS

- Many are not suitable for long term stabilization (over 6 months).
- Some may be toxic or persist in the environment.
- Some forms may clog hydroseeding equipment used to apply material.
- Do not prevent mass-wasting (landslides).

Soil Retaining Walls

Soil retaining walls are structures used to hold loose or unstable soil firmly in place. For example, soil tie backs and retaining walls can be used during excavation to prevent cave-ins and accidents, but they also are excellent permanent erosion control practices that retain soils and slopes to prevent them from moving. There are many different types of soil retaining structures that can be used. Some basic ones include:

- **Skeleton Sheeting:** Skeleton sheeting is the least expensive soil retaining system. It requires the soil to be cohesive (like clay). Construction grade lumber is used to brace the excavated face of the slope. This is a temporary practice.

- **Continuous Sheeting:** Continuous sheeting uses a material such as steel, concrete or wood to cover the face of the slope in a continuous manner. Struts and boards are placed along the slope to provide continuous support to the slope face.

- **Permanent Retaining Walls:** Permanent retaining walls may be necessary to provide support to the slope after construction is completed. Concrete, stone, or wood (horizontal telephone poles, etc.) retaining walls can be built and left in place.

When and Where to Use Retaining Walls

Soil retaining walls should be used where other methods of soil retention are not practical. They are especially applicable in the Virgin Islands to retain cut slopes along road and drive ways, parking lots, building sites, and other cut and fill areas where slopes or soils are not suitable for vegetative stabilization (Figure 3.13).

Figure 3.13. Rock retaining walls installed to stabilize base of steep slope above a sediment basin (*Estate New Hernhut, St. Thomas, 2000*).

What to Consider

Soil retaining walls are used for both erosion control and safety purposes. Retaining wall design must address foundation bearing capacity, sliding, overturning, drainage, and loading systems. These are complex systems and all but the smallest retaining walls should be designed by a licensed engineer.

ADVANTAGES OF RETAINING WALLS
• Provide safety to workers.
• Can be used as either temporary or permanent structures (depending upon design).
• Are exceptionally effective in preventing erosion and landsliding from unstable slopes and soils that cannot be stabilized using conventional methods.
DISADVANTAGES OF RETAINING WALLS
• Require the expertise of a professional engineer for all but the smallest retaining walls.
• May be expensive to design and install, depending upon site constraints, size and material used.

Soil Bioengineering

Soil bioengineering combines mechanical, biological and ecological concepts to stop and prevent shallow slope failures (or landslides) and erosion. The soil bioengineering practices discussed in this section can be divided into two general categories: living and non-living.

The *living approach* uses live plants to provide soil reinforcement and prevent surface erosion. Vegetated rock gabions and vegetated rock walls use porous structures with openings that plant cuttings are inserted into. The rock provides immediate resistance to sliding, erosion and washout. As the vegetation becomes established, roots bind the slope together into a unified mass.

Non-living approaches use rigid structures, like gravity retaining walls and rock buttresses to retain soil. Plants can be used in conjunction with these structures to create vegetated structures. The plants enhance the structures and help to reduce surface erosion.

When and Where to Use Soil Bioengineering

Soil bioengineering techniques are generally appropriate for immediate protection of slopes against surface erosion and shallow mass wasting (landslides), and provide cut and fill slope stabilization, earth embankment protection, and small gully repair treatment. These techniques are used when vegetative stabilization alone is not feasible. The use of soil bioengineering practices is limited on rocky or gravelly slopes that lack sufficient soil or moisture to support plant growth. Soil-restrictive layers, such as hardpans, may also prevent root growth.

What to Consider

Soil bioengineering is often a useful alternative for small, highly sensitive, or steep sites where the use of machinery is not feasible and hand labor is a necessity. However, rapid vegetative establishment may be difficult on extremely steep slopes. The soil bioengineering system selected should fit the site. The slope, soils, geology, hydrology and existing vegetation should be taken into account when designing the system. Existing vegetation should be retained whenever possible to provide protection against surface erosion and shallow slope failures. This vegetation can also be a source of cuttings to use in the practice. Native plant species that root easily should be used (turpentine tree (*Bursera simaruva*), white manjack (*Cordia sulcata*), hog plum (*Spondias mombin*), orchids, bromeliads, anthuriums – see USDA-NRCS *Common Planting Table*) or contact the USDA Natural Resources Conservation Service, UVI Cooperative Extension Service, or the V.I. Department of Agriculture for information on appropriate plants. The following soil bioengineering practices are most appropriate for conditions in the

Virgin Islands, although other practices may be applicable (consult the USDA-NRCS for further information on soil bioengineering practices).

Vegetated Rock Gabions: Rock gabions are rectangular baskets made from triple-twisted, hexagonal mesh of heavily galvanized steel wire placed in position, wired to adjoining gabion baskets, filled with large stone, and then folded shut and wired at the ends and sides. Live branches (or seeds) are then placed on each consecutive layer between the rock-filled baskets. These branches will take root inside the gabion basket and in the soil behind the baskets, binding the gabions to the slope (Figure 3.14).

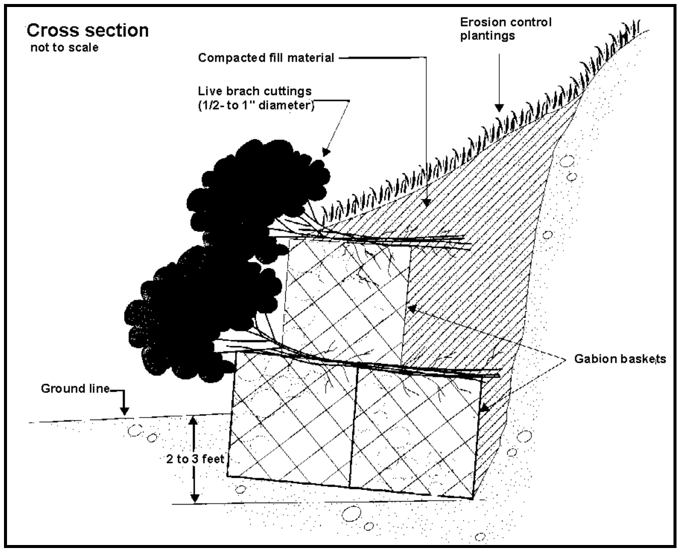

Figure 3.14. Vegetated rock gabion details (*USDA-SCS, 1992*). (Note: rooted/leafed condition of the living plant material is not representative of the time of installation).

This practice is used at the base of a slope where a low wall may be needed to stabilize the toe of the slope and reduce its steepness. It is not designed to resist large, lateral earth stresses. Vegetated rock gabions should be built a maximum of 5 feet in height, overall, including the excavation needed for a stable foundation. This practice is useful where space is limited and a more vertical structure is needed.

Vegetated Rock Wall: A vegetated rock wall is a combination of rock and live branch cuttings used to stabilize and protect the toe of steep slopes. Vegetated rock walls are different from retaining walls because they are placed against relatively undisturbed earth and are not intended to resist large lateral earth pressures (Figure 3.15). Vegetated rock walls are used where a low wall may be needed to stabilize the toe of the slope and reduce its steepness. This practice is especially useful where space is limited and natural rock is available.

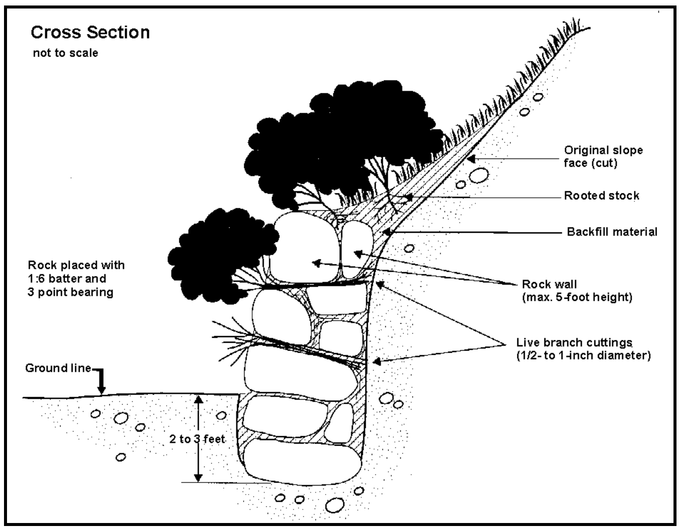

Figure 3.15. Vegetated rock wall details *(USDA-SCS, 1992*). (Note: Rooted/leafed condition of the living plant material is not representative of the time of installation).

Low wall/slope face plantings: This practice consists of a low retaining wall placed at the foot of a slope so that the slope can be flattened for planting. Vegetation established on the face of the slope protects against both surface erosion and shallow land slides (Figure 3.16). Different types of retaining walls can be used as low walls, the simplest being a gravity wall that resists lateral earth movement with its weight or mass. This includes masonry and concrete walls as well as reinforced earth or geogrid walls.

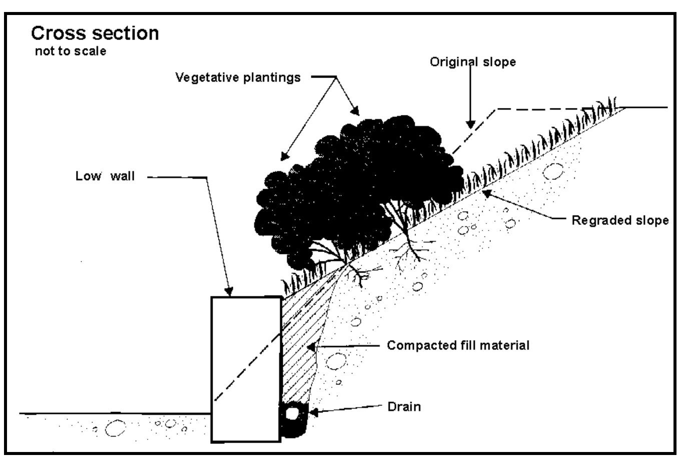

Figure 3.16. A low wall with plantings established on the slope above (*USDA-SCS, 1992*).

Tiered wall/bench plantings: An alternative to a low wall with a face planting is a tiered retaining wall, or terrace, system. This alternative effectively allows vegetation to be planted on slopes that would otherwise be too steep. Shrubs and trees planted on the benches screen the structure behind them and lend a more natural appearance while their roots protect the benches. Virtually any type of retaining structure can be used in a tiered wall system. A tiered wall system allows plant propagation on steep slopes and embankments.

ADVANTAGES OF SOIL BIOENGINEERING
• Soil bioengineering systems generally require minimal access for equipment and workers and cause relatively minor site disturbance during installation.
• Combined slope protection systems can be more cost-effective than the use of either vegetative treatments or structural practices alone, especially when using indigenous plant material.
• Are exceptionally effective in preventing erosion and landsliding from unstable slopes and soils that cannot be stabilized using vegetative methods alone.
• Can withstand heavy rainfalls immediately after installation.
• Is self-repairing by regeneration and growth once vegetation is established.
• Requires little maintenance.
DISADVANTAGES OF SOIL BIOENGINEERING
C May be expensive to design and install, depending upon site constraints, size and materials used.
C Depending on the species of plant material used, may be difficult to get adequate vegetation establishment.
C Requires periodic inspections until vegetation is established.

3.3 STRUCTURAL PRACTICES

Structural practices are used in sediment and erosion control to divert stormwater runoff away from exposed areas, to convey runoff, to prevent sediment from moving offsite, and to reduce the erosive forces of runoff waters. These controls can be either permanent or temporary practices, depending on how they are used. The structural practices described in this chapter include:

- Perimeter Dike/Swale
- Drainage Swale
- Temporary Storm Drain Diversion
- Silt Fence
- Gravel/Stone Filter Berm
- Stabilized Construction Entrance
- Check Dams/Triangular Dikes/Berms
- Sediment Traps
- Temporary Sediment Basin
- Storm Drain Inlet Protection
- Outlet Protection
- Gabion Inflow Protection

Temporary structural practices are used during construction to prevent sediment from moving offsite. The length of time that temporary practices are functioning varies since the sediment control strategy may change as construction activities progress. Permanent structural practices are used to convey stormwater runoff to a safe outlet away from erodible areas and/or to treat stormwater runoff to remove sediment. Permanent structural practices remain in place and continue to be used after construction is completed.

In general, structural sediment control practices are less effective that erosion control – i.e., it is much easier and more cost effective to keep the soil in place than it is to attempt to remove soil from stormwater. This is particularly true in the Virgin Islands since predominant soil types have high clay content. Clays are particularly difficult to remove from stormwater because of their very small particle size and propensity to stay suspended in stormwater for long time periods. **Most practices, such as silt fences, sediment traps, and gravel/stone filter berms, are not effective in removing clays from stormwater runoff.**

Perimeter Dike/Swale

A perimeter dike is a ridge of compacted soil. A swale is an excavated trench or channel. These two practices are used together to prevent stormwater runoff generated outside a construction site from entering and crossing the site and eroding bare soils or disturbed areas. Perimeter dikes and swales reduce the volume and speed of runoff on a site and channel stormwater to a stabilized discharge area or sediment trap (see sections on ***Sediment Traps*** and ***Temporary Sediment Basins***). The dike is built using the soil dug from the adjoining swale placed along the perimeter of the construction site or disturbed area. Dikes and swales can be either temporary or permanent stormwater control structures.

When and Where to Use Perimeter Dikes/Swales

Perimeter dikes/swales are generally built around the edge of the site before any earth change activity takes place. They may also be used to protect existing buildings, topsoil stockpiles, or other small areas that have not yet been fully stabilized. They are appropriate for sites less than or equal to two (2) acres in size.

What to Consider

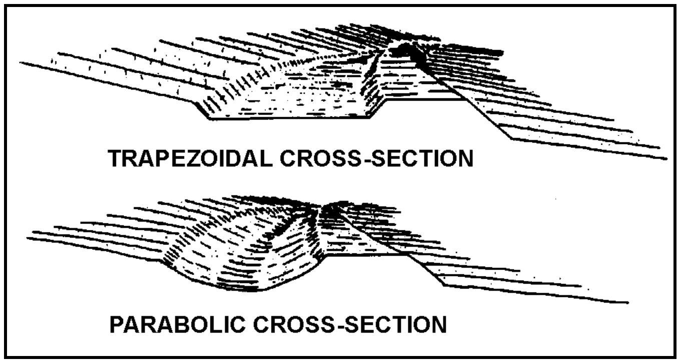

Figure 3.17. Examples of perimeter dikes/swales (*U.S. EPA, 1992*).

If temporary dikes and swales are to remain in place longer than 10 days they must be stabilized using either vegetation, erosion control matting, geotextile, rip-rap, or some other material. The distance from the bottom of the swale to the top of the dike should not be less than 18 inches. The bottom width of the dike and width of the swale should be a minimum of three (3) feet. The maximum allowable grade should **NOT** exceed 20 percent. Figure 3.17 shows two different types of perimeter dike/swale.

Stormwater runoff diverted by a perimeter dike/swale should be directed to an appropriate area for sediment removal (a sediment trap, basin, or filter area: see sections on ***Sediment Traps, Sediment Basins***, and ***Filter Strips***). Temporary perimeter dikes/swales may stay in place as long as 12 to 18 months, provided they are properly stabilized and inspected and maintained on a regular basis. They should remain in place until the area they were built to protect is permanently stabilized. Temporary and permanent control practices should be inspected once a week on a regular schedule and after every large or intense rain storm. Repairs should be made promptly.

ADVANTAGES OF PERIMETER DIKES/SWALES
• Are easy to install and are effective for channeling stormwater runoff away from areas subject to erosion.
• Can handle flows from large drainage areas.
• Are inexpensive because they use materials and equipment normally found onsite.
DISADVANTAGES OF PERIMETER DIKES/SWALES
• Can cause erosion and sediment transport downstream if they are not properly designed, built or stabilized.
• If water flows too fast, vegetation may be difficult to establish – slopes less than 20% are recommended.
• Require frequent maintenance, inspections and repairs.

Drainage Swale

A drainage swale is a channel excavated and located to convey runoff to a desired location. It typically has a lining of vegetation, erosion control matting, geotextile, rip-rap, concrete, or some other material.

When and Where to Use Drainage Swales

A drainage swale is used to route stormwater around or through an area without causing erosion. A swale can convey runoff from an undisturbed area surrounding the construction site to a stabilized outlet, where runoff is discharged at non-erosive rates. It can also be used to divert sediment-laden runoff away from a disturbed area, across disturbed areas to shorten overland flow distances, or from the base of a slope to a sediment trapping device.

What to Consider

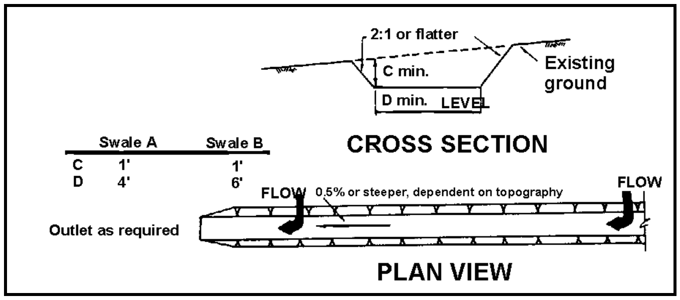

Figure 3.18. Temporary swale design example (*Empire State Chapter, Soil and Water Conservation Society, 1997*).

Swales should be lined with grass, sod, erosion control mats, geotextiles, rip-rap, or concrete. The type of liner used is dependent on the volume and velocity of the stormwater runoff to be conveyed. The swale should have a positive grade and should have no dips or low points where stormwater can collect. Figure 3.18 shows an example of swale design and Table 3.1 provides an example of how to design two different sized drainage swales.

Table 3.1. Example drainage swale designs (*Empire State Chapter, Soil and Water Conservation Society, 1997*).

	Swale A	Swale B
Maximum Drainage Area Contributing Runoff	< 5 Acres	5 - 10 Acres
Bottom Width of Flow Channel	4 feet	6 feet
Depth of Flow Channel	1 foot	1 foot
Side Slopes	2:1 (50% or 26°)or flatter	2:1 or flatter
Grade	0.5% minimum 20% maximum	0.5% minimum 20% maximum

ADVANTAGES OF DRAINAGE SWALES
• Swale excavation can be easily performed with earth moving equipment.
• Can transport large volumes of runoff.
DISADVANTAGES OF DRAINAGE SWALES
• Stabilization and design costs can make construction expensive.
• Effective use is restricted to areas with relatively flat slopes (< 8% for most designs).

Temporary Storm Drain Diversion

A temporary storm drain diversion is a pipe that redirects an existing storm drain system or outfall channel so that it discharges into a sediment trap or basin.

When and Where to Use Temporary Storm Drain Diversions

Storm drain diversions should be used to temporarily divert stormwater runoff flow going to a permanent outfall. This diverted flow should be directed to a sediment trapping device (see ***Sediment Traps*** or ***Temporary Sediment Basins*** section). A temporary storm drain diversion should be used for as long as the area draining to the storm drain remains disturbed.

What to Consider

Since the existing storm drain system will be modified, careful consideration needs to be given to the pipe configuration and the resulting impact of installation. The temporary diversions will need to be removed once construction is completed and the original storm drain system is restored. Therefore, appropriate restoration measures should be taken, such as flushing the storm drain before removing the sediment trapping device, and stabilizing the outfall and restoring grades.

ADVANTAGES OF TEMPORARY STORM DRAIN DIVERSIONS
• Requires little maintenance once installed.
DISADVANTAGES OF TEMPORARY STORM DRAIN DIVERSIONS
• Disturbs existing storm drain patterns.

Silt Fence

A silt fence, or filter fabric fence, is a temporary practice for sediment control. A silt fence is made of geotextile or filter fabric stretched across wood posts, rebar or a wire support fence. The lower edge of the material is vertically trenched into the ground and covered by backfill. Silt fences are most effective for removing sediment from overland flow. They reduce sediment loads entering receiving waters. They are also used to catch wind blown sand and to create an anchor for sand dune creation. Along with the typical wooden post and filter fabric method, there are several variations of filter fabric fence installation including fencing that can be purchased with pre-sewn pockets for use with steel rebar fence posts. ***(Use of steel rebar for fence posts is recommended in the Virgin Islands, especially on slopes greater than 20% or in stony or clayey soils).***

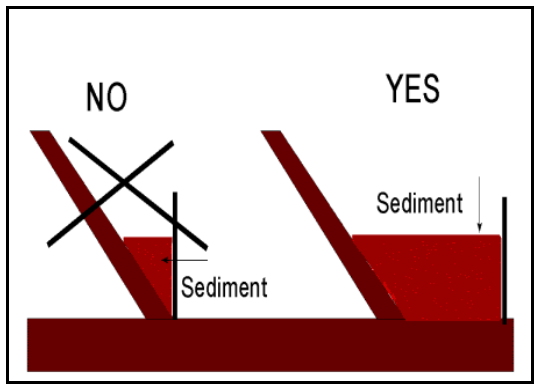

Figure 3.19. Poor silt fence placement (left) vs. proper silt fence placement (right) (*Fifield, 1996*).

When and Where to Use Silt Fences

Silt fences are the most widely and most incorrectly used sediment control practice in the Virgin Islands.

Silt fences should only be used to detain sediment on small construction sites, such as individual home sites. Silt fences should be installed **prior to** earth change activities. The fence should be placed away from the bottom of the slope (to increase holding capacity), along a line of uniform elevation perpendicular to the direction of flow (Figure 3.19). Silt fence material **MUST** be trenched into the ground to work properly (Figure 3.20). Fencing can also be placed across the direction of stormwater flow at the outer boundary of the work area. **Silt fences should NEVER be installed in guts or swales.**

Figure 3.20. Properly installed reinforced silt fence - note trenching, wire mesh and steel bars *(Estate Caret Bay, St. Thomas, 1999)*.

Silt fences used on slopes greater than 20% (5:1 or , or installed in rocky or clayey soils, should use 3/8" - ½" steel rebar stakes instead of wooden posts (Figure 3.21). Silt fences installed on slopes greater than 40% should use 3/8" - ½" steel rebar and wire mesh backing to prevent the fence from being knocked down by heavy stormwater flows. Double the height of the silt fence on slopes steeper than 1:1 or with a greater than recommended slope length (see Table 3.2). Attach the top and bottom of the second layer of geotextile to the rebar and wire mesh so that it overlaps the first layer by 6 inches. Staple the two layers together.

Figure 3.21. Properly installed silt fence (*Estate St. George's Hill, St. Croix, 1998*).

What to Consider

A silt fence is **NOT** appropriate for controlling runoff from a large area (greater than 5 acres). However, this type of fence is much more effective than a straw bale barrier if properly installed and maintained. (Straw bale barriers are **NOT** recommended for use in the Virgin Islands). Silt fences **MUST** be anchored and trenched into the ground or else they will fail. They should always be used in combination with other erosion and sediment control practices, such as temporary seeding, perimeter dikes and swales, drainage swales, sediment traps, etc. **The area below a silt fence should be undisturbed ground.**

The effective life span for a silt fence depends on the material and maintenance. Silt fences require frequent inspection and prompt maintenance to maintain effectiveness. The fence should be inspected after each rainfall. Check for areas where runoff has eroded a channel beneath the fence, or where the fence has sagged or collapsed from runoff flowing over the top. Remove sediment when it is one-third to one-half the height of the fence, or after each storm. (Accumulated sediment can be used for landscaping purposes once construction is completed.) Table 3.2 lists maximum **slope lengths** (distance down-slope between silt fences) for a silt fence depending upon steepness.

Table 3.2. Maximum allowable slope lengths contributing runoff to a silt fence (*Empire State Chapter, Soil and Water Conservation Society, 1997*).

Slope Steepness	Maximum Slope Length (feet)
2:1 (50% or ~26°)	50
3:1 (33% or ~19°)	75
4:1 (25% or ~14°)	125
5:1 (20% or ~11°)	175
Flatter than 5:1	200

Maximum drainage area for overland flow to a silt fence should not exceed ½ acre per 100 feet of fence. Also, **do not** use silt fences to retain sediment from concentrated stormwater flow (such as in a channel, gully, gut or other drainage way), the material is not designed and manufactured to withstand the force of concentrated flows.

ADVANTAGES OF SILT FENCING
• Reduces the speed of stormwater runoff and removes some sediment from runoff, protecting downstream areas from sedimentation.
• Is inexpensive and easy to install.
• Is suitable for smaller developments (such as individual home sites or those less than 5 acres).
• Requires minimal clearing and grubbing for installation.
DISADVANTAGES OF SILT FENCING
C Is not suitable for larger developments (greater than 5 acres).
C Un-reinforced (no steel rebar, wire netting) silt fences are not suitable for slopes greater than 20%.
C Fences with wood stakes are difficult to install in stony or clayey soils - use steel rebar stakes instead.
C **WILL FAIL IF IT IS NOT PROPERLY ANCHORED AND TRENCHED INTO THE GROUND!**
C Requires frequent inspection and maintenance to ensure effectiveness.

Gravel/Stone Filter Berm

A gravel, stone or rock berm is a temporary barrier of loose gravel, stone, or rock built across the bottom of a slope to slow runoff from leaving a site. They can also be used to divert flow from an exposed traffic area. These berms can also be used for directing runoff from a right-of-way to a stabilized outlet.

When and Where to Use Filter Berms

Gravel or stone filter berms are used where roads and other rights-of-way under construction accommodate vehicular traffic. They are meant for use in areas with gentle slopes. They also may be used at traffic areas within a construction site. **Berms should be used in conjunction with other temporary sediment control practices, such as diversion dikes and swales, drainage swales, silt fences, temporary seeding, and/or sediment traps.**

What to Consider

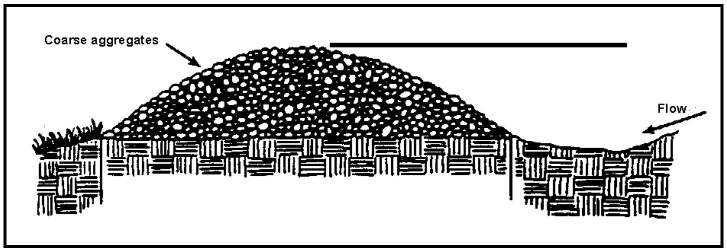

Figure 3.22. Example of a gravel filter berm (*U.S. EPA, 1992*).

Berm spacing depends on the steepness of the slope – berms should be placed closer together as the slope increases. The berm should be inspected regularly after each rainfall, or if breached by construction or other vehicles. All needed repairs should be performed immediately. Accumulated sediment should be removed and properly disposed of and the geotextile or filter material replaced, as necessary (Figure 3.22).

ADVANTAGES OF FILTER BERMS
• Reduce the speed of stormwater runoff.
• Berms are fairly inexpensive and easy to install, and work well on slopes up to 40%.
DISADVANTAGES OF FILTER BERMS
• Have a limited life span.
• Can be difficult to maintain due to clogging with mud.
• Frequent inspection and maintenance is necessary to ensure effectiveness.

Stabilized Construction Entrance

A stabilized construction entrance is a section of the construction road adjacent to a paved road that is stabilized with geotextile and large stone or gravel. A stabilized construction entrance is designed to reduce the amount of soil tracked off of the construction site by vehicles leaving the site. The rough surface of the stone or gravel shakes and pulls the soil off of vehicle tires as they drive over the entrance. The stone also reduces erosion and rutting on the portion of the road that it is installed on by protecting the soil below. Filter fabric or geotextile separates the stone from the underlying soil, preventing the stone from being ground into the soil. The fabric also reduces rutting caused by vehicle tires by spreading the weight of the vehicles over a larger soil area than the tire width.

When and Where to Use Stabilized Construction Entrances

A stabilized construction entrance should be installed at every point where traffic enters or leaves a construction site **before** construction begins on the site. For individual home sites, the construction entrance should be located where the permanent driveway will be sited. Stabilized construction entrances should not be used on existing pavement.

What to Consider

Stabilized construction entrances should be wide and long enough so that the largest construction vehicle will fit in the entrance with overlap available. A good rule of thumb is for the entrance to be a minimum of 50 feet long (30 feet for an individual home site) and 10 feet wide with a flare at the existing road to provide turning radius. Stone, rock or gravel (2" - 3") should be placed at least 6 inches deep on top of geotextile over the length and width of the entrance (Figure 3.23).

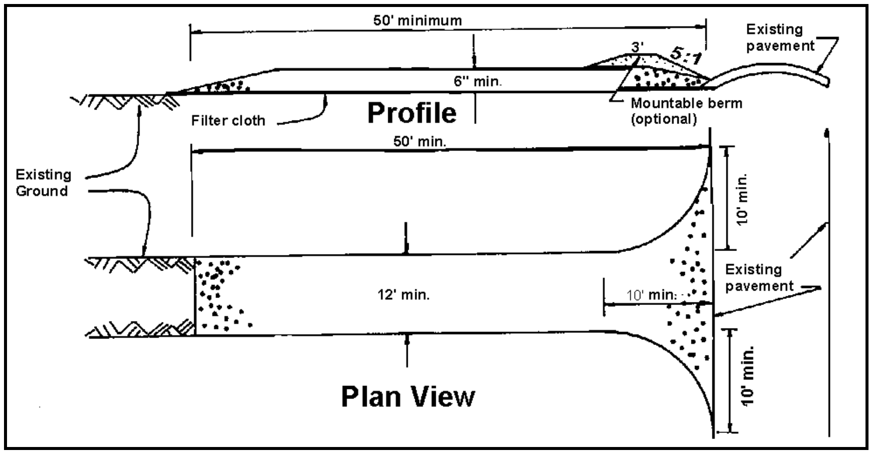

Figure 3.23. Stabilized construction entrance design *(Empire State Chapter, Soil and Water Conservation Society, 1997)*.

ADVANTAGES OF STABILIZED CONSTRUCTION ENTRANCES
• Are very effective in reducing the amount of soil tracked off of a construction site.
• Can improve the appearance of the construction site from the public's point of view.
DISADVANTAGES OF STABILIZED CONSTRUCTION ENTRANCES
• Only work if they are installed at every location where traffic leaves and enters the site.
• Cannot always remove all of the soil tracked off of disturbed areas by vehicles.
• Stone may have to be added to maintain effectiveness.

Check Dams/Triangular Dikes/Berms

A check dam is a small, temporary or permanent dam constructed across a drainage ditch, swale, or channel to reduce the speed of concentrated flows. Reduced runoff speed reduces erosion and gullying in the channel and allows sediments to settle out.

When and Where to Use Check Dams

A check dam should be installed in steeply sloped swales or channels, or in swales where adequate vegetation cannot be established. Check dams limit erosion by reducing flow in small open channels that are degrading or subject to erosion. A check dam may be built from stone, rip-rap, pea gravel-filled sand bags, or manufactured pervious berms or barriers such as a Triangular Silt Dike™ (Figure 3.24), EnviroBerm®, Geo-Ridge® berm, coir (coconut fiber) rolls or "logs," or other similar product.. **Check dams should NOT be built in streams or guts.** They block normal streamflow, altering drainage patterns, and can lead to channel bypass and dramatically increased erosion.

Figure 3.24. Installation of a triangular dike as a check dam in a drainage swale *(Estate St. George's Hill, St. Croix, 1998)*.

What to Consider

Check dams should be used only in small open channels that will not be overtopped by flow once the dams are built. The maximum drainage area above the check dam should not be larger than two (2) acres. The center section of the check dam should be lower than the edges, and should not be higher than two (2) feet. Check dam side slopes should be 2:1 or flatter. Dams should be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam (Figure 3.24).

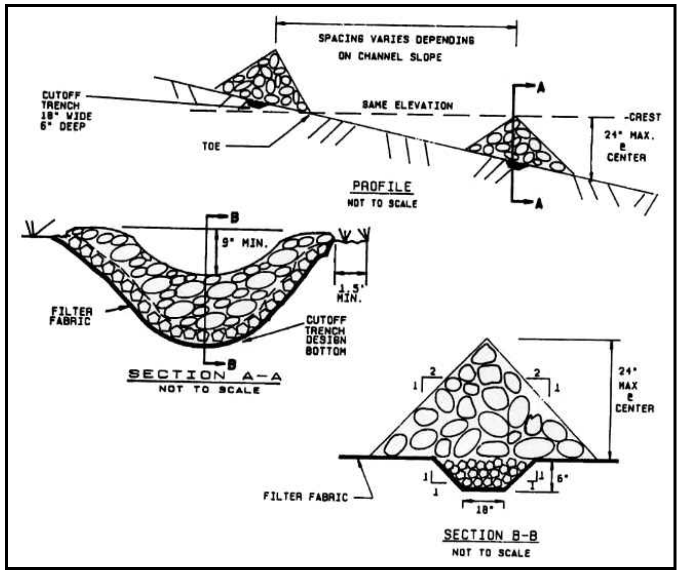

Figure 3.25. Check dam design example *(Empire State Chapter, Soil and Water Conservation Society, 1997)*.

After each significant rainfall, check dams should be inspected for sediment and debris accumulation. Sediment should be removed when it reaches one half the original dam height. Check for erosion at edges and repair promptly. After construction is complete, all stone and rip-rap should be removed if vegetative erosion controls will be used for permanent stabilization. It is important to know expected erosion rates and runoff flow rate for the swale or channel in which this practice is to be installed. Contact DPNR's Division of Environmental Protection, USDA Natural Resources Conservation Service, the UVI Cooperative Extension Service, or a licensed engineer for assistance in designing this practice.

ADVANTAGES OF CHECK DAMS
• Are inexpensive and easy to install.
• May be used permanently if designed properly.
• Allow a high proportion of sediment in stormwater runoff to settle out.
• Reduce velocity and may provide water aeration.
• May be used where it is not possible to divert runoff flow or otherwise stabilize the channel.
DISADVANTAGES OF CHECK DAMS
• May kill grass linings in channels if the water level remains high after it rains or if there is significant sedimentation.
• Can reduce the hydraulic capacity of the channel.
• May create turbulence that can erode channel banks.

Sediment Traps

A sediment trap is built by excavating a pond or by installing an earthen embankment across a low area or drainage swale. An outlet or spillway from the trap is built using large stones or aggregate to slow the release of stormwater runoff. Sediment traps are designed to retain runoff long enough to allow most of the sediment to settle out. There are six basic types of sediment traps: pipe outlet traps, grass outlet traps, storm inlet traps, swale traps, stone outlet traps, and rip-rap outlet traps.

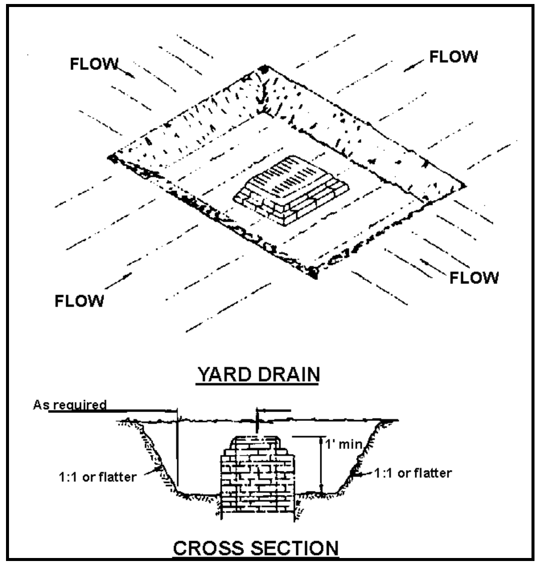

Figure 3.26. Storm inlet sediment trap design (Empire State Soil and Water Conservation Society, 1991).

When and Where to Use Sediment Traps

A temporary sediment trap should be used in conjunction with other temporary practices, such as gravel construction entrances, temporary seeding, silt fences, and diversion dikes, swales, or channels. Sediment traps are suitable for small drainage areas and should be installed at stormwater discharge points from a disturbed area. Pipe, stone and grass outlet sediment traps can handle maximum drainage areas of 5 acres or less; storm inlet traps can handle 3 acres or less; swale traps can handle 2 acres or less; and rip-rap outlet traps can handle 10-15 acres. Sediment traps should **NOT** be installed in guts or used to artificially break up a natural drainage area into smaller sections where a larger device (sediment basin) would be more appropriate. Figures 3.26 to 3.29 show the different types of outlets that can be used with sediment traps. Larger drainage areas require larger sediment traps, and larger traps require more detailed engineering design.

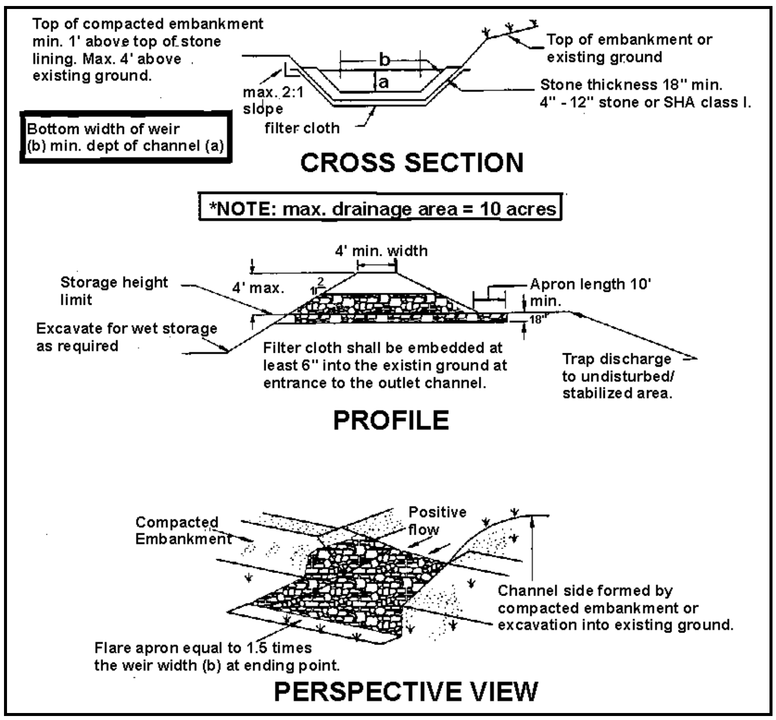

Figure 3.27. Rip-rap outlet sediment trap example *(Maryland Department of the Environment, 1994)*.

What to Consider

The sediment trap should be large enough to allow soil particles to settle out of stormwater and should have enough capacity to store collected sediment until it is removed. The volume of sediment storage that the sediment trap provides depends upon the amount and intensity of expected rainfall and on estimated quantities of sediment in stormwater runoff. However, storage capacity should allow for an average of 3600 cubic feet per acre of drainage area contributing stormwater to the trap. This sizing is used in areas where the soils have high clay contents in order to allow for greater settling of fine particles. Due to the predominance of clayey soils in the Virgin Islands, sizing basins to 3600 ft^3 per acre of drainage area will allow for greater sediment removal through longer retention of sediment-laden stormwater. However, larger sediment traps need more detailed engineering design and may not be practical for small sites.

Sediment traps should be installed **prior** to grading or filling, and they must be located at least 20 feet away from an existing building foundation. Sediment trap embankment height should not exceed 5 feet and should have a minimum 4 foot wide top and side slopes of 2:1 or flatter. The trap embankment should be compacted during construction. The sediment trap outlet should be designed so that sediment does not leave the trap and so that erosion at or below the outlet does not occur. Sediment traps must outlet water onto stabilized (preferably undisturbed) ground, or into a stabilized channel, drainage, or storm drain system (Maryland Department of the Environment, 1994). Contact DPNR's Division of Environmental Protection, USDA Natural Resources Conservation Service, the UVI Cooperative Extension Service, or a licensed engineer for assistance in designing this practice.

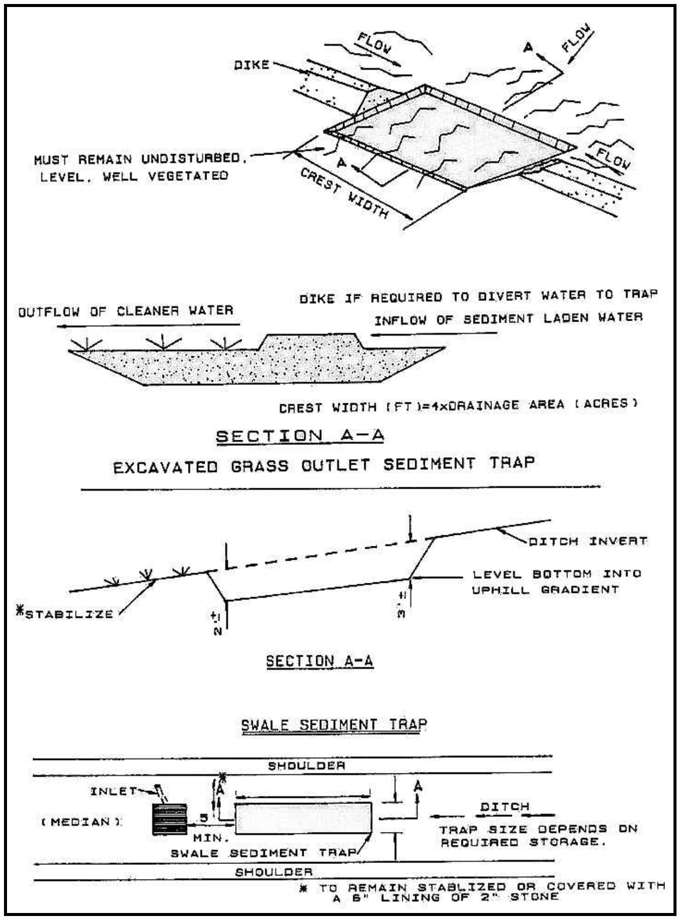

Figure 3.28. Grass outlet and swale outlet sediment trap designs (*Empire State Chapter, Soil and Water Conservation Society, 1997*).

The effective life of a sediment trap depends on proper maintenance. The trap should be easily accessible for regular maintenance and sediment removal. Traps should be inspected after each rainfall and cleaned when one-third (⅓) to one-half (½) the design volume has been filled with sediment. The trap should continue to be used and maintained until the site is permanently stabilized by vegetation and other permanent practices. After completion of construction and site stabilization, all sediment traps should be removed and the trap areas should be graded and vegetatively stabilized.

ADVANTAGES OF SEDIMENT TRAPS

- Protect downstream areas from sedimentation.
- Are relatively inexpensive and easy to install.
- Are suitable for individual home sites or smaller developments (up to 10 acres, depending upon the type of sediment trap (see Appendix B).

DISADVANTAGES OF SEDIMENT TRAPS

C Are not suitable for large developments or steep slopes.

C Are only effective if properly maintained.

C Will not remove very fine silts and clays from stormwater runoff.

C Must be removed after construction and stabilization are completed, unless converted to a permanent retention basin (see Chapter 4).

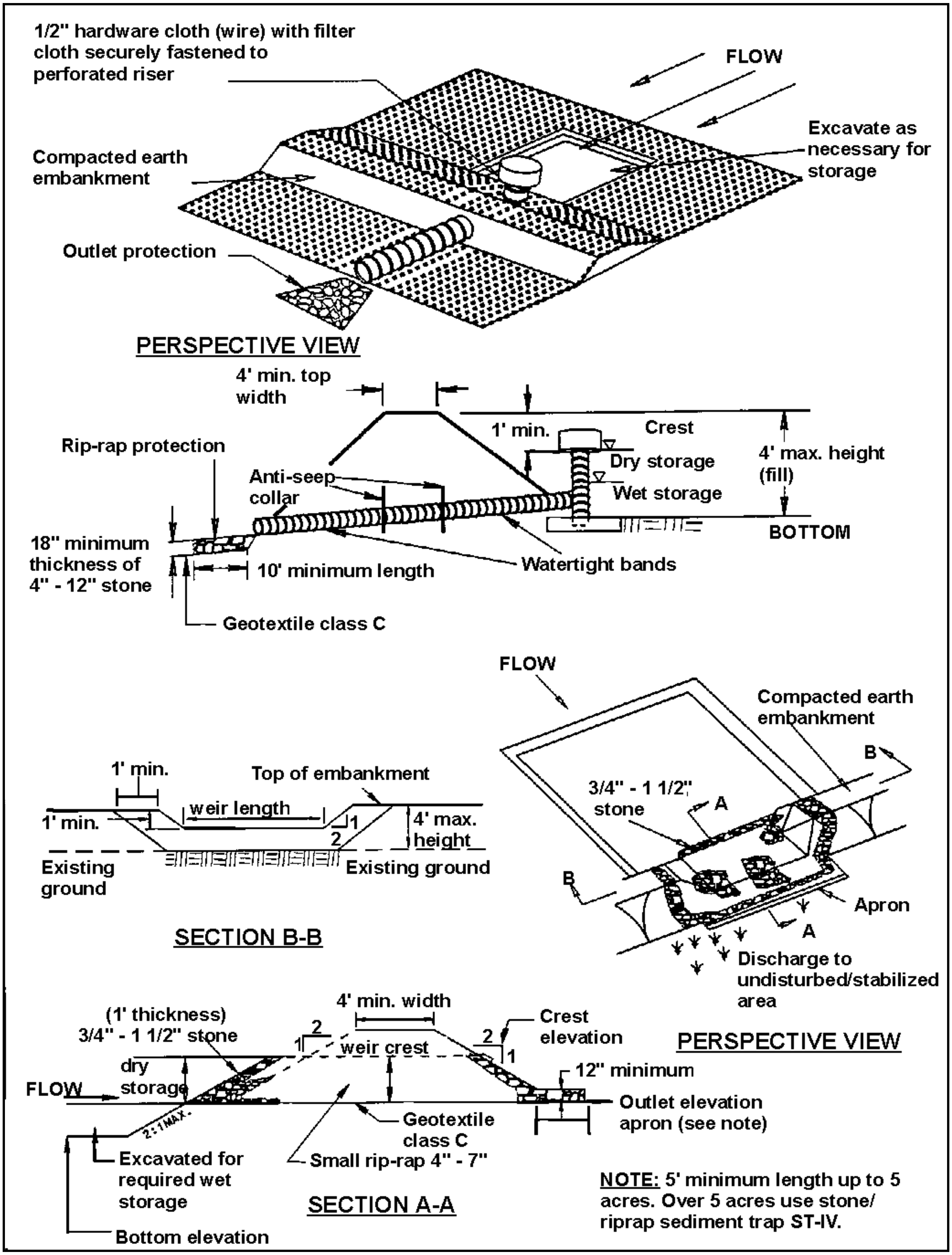

Figure 3.29. Examples of pipe and stone outlet sediment traps *(Maryland Department of the Environment, 1994)*.

Temporary Sediment Basin

A temporary sediment basin is a settling pond with a controlled stormwater release structure used to collect and store sediment produced by construction activities. A sediment basin can be constructed by excavation and/or by placing an earthen embankment across a low area or drainage swale or channel. Sediment basins can be designed to maintain a permanent pool or to drain completely dry. The basin detains sediment-laden runoff from larger drainage areas long enough to allow most of the sediment to settle out.

The pond has a riser and pipe outlet with a gravel outlet or spillway to slow the release of runoff and provide some sediment filtration. By removing sediment, the basin helps prevent clogging of offsite conveyance systems and sediment-loading of receiving waters.

When and Where to Use Temporary Sediment Basins

Temporary sediment basins are usually designed for disturbed areas larger than 5 acres. A sediment basin should be installed before clearing and grading is undertaken. It should **NOT** be built in a stream or gut. The creation of a dam at these sites may result in destruction of aquatic and moist forest habitats and flooding may result from dam failure. A temporary sediment basin should only be used at sites where there is sufficient space and appropriate topography. A temporary sediment basin used in combination with other control practices such as temporary seeding, diversion dikes and swales, drainage swales, and/or mulching and matting is especially effective in removing sediment.

What to Consider

The pond area in a temporary sediment basin should be large enough to hold runoff long enough for sediment to settle out. Sufficient space should be allowed for collected sediments. Sediment trapping efficiency is improved by providing the maximum surface area possible. Because finer silts and clays may not settle out completely, additional erosion control measures should be used to minimize release of fine silt. Runoff should enter the basin as far from the outlet as possible to provide maximum retention time (i.e., the flow path, or length of flow in the sediment basin should be maximized. Appendix B has detailed specifications and criteria to follow in designing a sediment basin to fit each specific site. Figure 3.30 depicts a sample sediment basin design.

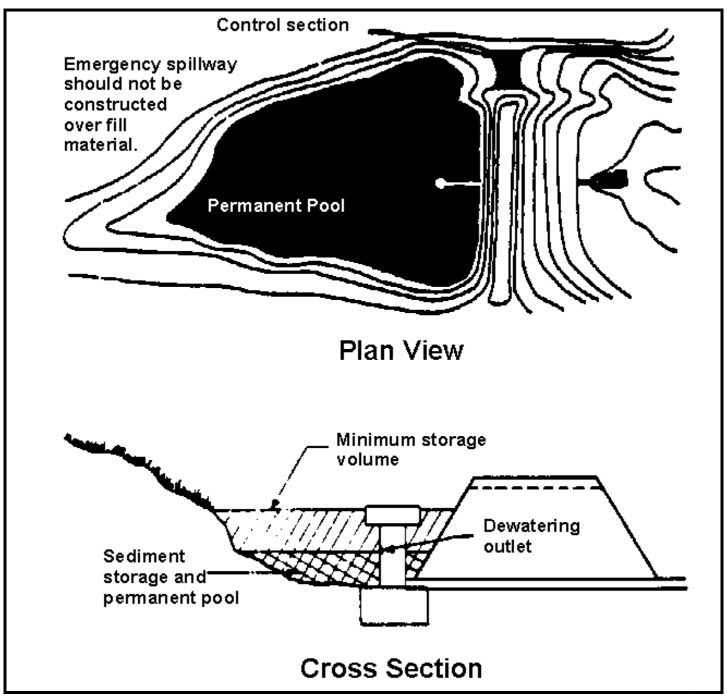

Figure 3.30. Temporary sediment basin design (*U.S. EPA, 1992*).

The useful life of a sediment basin depends on regular maintenance. Sediment basins should be readily accessible for maintenance and sediment removal. They should be inspected after each rainfall event and be cleaned out when about half the volume has been filled with sediment. The basin should remain in operation and be properly maintained until the construction site is permanently stabilized by vegetation. If the basin is located near a residential area, it is recommended for safety reasons that a sign be posted (child hazard, no playing) and that the area be secured by a fence. A well-built temporary sediment basin that is large enough to handle post-construction runoff volume may later be converted to use as a permanent stormwater management structure (see Chapter 4).

The outlet pipe and spillway of the sediment basin should be designed by an engineer based upon an analysis of the expected runoff flow rates from the site. Contact DPNR's Division of Environmental Protection, USDA Natural Resources Conservation Service, the UVI Cooperative Extension Service, or a licensed engineer for assistance in designing this practice.

ADVANTAGES OF TEMPORARY SEDIMENT BASINS
• Protects downstream areas from clogging or damage due to sediment deposits generated during construction activities.
• Can trap smaller sediment particles than sediment traps due to longer detention time.
• Can be converted to a permanent stormwater detention structure, once construction is complete.
DISADVANTAGES OF TEMPORARY SEDIMENT BASINS
• Requires regular maintenance and removal of accumulated sediment and debris.
• Will not remove very fine silts and clays unless used in conjunction with other sediment and erosion control practices.
• Is more expensive than other methods of sediment removal and requires larger area for installation.
• Requires careful adherence to safety practices since ponds may attract children.

Storm Drain Inlet Protection

Storm drain inlet protection consists of a permeable barrier placed around any inlet or drain to filter sediment out of stormwater. This practice prevents sediment from entering the storm drain inlet structures and getting into the storm drain system. It also prevents the silting-in of inlets, storm drainage systems, or receiving channels. Inlet protection may be composed of gravel and stone with a wire mesh filter, block and gravel, or geotextile (filter fabric). There are four basic types of inlet protection recommended in the V.I.: stone and block drop inlet protection, excavated drop inlet protection, curb drop inlet protection, and geotextile drop inlet protection (see Figures 3.32 and 3.33). Commercially manufactured inlet inserts (Beaver Dam™, Silt Sack™, etc., see Figure 3.31) that remove sediment and other pollutants from are also available, but have not been tested in the V.I.

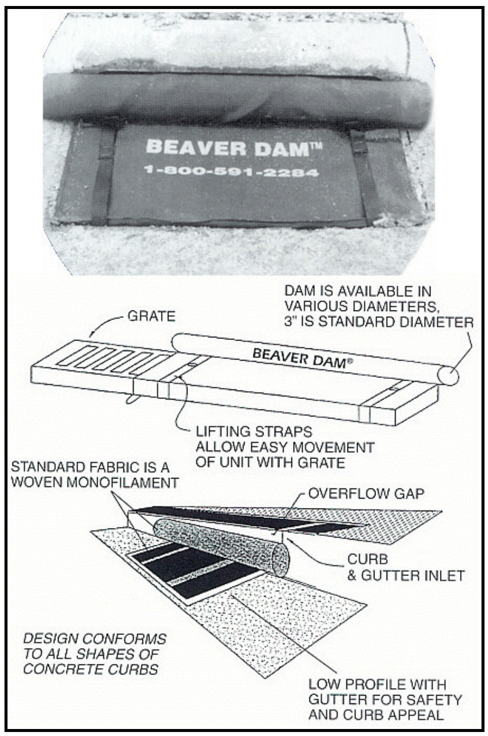

Figure 3.31. Example installation and diagram for Beaver Dam™ storm drain inlet protection (*Dandy Products, Inc., 2001)*.

When and Where to Use Inlet Protection

This practice should be used where the drainage area to an inlet is disturbed, it is not possible to temporarily divert the storm drain outfall into a trapping device, for small drainage areas where storm drain inlets will be ready for use before final stabilization, where a

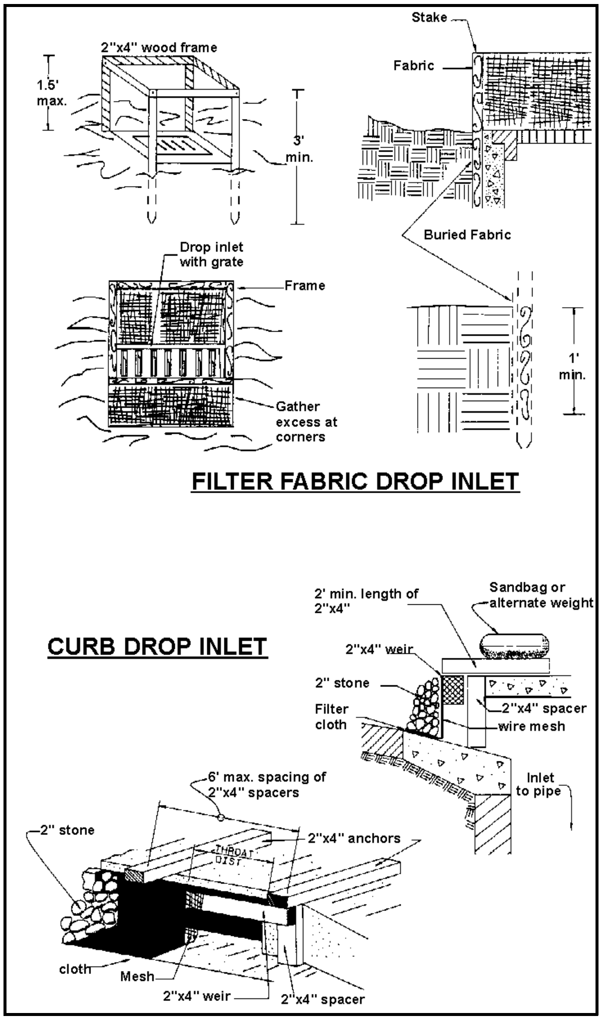

Figure 3.32. Examples of filter fabric drop inlet and curb drop inlet storm drain protection (*Empire State Chapter, Soil and Water Conservation Society, 1997*).

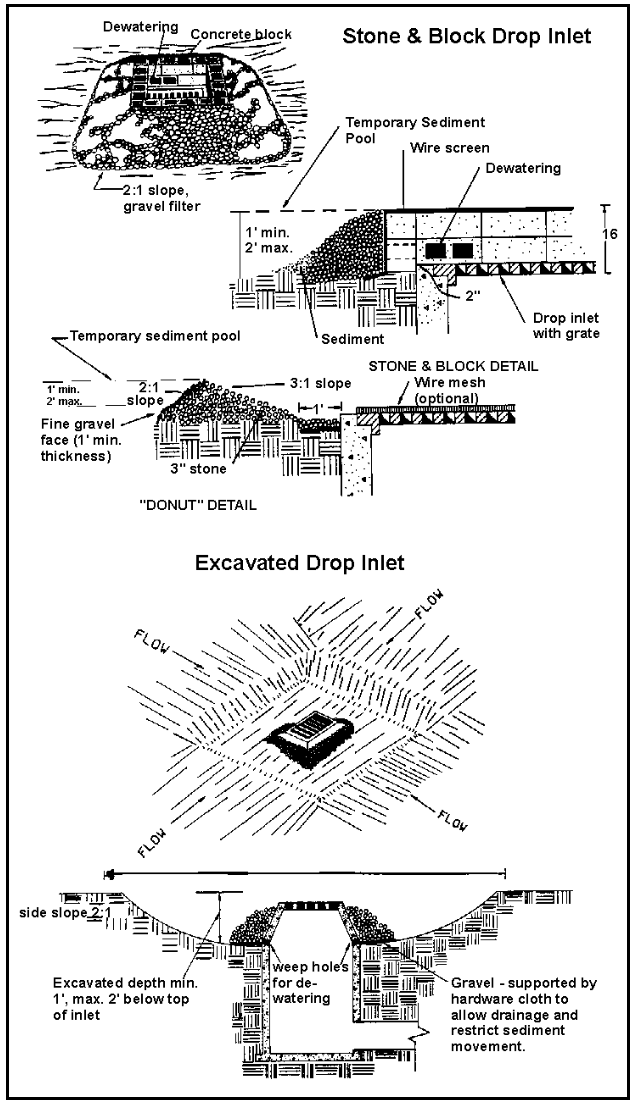

Figure 3.33. Examples of stone and block inlet and excavated drop inlet storm drain protection (*Empire State Chapter, Soil and Water Conservation Society, 1997*).

permanent storm drain structure is being constructed onsite, or where watertight blocking of inlets is not advisable. Straw bales are **NOT** recommended for this practice. It should **NOT** be used in place of sediment trapping devices.

Geotextiles are used for inlet protection when stormwater flows are relatively small with low velocities (Figure 3.32). This practice **cannot** be used where inlets are paved because the filter fabric must be staked into the ground. However, commercially manufactured inlet inserts (Beaver Dam™, Silt Sack™, etc., see Figure 3.31) can be used over flat grates, for curb and gutter inlets, or median barrier inlets. Block and gravel filters can be used where velocities are higher. Gravel and mesh filters can be used where flows are higher and subject to disturbance by site traffic (Figure 3.33).

What to Consider

Storm drain inlet protection is not meant for use in drainage areas that are larger than one acre or for large, concentrated stormwater flows. This practice should be installed before any soil disturbance takes place in the drainage area. The type of material used will depend on site conditions and the size of the drainage area.

Inlet protection should be used in combination with other practices, such as small sediment traps, to provide more effective sediment removal. Inlet protection structures should be inspected regularly, especially after a rainstorm. Repairs and sediment removal should be performed as necessary. This practice should be removed only after the disturbed areas are completely stabilized.

ADVANTAGES OF STORM DRAIN INLET PROTECTION
• Effective in preventing clogging of existing storm drainage systems and reduces receiving water siltation.
• Reduces the amount of sediment leaving the site.
DISADVANTAGES OF STORM DRAIN INLET PROTECTION
• May be difficult to remove collected sediment.
• Requires regular maintenance and cleaning.
• May cause erosion elsewhere if clogging occurs.
• Is practical only for low sediment, low volume flows (disturbed areas 1 acre or less).

Outlet Protection

Outlet protection reduces the depth, speed and energy of concentrated stormwater flows, reducing erosion and scouring at stormwater outlets of culverts, swale and drainage channels. Outlet protection also reduces the potential for downstream erosion. This protection can be achieved through a number of methods including stone or rip-rap, concrete aprons, paved sections, and settling basins installed below the storm drain outlet.

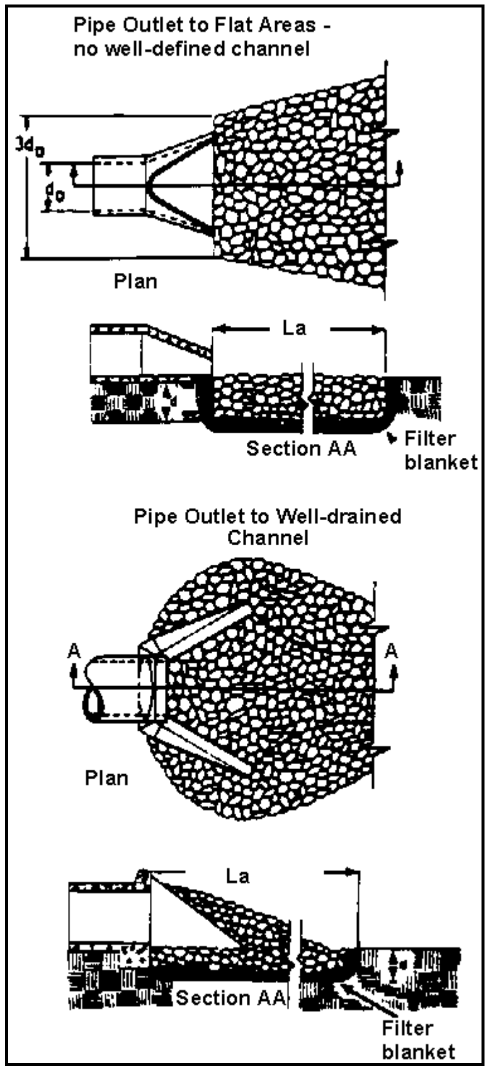

Figure 3.34. Examples of rock outlet protection designs (*U.S. EPA, 1992*).

When and Where to Use Outlet Protection

Outlet protection should be installed at all pipe, interceptor dike, swale, culvert or channel section outlets where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel. This practice applies to culvert outlets of all types; pipe conduits from all sediment basins, dry stormwater ponds, and permanent ponds; and new channels built as outlets for culverts or other drainage ways. Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools (small permanent pools located at the inlet to or the outfall from control practices). Outlet protection should be installed early during construction activities, but may be added at any time, as necessary.

What to Consider

The exit speed of runoff as it leaves the outlet protection structure should be reduced to levels that minimize erosion. The design of outlet protection depends on the location. Pipe outlets at the top of cuts or on slopes steeper than 10 percent cannot be protected by rock aprons or rip-rap sections because re-concentration of runoff flows and high velocities may occur after the flow leaves the apron. Contact DPNR's Division of Environmental Protection, USDA Natural Resources Conservation Service, the UVI Cooperative Extension Service, or a licensed engineer for assistance in designing for tailwater depth, apron size, bottom grade, alignment, materials, thickness, stone quality, and filter for this practice. Appendix B contains design specifications and example design procedure calculations (see example in Figure 3.34).

Once a rip-rap outlet has been installed, maintenance needs are usually low. Outlet protection should be inspected on a regular schedule to look for erosion and scouring and to check if any stones have been dislodged. Outlets must be kept clean of clogging debris. Repairs should be made promptly.

ADVANTAGES OF OUTLET PROTECTION
• Provides, with riprap-lined apron (the most common outlet protection), a relatively low-cost method that can be installed easily on most sites.
• Removes sediment in addition to reducing runoff speed.
• Can be used at most outlets where flow speed is high.
• Is an inexpensive but effective practice.
• Requires less maintenance than many other practices.
DISADVANTAGES OF OUTLET PROTECTION
• May cause problems in removing collected sediment (without removing and replacing the outlet protection structure itself).
• May require frequent maintenance for rock outlets with high velocity flows.
• May be unsightly.

Gabion Inflow Protection

Gabion inflow protection uses a temporary, lined drainage way installed to convey concentrated stormwater runoff into sediment traps and basins in order to prevent erosion of the flow channel. Gabions are constructed of rock or concrete within a flow channel to stabilize the channel. It should be used in conjunction with dikes, swales or other water control devices as warranted by site conditions.

When and Where to Use Gabion Mattresses

Gabion inflow protection should be used where stormwater runoff entering sediment basins or traps will cause erosion of the embankments or channels leading to them. Runoff can be directed to the entrance of the gabion using dikes or swales.

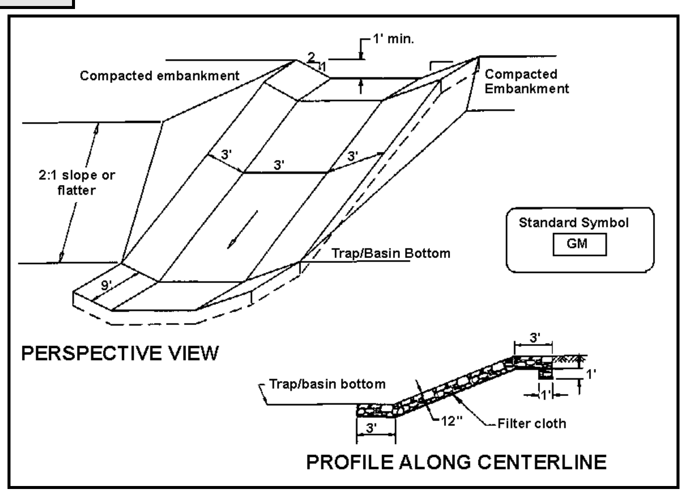

Figure 3.35. Gabion mattress inflow protection (*Maryland Department of the Environment, 1994*).

What to Consider

A gabion mattress should be constructed of 9'x3'x9' gabion baskets to form a cross-section one foot deep with 3:1 side slopes and a 3 foot bottom width (see Figure 3.35). The top mattress should be anchored into the ground at least one foot. Geotextile (or filter) fabric should be installed under all gabion baskets. The fabric used should be the same as that used for swale channel stabilization (see ***Drainage Swale*** and ***Silt Fence*** sections).

ADVANTAGES OF GABION INFLOW PROTECTION
• Removes sediment in addition to reducing runoff speed.
• Can be used at most inlets where flow speed is high.
• Requires less maintenance than many other practices.
DISADVANTAGES OF GABION INFLOW PROTECTION
• May cause problems in removing collected sediment (without removing and replacing the inlet protection structure itself).
• May require frequent maintenance for gabion inlets with high velocity flows.
• May be expensive.

3.4 REFERENCES

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CHAPTER 4: STORMWATER RUNOFF CONTROL PRACTICES
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CHAPTER 4: STORMWATER RUNOFF PRACTICES

4.1 INTRODUCTION

During development, both the landscape and the hydrology of a parcel of land can be significantly altered. The following may occur both during and after development:

- Soil porosity changes;
- Impermeable surfaces increase;
- Water retention on-site decreases;
- Channels and other water conveyances are built;
- Slopes change;
- Vegetative cover decreases; and
- Soil surface roughness decreases.

These changes result in increased runoff volumes and velocities (or speeds) which can scour and erode guts, steep slopes, and unvegetated areas, and cause downstream siltation of roads, parking lots, yards, ponds, beaches, seagrass beds, coral reefs, and other coastal areas. In addition, impervious surfaces can also increase water temperatures.

Stormwater management practices are designed to perform one or more of the following functions: decrease the erosive potential of increased runoff volumes and velocities caused by land development; remove sediment and other pollutants in stormwater runoff that result from activities that occur during and after development; preserve or improve drainage patterns and other hydrologic conditions so that they closely resemble conditions previous to development; and preserve natural systems. Stormwater control practices rely on three different processes to treat runoff: **filtration, detention**, and **infiltration**.

4.2 FILTRATION PRACTICES

Examples of filtration practices that are suitable for conditions in the Virgin Islands include:

- Buffer zones;
- Grassed swales;
- Sand filters; and
- Water quality Inlets

Filtration practices treat sheet flow runoff by using vegetation or sand to filter and settle pollutants. In some cases, infiltration and treatment of runoff in the subsoil may also occur. Some practices can also be installed in storm drains to remove pollutants from water, particularly sediment, oil and grease. After being filtered, the stormwater runoff can be routed into guts, drainage channels, or other waterbodies; evaporated; or infiltrated into the surrounding soil. The microclimate of the area must be considered in selecting vegetative systems.

Buffer Zones

Buffer zones are areas of vegetated land along a shoreline, wetland or gut where development is prohibited. Buffer zones are intended to physically protect and separate guts, wetlands and shorelines from development activities. They also provide stormwater management, filter pollutants from stormwater runoff, provide food and cover for wildlife and aquatic organisms, and provide cooling shade (CH2M Hill, 1998). There are three types of buffer zones: setbacks, vegetated buffers and engineered buffers (CWP, 2001).

Setbacks are areas that separate waterways from potential pollution hazards (typically development sites). Vegetated buffers are natural areas that exist to divide land uses or provide landscaping. Engineered buffers are areas specifically designed to treat stormwater before it enters a gut, wetland or coastal area (CWP, 2001). They may closely resemble natural ecosystems, such as grassy pastures or forests. Buffer zones are designed specifically to protect waterbodies, slow stormwater runoff and remove pollutants from stormwater, and in this way differ from ***Filter Strips*** (see Chapter 3), which are designed specifically to filter sediment from runoff.

When and Where to Use Buffer Zones

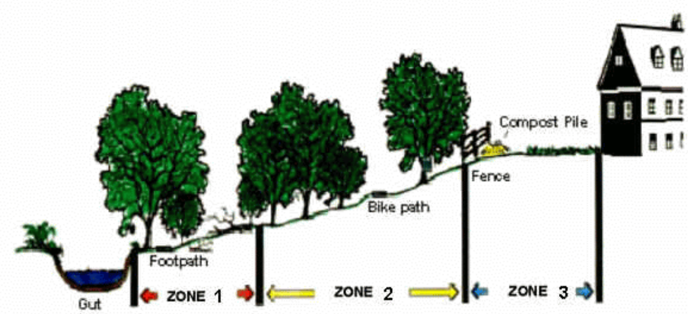
Forested buffers are well-suited to protect water quality and improve aquatic habitat in urban and suburban landscapes. Buffer zones are generally used to protect guts, wetlands and/or shorelines from development activity, to treat stormwater runoff from low density residential or resort developments, or to treat agricultural runoff. One buffer zone design utilizes a three zone system with inner, middle and outer zones (Figure 4.1). Buffer zones can increase infiltration and recharge to groundwater, slow stormwater runoff, reduce erosion of guts and shorelines, improve and increase aquatic habitat, filter sediment, and remove soluble nitrogen and phosphorus from stormwater (CH2M Hill, 1998).

What to Consider

Setbacks should have a minimum width of 100 feet to provide adequate protection of waterbodies from development activities. However, in urban and suburban areas where open space is limited, narrower buffers adjacent to guts and wetlands can still be beneficial.

Effective buffer zone design (Figure 4.1) is based on criteria that determine how a buffer will be sized, delineated, managed and crossed (see Appendix C).

The Three-Zone Buffer System



CHARACTERISTICS	ZONE 1	ZONE 2	ZONE 3
FUNCTION	Protect physical integrity of aquatic ecosystem	Provide distance between upland development and aquatic zone	Prevent Encroachment and Filter Backyard Runoff
WIDTH	Minimum 25 feet plus wetlands and critical habitats	50 - 100 feet, depending on type of water body, slope and 100 year floodplain	25 foot minimum setback for structures
VEGETATIVE TARGET	Undisturbed mature forest, reforest if grass	Managed forest, some clearing allowable	Forest encouraged, but usually turfgrass
ALLOWABLE USES	*Very Restricted* e.g., flood control, utility right of ways, footpaths, etc.	*Restricted*, some recreational uses, some stormwater BMPs, bike paths, tree removal by permit	*Unrestricted*, e.g. residential uses, including lawn, garden, compost, yard wastes, most stormwater BMPs.

Figure 4.1. Three-zone aquatic buffer system (*CWP, 2001*).

For optimal stormwater treatment, buffers can be designed with three lateral zones: a stormwater depression leading to a grass filter strip in turn leading to a forested buffer. The stormwater depression (or basin) captures and stores stormwater during smaller storm events. Larger stormflows are bypassed directly into a channel. The runoff captured in the depression can the be spread across a grass filter strip (see Chapter 3). The grass filter then discharges into a wider forest buffer designed so that all the stormwater is absorbed into the soil and not discharged to the water body (CWP, 2001).

Maintenance will be needed for any type of buffer zone. Buffer boundaries should be well-defined and visible before, during and after construction. Buffers designed to capture and treat stormwater runoff from urban or suburban areas will also need regular maintenance to prevent gullies from forming and bypassing the treatment. Also, because buffer zones are maintained differently than park lawns, they may sometimes be seen as dangerous or unkempt public places. Concerns may arise that the development of shrubby vegetation will interfere with unimpeded views or be abused as dumping places for trash and litter. Therefore, an educational program highlighting the environmental and recreational benefits of buffers should be a part of restoration programs (CH2M Hill, 1998).

How Effective Are Buffer Zones?

Buffers lower runoff velocity, preserve natural vegetation around guts, wetlands and shorelines, stabilize banks of drainage channels and guts, and slightly reduce both runoff volume and watershed imperviousness. In some cases, buffers can also help to reduce the size and cost of downstream stormwater control facilities. The pollutant removal effectiveness of buffer zones ranges widely and depends on the buffer type and design. Setbacks are designed to prevent pollution from neighboring land uses, they are not designed for pollutant removal during a storm (CWP, 2001).

Buffers, when designed correctly, can remove sediment, organic material, and many trace metals from stormwater runoff. The rate of pollutant removal is thought to be a function of the length, slope and soil permeability of the buffer, the size of the contributing runoff area, and the runoff velocity. Forested, or wooded, buffers tend to remove a greater variety of pollutants than grassed filter strips, but since there is less vegetative ground cover with forested buffers, they also need to be twice as wide as grassed buffers. Grass buffers are more effective for trapping sediment, but forested buffers are more effective in reducing nutrient loads.

ADVANTAGES OF BUFFER ZONES
• Relatively inexpensive to establish (cost almost nothing if preserved before the site is developed).
• Can remove a high percentage of sediment and attached pollutants if designed properly.
• Can provide privacy barrier, cooling shade, wind break, noise reduction, wildlife habitat, and protection of guts, wetlands, shorelines and their vegetation.
• Can protect increase infiltration, reducing flooding potential.
• Maintenance tasks and costs are minimal for “natural” buffer strips.
• Can provide recreational benefits.
DISADVANTAGES OF BUFFER ZONES
• Potential loss of developable land.
• Potential misuse of buffer zones as trash or litter dumps.
• Potential increase in nuisance species (mosquitoes, mongoose, etc.)

Grassed Swales

Grassed swales are shallow, vegetated, man-made ditches and channels designed to treat and infiltrate a specified volume of stormwater runoff. The grass in the swale prevents erosion, filters sediment, and provides some nutrient uptake. The underlying soil can also provide some filtering and treatment, absorb water, and decrease stormwater volumes. Grassed swales can also be used to convey stormwater runoff. **Enhanced grassed swales**, or **biofilters**, use check dams and wide depressions to increase runoff storage and promote settling of pollutants.

When and Where to Use Grassed Swales

A **grassed swale** is an infiltration/filtration method that is usually used to provide pretreatment before stormwater runoff is discharged to treatment systems or a water body. Swales are typically used in small residential or commercial developments and are well suited to treat road or highway runoff, or as an alternative to curb and gutter drainage systems. Swales are almost always used in combination with other stormwater control or treatment practices.

What to Consider

Grassed swales are not appropriate in arid areas where it is difficult to establish good vegetative cover. Individual grassed swales should be used to treat small drainage areas (less than 5 acres). Grass swales are not effective if they are built on slopes greater than 5% because stormwater velocity becomes too great and causes erosion and prevents adequate infiltration or filtering. However, for steeper slopes (up to 15%), check dams (see Chapter 3) can be installed to slow runoff and provide greater filtration and infiltration. Grassed swales should also not be used in areas where groundwater is within two feet of the bottom of the swale.

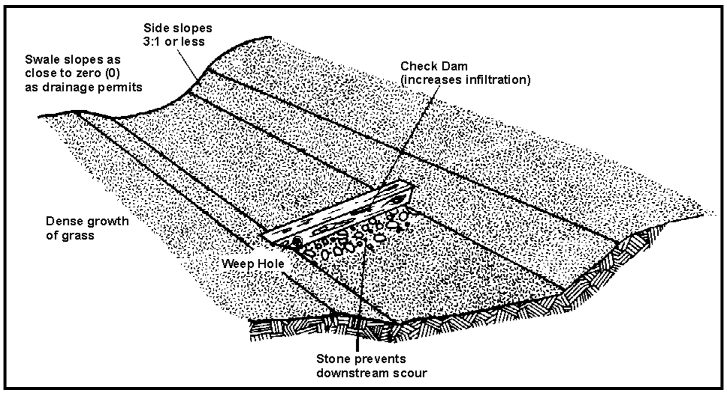


Figure 4.2. Grassed swale design (*Schueler, 1987*).

Swale slopes need to be graded as close to zero as possible, and side-slopes should be no greater than 3:1 (Figure 4.2). The flat channel should be between two (2) and eight (8) feet wide. A dense cover of hardy, low-growing, erosion-resistant grass or groundcover must be established (such as bermuda, bahia, hurricane or zoysia grass). Swales should be mowed frequently during the wet season to stimulate grass growth, control weeds, and maintain the system's capacity. Swales should never be mowed shorter than 4 inches. The soils underneath grassed swales need to be very permeable (infiltration rate greater than 0.5 in/hr). Wood, rock or stone check dams can also be installed in swales to promote infiltration, but earth or soil should not be used because moderate to severe storms will blow out the dam.

Swale maintenance primarily involves keeping the grass cover dense. This requires periodic mowing, occasional spot seeding, and weed control. Home owners are usually responsible for this maintenance. However, close mowing and excessive fertilizer and pesticide applications can adversely affect swale performance and negate any pollution reduction benefits the swale may have.

How Effective Are Grassed Swales?

Grassed swales control peak stormwater runoff discharges by reducing runoff velocity and infiltrating a portion of the stormwater runoff volume that passes through the swale. However, runoff infiltration is limited, and is never more than 10% of total volume. Pollutants are removed by the filtering action of the grass, deposition into low velocity areas, or infiltration into the subsoil. However, if a swale is constructed in soils having low permeabilities, there will be no soluble pollutant removal and low to moderate sediment and other particulate pollutant removal. Also, swales require relatively level slopes to function properly. The over-application of fertilizers and pesticides by homeowners can make swales a **source** of pollutants, rather than a treatment practice.

ADVANTAGES OF GRASSED SWALES
• Are more economical to establish than curb and gutter drainage systems. • Have relatively low maintenance requirements. • Can protect surface infiltration trenches and storm drains from sediment clogging.
DISADVANTAGES OF GRASSED SWALES
• Will not work on slopes greater than 5%. • Provide low to moderate particulate (sediment, etc.) removal and minimal soluble pollutant removal.

Sand Filters

A **sand filter** is usually a two-staged practice; the first stage is a chamber for settling sediment and other particles in stormwater and the second is a sand-filled filter bed with a subsurface drain. Stormwater runoff is diverted into the first chamber where large particles (sand, debris) settle out, and then flows to the second chamber where small particles (clays) and some other pollutants (oil and grease, heavy metals) are filtered out. The stormwater that seeps through the sand is collected in underground pipes and can then be reused for irrigation or returned back to the drainage channel or gut. **Enhanced sand filters** use layers of peat, limestone, and/or topsoil, and may also have a grass cover crop, to improve pollutant removal efficiency. **Sand-trench** systems have also been developed to treat parking lot runoff.

When and Where to Use Sand Filters

Sand filters can be used on most development sites and have few constraining factors, but are best to use on small sites (a maximum of 5 acres for surface sand filters or 2 acres for perimeter or underground filters). Sand filters used for larger drainage areas often clog, necessitating sand replacement. Most sand filters have been used on small parking lots. Sand filters are especially suitable for areas with thin clay soils, hilly terrain, high evapotranspiration rates, low soil infiltration rates, limited space, and frequent droughts (Schueler, 1994). Most sand filters have a contributing watershed area between a half an acre and ten acres, although the upper limit for usage is 50 acres. Sand filters can also be used for retrofit purposes and in small developments in urban or suburban areas. Figure 4.3 presents an example sand filter system.

What to Consider

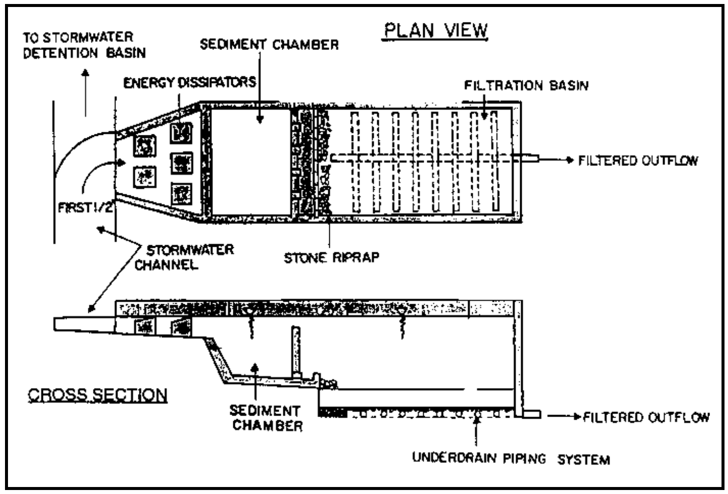


Figure 4.3. Sand filter system (*Austin, Texas, 1991*).

Sand filters require relatively simple, but frequent (quarterly), maintenance such as raking, surface sediment removal, and removal of trash, debris and leaf litter. Replacement of the surface sand layer (top 2-3 inches) may also needed on a relatively frequent basis (every 2 to 3 years). Sand filters are costly (up to $10,000 to $20,000 per impervious acre treated), but are long-lived and have lower maintenance and rehabilitation costs than infiltration trenches, and are more widely applicable to environmental conditions in the Virgin Islands.

Sand filters need flow splitter designs that will not clog. Flow splitters are used to bypass larger flows to the storm drain system or a stabilized channel. Sand filters also need adequate access and regular removal of surface sediment to ensure longevity. They also require two to four feet of available head (the vertical drop between the entrance and exit of a filter for gravity flow through the filter) for most off-line applications. The pretreatment chamber should be able to hold at least 25% of the runoff volume to be treated in the practice. The sand filter chamber should be able to hold at least 75% of the runoff volume to be treated in the practice. Typical runoff volumes used are those from a 1" storm or ½" of runoff over the entire area draining to the practice. Sand filters can be used in areas where groundwater quality is not a critical concern – they should NOT be used in wellhead protection areas unless treated water is routed to another practice for further treatment or removal. Cheaper geotextiles or soil liners can also be used instead of concrete liners.

ADVANTAGES OF SAND FILTERS
• Excellent longevity and very few environmental limitations.
• Require little or no developable land (most are placed underground or on margins of parking lots).
• Can be applied to most development sites and can be used in areas with thin soils and steeper slopes.
• Have low maintenance/rehabilitation costs.
• Are useful in watersheds where concerns over groundwater quality prevent the use of infiltration.
• Have moderate to high pollutant removal capability.
DISADVANTAGES OF SAND FILTERS
• Have frequent maintenance requirements.
• Large, surface sand filters without grass covers may not be attractive in residential areas.
• Some stormwater runoff will bypass filter during a large storm event.
• Do not provide stormwater QUANTITY control.
• High installation cost.

Water Quality Inlets

Water quality inlets (also called oil-grit separators) are three-stage underground structures designed to remove oil, grease, other absorbed hydrocarbons, heavy sediment and other floating substances from stormwater runoff before it is discharged to the storm drain system and/or to guts, ponds or coastal waters (CH2M Hill, 1998). Other pre-fabricated products that perform a similar function are called storm drain or catch basin inserts. The many different kinds and models available range from filter devices to remove sediment to pre-fabricated oil-grit separators to multi-stage treatment units that incorporate vegetation to help remove nutrients and other pollutants (Figure 4.4).

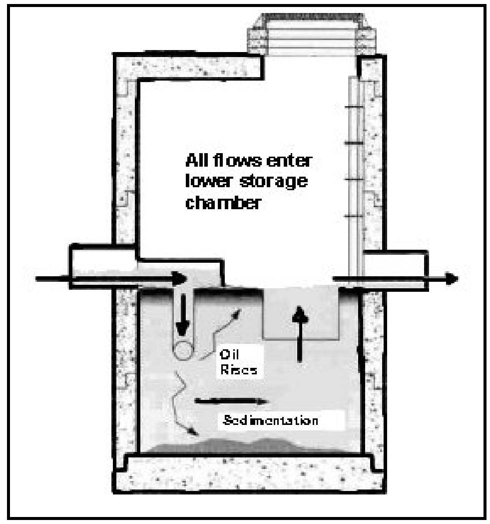


Figure 4.4. Storm*ceptor*® operation during normal flow conditions (*Stormceptor® Technical Manual, 1997*).

When and Where to Use Water Quality Inlets

Water quality inlets are used on sites that are expected to receive heavy vehicular traffic or large amounts of petroleum. The inlets are usually placed to catch the oil and fuel that leak from cars and trucks in parking lots, service stations, or loading areas (Figure 4.5). The inlets can reduce maintenance of infiltration systems, detention basins, and other stormwater devices and be used as a first stage of treatment by removing oil and sediment from stormwater before it enters another larger stormwater pollution control practice, like a wet pond.

Water quality inlets can be installed in most areas for drainage areas no larger than 1 acre. They can be installed in most any soil or terrain, and can be used near or at the impervious surface contributing the stormwater runoff. Inlets need enough land area for the structure and to allow access for proper maintenance.

What to Consider

The pollutant removal efficiency of storm drain inserts or water quality inlets varies depending on the volume of the practice, flow velocity, and the depth of the baffles and elbows in the chamber. These practices should be inspected regularly and cleaned at least twice a year to remove sediment, accumulated oil and grease, floatables and other pollutants. The wastes removed may be hazardous (such as petroleum products) and may need to be disposed of with a licensed hazardous waste hauler.

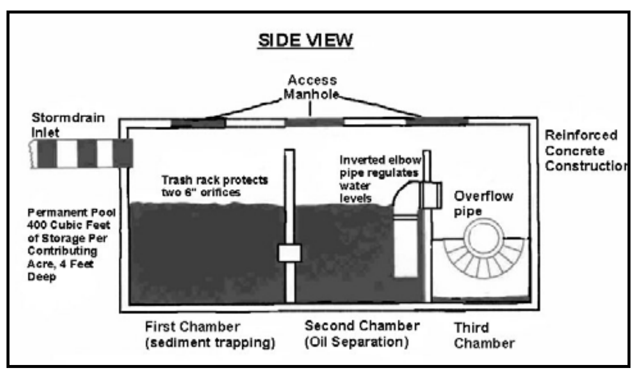


Figure 4.5. Schematic design of an oil-grit separator *(Schueler, et al., 1992*).

ADVANTAGES OF WATER QUALITY INLETS/OIL-GRIT SEPARATORS
• Easily installed.
• Can effectively remove oily pollutants.
• Small inlets can be distributed over a large drainage area, instead of building a single large structure.
• Are not unsightly, because are hidden underground.

DISADVANTAGES OF WATER QUALITY INLETS/OIL-GRIT SEPARATORS
C Have frequent maintenance requirements.
C Low removal of contaminants other than oil, grease and coarse sediment.
C Difficult to maintain because of enclosed, underground design.
C Sometimes odor is a problem.
C Do not provide stormwater QUANTITY control.

4.3 DETENTION PRACTICES

Examples of detention practices that are suitable for conditions in the Virgin Islands include:

- Extended detention ponds; and
- Constructed wetlands

Detention practices temporarily hold runoff to control runoff rates and volumes, and to settle and retain sediment and other pollutants. All detention practices use settling to remove particulate pollutants (sediment, organic matter, etc.). Properly designed extended detention ponds can minimize erosion of downstream channels by controlling water discharge speed. They can also remove nutrients and provide wildlife habitat if they are landscaped and designed properly. Constructed wetlands and multiple-pond systems can further reduce pollutants in runoff. Many of these systems are currently being designed to include vegetated buffer strips to provide enhanced wildlife habitat and scenic areas.

Extended Detention Ponds

Extended Detention (ED) ponds temporarily hold a portion of stormwater runoff for up to 24 hours after a storm, using a fixed outlet to regulate outflow at a specified rate. This allows sediment and other pollutants to settle out of stormwater. ED ponds are usually "dry" between storms and do not have any permanent standing water. They are typically made up of two stages: an upper stage that stays dry except for larger storms and a lower stage that is designed to treat average storms. Temporary and most permanent ED ponds use a riser with an anti-vortex trash rack (a type of trash screen that does not cause whirlpools to form in the pond or riser) on top to control trash. Enhanced ED ponds also have a plunge pool near the inlet, a micropool at the outlet, and an adjustable, reverse-sloped pipe as the ED control orifice (Figure 4.6).

When and Where to Use Extended Detention Ponds

Extended detention ponds can be implemented in most new developments, and can also be used to retrofit existing dry ponds in older urbanized areas. They can be used on development sites 10 acres and greater. Soils should neither be extremely impermeable (D soils) or extremely permeable (A soils). ED ponds can also be lined with impermeable materials so that no infiltration occurs. The water collected can then be used to irrigate gardens or lawns. The space required for ED ponds is usually less than 5% of the total site area.

What to Consider

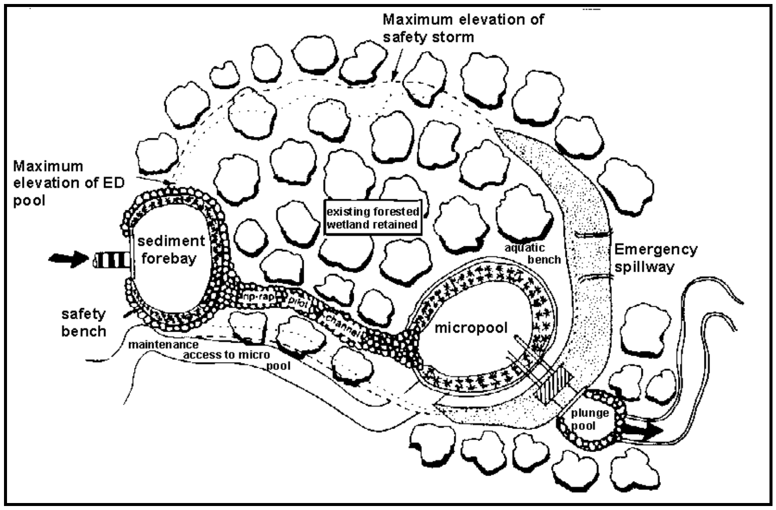


Figure 4.6. Dry extended detention (ED) pond design (*Schueler et al., 1992*).

Runoff should be detained for at least 24 hours to ensure sufficient pollutant removal. ED ponds should be designed, at a minimum, to store the stormwater runoff volume of a one-inch storm. Different areas of the U.S. have developed rules for sizing extended detention ponds – these rules specify both a volume of stormwater runoff to be detained and a length of time over which the runoff is released. Some sizing recommendations include:

- A volume equivalent to ½-inch of runoff distributed over the contributing watershed and released over a 40-hour period;
- Runoff volume generated from the one-year, 24-hour design storm and released over a minimum of 24 hours;
- Runoff volume generated from the two-year, 24-hour design storm, released over 24 hours;
- Runoff volume generated from a one-inch storm released over 24 hours; and
- "First-flush" runoff volume (½-inch per impervious acre) released over 24 hours.

Two-stage ED ponds are most effective in removing pollutants. Slopes leading to the pond should be gentle enough to prevent gully erosion of pond banks (i.e., side slopes no greater than 3:1 and banks no steeper than 2:1). If banks are steeper than 2:1 they should be stabilized with rip-rap to prevent erosion. The slope of the upper stage of the ED pond should be between 2 and 5% to promote rapid drainage. The drainage channel immediately below the pond outlet should be lined with large stone riprap and graded to a slope ~ 0.5%. A layer of filter cloth that conforms to the natural dimensions of the channel should be laid down and anchored with 18"-30" stone riprap.

ED ponds require routine maintenance including mowing, inspections, debris and litter removal, erosion control, and nuisance control. Other maintenance that may be necessary includes structural repairs and equipment replacement, and sediment removal.

How Effective Are ED Ponds?

Extending the detention time of dry ponds is an effective, low cost way to remove sediment from stormwater runoff and to minimize downstream channel erosion. If stormwater can be detained for 24 hours or more, as much as 90% of the particulate pollutants in stormwater runoff can be removed. However, ED ponds only slightly reduce the levels of soluble nutrients in stormwater runoff, unless a shallow marsh is created in the wetter portion of the pond. ED ponds can also significantly reduce the frequency of erosive downstream floods.

ADVANTAGES OF ED PONDS
• Significant pollutant removal, if designed properly.
• Creation of local wetland and enhanced wildlife habitat.
• Limited protection of downstream aquatic habitat.
• Only 10% more costly than conventional dry ponds.
DISADVANTAGES OF ED PONDS
• Occasional nuisance problems (odor, debris, mosquitos, and weeds).
• Moderate to high routine maintenance needs.
• Eventual need for costly sediment removal and disposal.

Constructed Wetlands

Constructed wetlands are engineered systems designed to imitate natural wetlands ability to improve water quality by treating and containing stormwater runoff and pollutants and decreasing pollutant loadings to coastal waters. Constructed stormwater runoff wetlands simulate natural wetlands and attempt to replicate all of the functions of natural wetlands.

When and Where to Use Constructed Wetlands

Wetlands can be constructed around the outside of a pond or in a sediment forebay (Figure 4.7).

What to Consider

The most reliable method to create a constructed wetland is to transplant live plants or dormant rhizomes from nursery stock. Transplantation from existing wetlands is not usually as effective and can be detrimental to the source wetland. Most wetland species thrive in water less than one foot deep. To create these depths over a wide area, sites usually need to be graded. Also potential sites must have enough baseflow (subsurface water flow) or surface flow re-routing to ensure that severe seasonal evaporation does not damage wetland vegetation. To achieve optimal pollutant removal, the surface area of the wetland should be the size of about 2 to 3% of the total contributing watershed area.

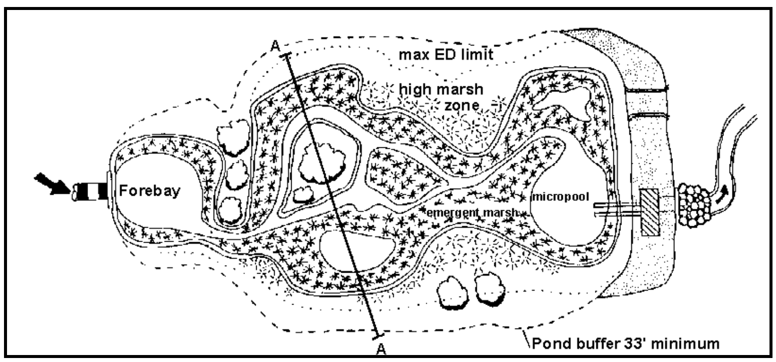


Figure 4.7. Example of a shallow marsh planting strategy (*Schueler et al., 1992*).

How Effective Are Constructed Wetlands?

Establishing wetland species around new or existing wet ponds, dry ponds, or sediment basins is an effective, low cost way to remove sediment and soluble pollutants from stormwater runoff, to minimize downstream channel erosion, and to minimize stormwater runoff peaks. Constructed wetlands can also significantly reduce flooding frequency downstream.

ADVANTAGES OF CONSTRUCTED WETLANDS
• Significant pollutant removal, if designed properly.
• Creation of wildlife habitat and propagation of threatened or endangered wetland species.
• Limited protection of downstream aquatic habitat.
• Stabilizes pond or basin floors to prevent erosion.
• Vegetation costs are small portion of pond construction costs.
DISADVANTAGES OF CONSTRUCTED WETLANDS
• Difficulty in establishing native wetland vegetation.
• Engineering design assistance is limited.
• Need for steady water source.
• Increase of mosquitoes in stagnant areas.

4.4 INFILTRATION PRACTICES

Some infiltration practices that are appropriate for use in the Virgin Islands include:

- Porous pavers;
- Infiltration trenches; and
- Bioretention areas.

Infiltration practices treat stormwater runoff by filtering it through the soil. Under natural conditions, water percolates through the soil, where filtration and biological action remove pollutants. However, stormwater treatment systems that use soil absorption require deep, permeable soils at separation distances of at least 4 feet between the bottom of the structure and the groundwater. Long-term effectiveness of these practices depends on proper operation and maintenance. ***Infiltration systems, some filtration devices, and sand filters should be installed AFTER construction has been completed and the site has been permanently stabilized.***

Infiltration and filtration systems that are clogged by sediment generated during construction activities or because of premature use of these systems will fail.

Porous Pavers

There are two categories of porous paving or alternate pavers: paving blocks and other surfaces including gravel, cobbles, brick or natural stone. Porous paving materials are used in low-traffic areas (such as low-use parking lots, emergency areas, driveways, walkways) in place of asphalt or concrete. Concrete tire-tracks with grassed interiors can also be used for steeper driveways (Figure 4.8). Paving blocks can be concrete, cement or high-strength plastic grids placed on a pervious base such as gravel or sand (Figure 4.9) The grids or pavers are then filled with pervious materials such as sand, gravel or soil. Grids filled with soil can be seeded to attain a grassed or lawn surface. The resulting system provides a load-bearing surface that can to support vehicles while allowing infiltration of surface water into the underlying soil or bedrock (Figure 4.10). This reduces stormwater runoff volume and discharge rate and improves water quality.

Figure 4.8. Porous driveway option (*Estate Lerkenlund, St. Thomas*).

When and Where to Use Porous Paving

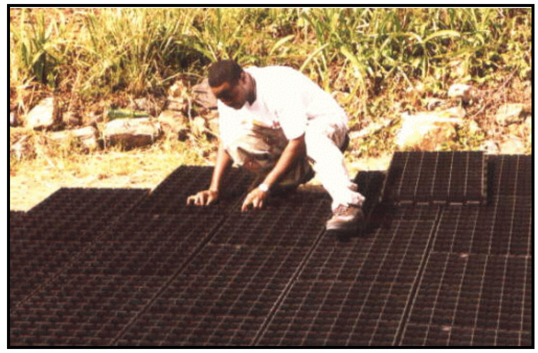


Figure 4.9. Installation of interlocking plastic grid pavers at UVI-CES Demonstration Garden, St. Thomas *(photo by Dale Morton, UVI-CES*).

Porous paving should only be used for lower volume parking areas where heavy compaction will not be a problem, and is most effective on sites with gentle slopes and moderate to highly permeable soils.

Webbed cellular confinement systems work very well in reducing erosion and stormwater runoff from gradual driveways and low-use roads. For these uses, it is necessary for rock (gravel or crusher run) to be used as fill material instead of soil, in order to provide sufficient load support (especially if filter fabric is not placed below the webbing and fill material).

Grassed block/grid cellular confinement systems can work well in controlling erosion and stormwater on fairly level, low-use traffic areas, such as emergency access areas, driveways or parking lots. For higher or heavier used parking areas, gravel fill would be more appropriate, as continual vehicular traffic damages the grass base. Some disadvantages for use in the V.I. have been observed on the grassed demonstration system. First, the subsurface must be completely level for the blocks to lay properly. Secondly, for a grassed parking area that requires soil fill, the blocks should be filled by hand in order to avoid over-filling with soil. Over-filling reduces the blocks ability to protect grasses planted within the system so that continual traffic will damage the sod.

How Effective is Porous Paving?

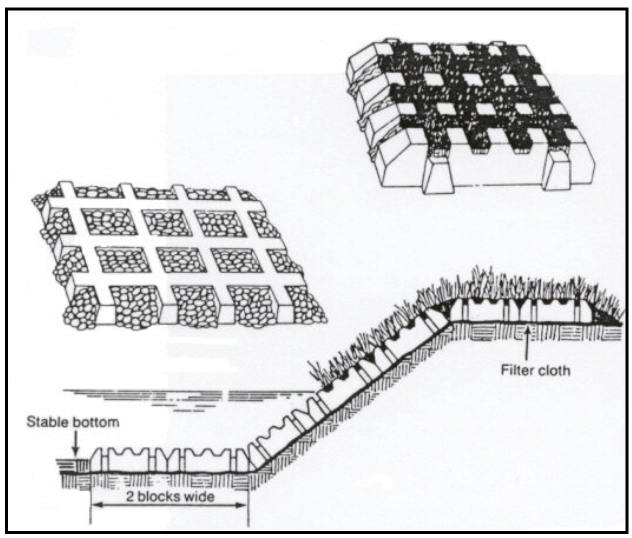


Figure 4.10. Diagram of concrete grid pavers (*Empire State Chapter, Soil and Water Conservation Society, 1997*).

Porous paving can provide hydrologic conditions that are similar to pre-development conditions. If installed properly, this practice can control peak stormwater discharges and can also reduce stormwater runoff volumes through infiltration. Porous paving materials are **NOT** intended to remove coarse sediment particles, but can provide significant pollutant removal if the subsurface soil has adequate infiltration capacity. Because sediments can rapidly clog the base of the pavers, it is essential that practices (such as filter strips, sediment traps, etc.) are used to keep coarse sediments and other particles from entering the pavement surface. The gravel or sand base beneath the pavers may also be lined with filter fabric to prevent the rock material from becoming imbedded. Grassed porous pavers should only be used for emergency or overflow parking areas because compaction caused by daily traffic flow will kill grassed areas.

ADVANTAGES OF POROUS PAVERS
• Has load-bearing strength, longevity, and maintenance requirements similar to conventional pavement, when properly installed. • Increases stormwater infiltration, decreases runoff volume, removes some pollutants, and preserves the natural water balance at the site. • Reduces or eliminates the need for curbs and gutters in residential areas and for downstream conveyance systems. • Provides a safer driving surface with better skid resistance and reduced hydroplaning.
DISADVANTAGES OF POROUS PAVERS
• If it becomes clogged it is difficult and costly to repair. (The risk of premature clogging is high, and can only be prevented if sediment is kept off the pavement before, during and after construction by filter strips, sediment traps, etc.) • Not appropriate for high traffic areas.

Infiltration Trenches

Infiltration trenches are shallow, excavated ditches that have been backfilled with stone or gravel to form an underground reservoir. Stormwater runoff is diverted into the trench and gradually infiltrates into the subsoil and eventually into groundwater. Variations in infiltration trench design include enhanced infiltration trenches (trenches that have extensive pretreatment systems to remove sediment and oil). Trench size depends on the design storm volume of runoff to be controlled and the degree of infiltration (or infiltration rate) of the soil or subsoil (Figure 4.11).

When and Where to Use Infiltration Trenches

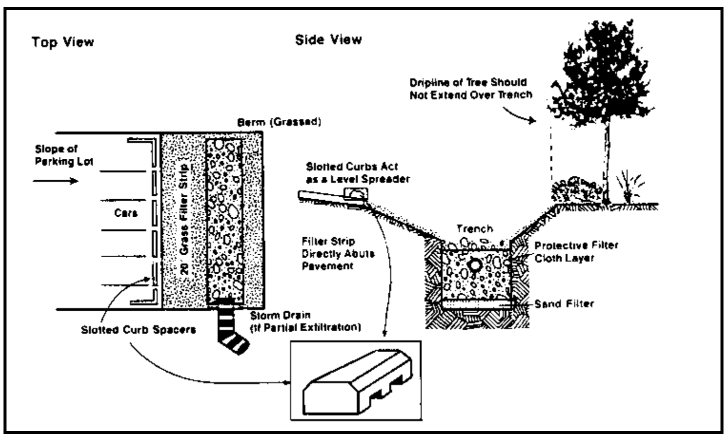


Figure 4.11. Parking lot perimeter trench design *(Schueler, 1987)*.

Individual trenches are used primarily for on-site runoff control, and are rarely practical or economical on sites larger than five acres. Trenches are **NOT** designed to trap coarse sediments. Runoff water should be pre-treated (with filter or buffer strips or some other kind of sediment trapping device) to remove sediment and other particles to lower trench failure rates. Trenches should be placed on flat ground (5% slope or less), but the slopes of the site draining to the practice can be up to 15%. Trenches are not practical for use in soils with infiltration rates less than ½ inch/hour or more than 3 inches/hour, or with more than 20% clay or 40% silt/clay content (CWP, 1998). Trenches should be located in areas with deep soils – 2' to 5' of clearance from the bottom of the trench to bedrock or water table is recommended (Schueler, 1992).

What to Consider

Trenches have limited maintenance requirements aside from routine inspections and strict erosion and sediment control. However, if a trench is allowed to clog, partial or complete replacement of the structure may be required. Trenches have limited applications on steep slopes (>15%).

Different Uses

Infiltration trenches can be located on the surface or below ground. Surface trenches may capture runoff directly from adjacent land areas, after it has been filtered through a buffer (Figure 4.12). Underground trenches are used for more concentrated runoff (from pipes, channels or storm drains). However, special inlets need to be installed in underground trenches to prevent coarse sediment, oil and grease from clogging the trench.

Figure 4.12. Graveled infiltration areas in a parking lot, St. Croix *(photo by Dale Morton, UVI-CES)*.

Surface trenches are recommended for residential areas, where the smaller amounts of sediment and oil that are present can be trapped by grass filters (Figure 4.13). Because the surface is exposed, these trenches have a slightly higher risk of clogging than underground trenches, but they are also easier to maintain and inspect. **Underground trenches** are best suited for larger developments (10 acres or greater) where concentrated runoff from pipes or channels is directed to the trench. However, the runoff needs to be pre-treated before entering the trench, and it also needs to be evenly distributed within the trench. Underground trenches are also more difficult and costly to maintain.

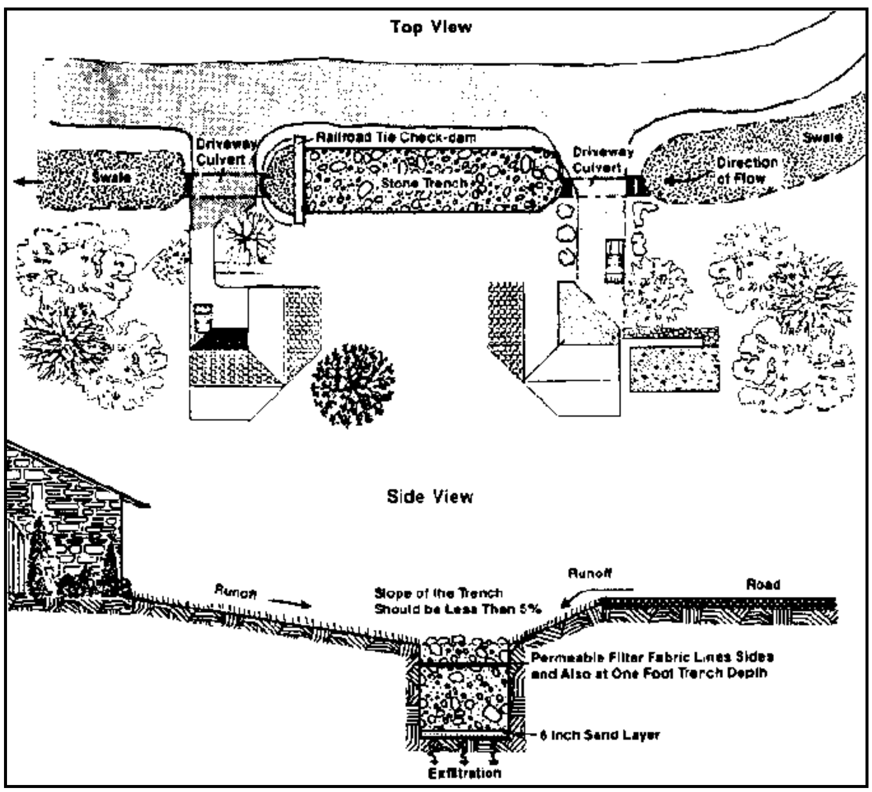


Figure 4.13. Swale/trench design for a development (*Schueler, 1987*).

How effective are infiltration trenches?

Infiltration trenches can potentially reduce stormwater runoff so that hydrologic conditions are close to pre-development conditions. Trenches designed to infiltrate all incoming water into the surrounding soil can effectively reduce peak discharge rates associated with the **design storm** (the size of storm a given practice is designed to handle). However, for both physical and economic reasons, it is not always practical to design trenches for very large or infrequent storms. In this case, trenches that are designed to infiltrate part of the runoff into the surrounding soil and collect the rest in a perforated underdrain at the bottom of the trench and direct it to a central outlet, are more appropriate. Trenches can also reduce the increases in post-development runoff volume that are produced by small or medium-sized storms. The effectiveness of a trench in reducing stormwater runoff volumes is a function of the amount of water that can be infiltrated into the surrounding soil profile.

Infiltration trenches are not intended to remove sediment. They are designed to remove fine particles and soluble pollutants by filtration through the trench and surrounding soil profile. Pollutant removal in a trench can be enhanced by increasing the surface area of the trench bottom (i.e., make the trench shallow and broad rather than narrow and deep). This will provide more area to increase infiltration into the surrounding soil profile and provides more soil below the trench to further filter water. The greatest reduction of nutrients, metals, and bacteria will occur in soils that have higher clay contents and/or organic matter, and the least reduction will occur in sandy soils. Unfortunately, soils that maximize pollutant absorption also tend to have very low infiltration rates. However, these soils are most prone to blockage, so it is vital that large particles are removed from stormwater runoff (by a filter strip or other practice) before it enters the trench area.

The trench should be designed to completely drain within three days after the maximum design storm event. If a trench is constructed over soils with a lower infiltration capacity, it may be advisable to adjust the depth of the trench so that it drains in two days or less, as a safety margin. However, if a trench drains in less than 6 hours, it will not provide adequate pollutant removal.

Test wells should be installed in every trench to monitor draining times after installation. The water level in the well should be measured daily after a large storm. If the trench does not completely drain after 3 days it usually means that the bottom of the trench is clogged and needs to be cleaned out. Otherwise, if a partial exfiltration trench empties completely within one day, it means that either the underdrain is too large or that the bottom of the trench has clogged, or both.

ADVANTAGES OF INFILTRATION TRENCHES
• Preserve natural groundwater recharge capabilities.
• Are relatively easy to fit into margins, perimeters and other un-utilized areas of a parking lot or development site.
• Are one of the few BMPs that provide pollutant removal on small sites or developments wedged in between existing developments.
DISADVANTAGES OF INFILTRATION TRENCHES
• Difficulties in keeping sediment out of the structure during site construction (especially if construction occurs in phases).
• The need for careful construction of the trench and regular maintenance.
• Possible risk of groundwater contamination if toxic materials are introduced.
• Require relatively flat area for the trench, 2 to 5 feet of soil profile, and well-drained soils.

Bio-Retention

Bioretention systems are landscaped areas made of soil and sand mixtures and planted with native plants that are used to filter stormwater runoff on residential and non-residential sites (CH2M Hill, 1998). They are usually located in parking lot islands or within small pockets in residential land uses. Systems can be inline, located in grasses swales modified to enhance pollutant removal (Figure 4.14), but are more commonly located offline. In offline systems, surface runoff is directed into shallow, landscaped depressions. These depressions are designed to mimic many of the pollutant removal mechanisms that operate in forested ecosystems. During storms, runoff ponds above the soil and mulch, filtering through to the subsoil or to a perforated underdrain returning to the storm drain system (Figure 4.15, next page). Runoff from larger storms bypasses the system directly into the storm drain system.

When and Where to Use Bioretention

Bioretention is used on small sites (less than 5 acres) with flat slopes (5% or less), typically parking lots or small residential areas, and for small storm events (1- to 5-year, 24-hour storm). It can be used in almost any soil because the soil is made and placed in the system. Bioretention systems should be separated from the water table by at least 3 feet.

What to Consider

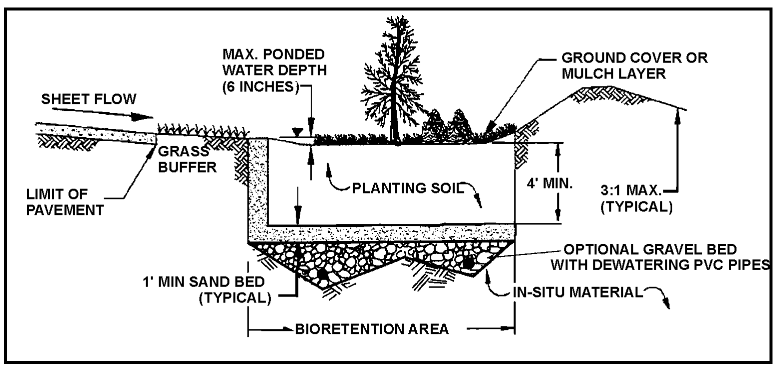


Figure 4.15. Off-line bioretention system design *(CH2M Hill, 1998)*.

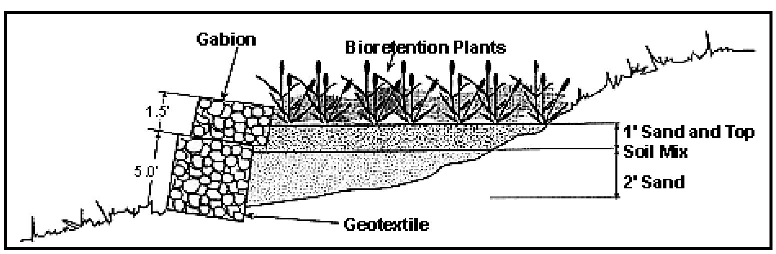


Figure 4.14. On-line bioretention cross section - incorporated into a grass swale with a mild to moderate slope *(CH2M Hill, 1998)*.

Bioretention systems are most effective if they are as close as possible to the source of runoff. They have five basic features: pretreatment, treatment, conveyance, maintenance reduction and landscaping. **Pretreatment** practices like grassed filter strips capture and remove coarse sediment from runoff water to reduce maintenance and clogging of the system. A pea gravel level spreader (spreads flow evenly with no channels) can also be used.

Treatment designs should size the system between 5% and 10% of the impervious area draining to it, install a sand/soil filter bed with a mulch layer above the soil bed, and allow runoff to pond 6" to 9" deep above the filter bed.

Stormwater should be **conveyed** to and from the practice to minimize erosion. Bioretention systems include an underdrain system (perforated pipe in a gravel bed) that collects filtered runoff at the bottom of the filter bed and channels it to the storm drain system. An overflow structure also needs to be designed to route flow from large storms to the storm drain system. All parts of the system should be easily accessible for **maintenance**.

Landscaping bioretention systems is vital for the system to function properly. Native vegetation should be used for landscaping, where possible. Plants should be selected that can tolerate both wet and dry conditions (such as cattails, *typha* sp.). The edges of the bioretention area are usually dry and so can be landscaped with native plants appropriate to that area. It is best to select a combination of trees, shrubs and ground covers.

Different Uses

A **partial exfiltration** bioretention area can be used on sites with appropriate soils (see ***Infiltration Trenches***, page 4-12) that can adequately absorb the "exfiltrated" stormwater runoff. In this type of system, the filtered stormwater runoff is dispersed into the surrounding soil. The underdrain is only installed on a small part of the bottom of the system, and acts as an overflow for larger storm events.

How Effective are Bioretention Systems?

When properly designed and sized, bioretention systems can provide stormwater control and treat runoff from small storms on small drainage areas. However, the five features of the bioretention system must be designed properly to achieve optimal performance.

ADVANTAGES OF BIORETENTION SYSTEMS
• Preserve the natural water balance of the site.
• Can serve larger developments.
• Can be used as sediment basins during construction.
• Are cost-effective when compared with other stormwater management practices.
DISADVANTAGES OF BIORETENTION SYSTEMS
• Can have a fairly high failure rate due to unsuitable soils.
• Need frequent maintenance.
• Possible nuisance from odor, mosquitos, soggy ground.

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CHAPTER 5: ESTIMATING EROSION ON CONSTRUCTION SITES USING THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE)
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CHAPTER 5: ESTIMATING EROSION ON CONSTRUCTION SITES USING THE REVISED UNIVERSAL SOIL LOSS EQUATION (USLE)

Prepared in 1995 by Maria Montes, Agronomist, USDA-NRCS Caribbean Area,
Modified in 2002 by Julie Wright, Natural Resources Program Supervisor, UVI-CES

5.1 INTRODUCTION

The development of the Universal Soil Loss Equation (USLE) began in 1940 as a cooperative effort by the State Experiment Stations, the Science and Education Administration, the Soil Conservation Service (now the Natural Resources Conservation Service), and the National Weather Service. The USLE has been reviewed and updated many times since it was first developed. The last major revision began in 1987, and the current form now used is called the Revised Universal Soil Loss Equation (RUSLE). The Soil and Water Conservation Society (SWCS, www.swcs.org) is currently marketing RUSLE software.

RUSLE is an erosion model designed to predict long-term annual soil loss carried by runoff from fields and rangeland under specific cropping and management conditions (USDA-NRCS, 1995). It is also applicable to non-agricultural conditions such as construction sites. RUSLE retains the equation structure of USLE, but the technology for evaluating these factors has been altered and new data added. RUSLE has been computerized to assist with calculations, and three databases for deriving these factors have been developed.

Even though the RUSLE is only an estimate, it is still the best method available to estimate soil erosion. The information that is used in predicting soil erosion is constantly being updated. However, great care must be taken to ensure that the RUSLE is used correctly. A basic knowledge of the factors used in calculating soil loss is essential. For assistance with the use of the RUSLE, please contact the University of the Virgin Islands Cooperative Extension Service or the USDA Natural Resources Conservation Service.

An alternative method was developed by Colorado State University, in collaboration with USGS, Island Resources Foundation, Inc., and the Virgin Islands National Park. Their GIS-based road surface erosion model (ROADMOD) estimates road surface erosion and sediment delivery from a digitized road network (MacDonald, et. al., 1997) utilizing data collected in the early 1990s on St. John. Input data for this model include an ASCII file, exported from a GIS, that lists road segments and segment characteristics such as segment identification number; connections to and from other segments; segment length, width, and slope; road surface (paved or unpaved); whether the segment is a discharge location; and a factor to proportionalize flow if it is split between downstream segments (MacDonald, et. al., 1997). The model uses a predictive equation:

$$E = 0.00057A \times S + 0.034 \qquad [EQ. 5\text{-}1]$$

where

E is the cross-sectional road erosion in cubic meters per meter of road length per year, or square meters,
A is the upslope road drainage area in square meters, and
S is the segment slope as a decimal.

For information on utilizing this model to predict road surface erosion in the Virgin Islands, please contact Dr. Lee H. MacDonald, Department of Earth Resources, Colorado State University, Fort Collins, CO 80523-1482 or Island Resources Foundation, Inc. at www.irf.org.

5.2 REVIEW OF RUSLE AND FACTORS

The method described herein is based on the Revised Universal Soil Loss Equation (RUSLE) and it is used to predict soil loss from sheet and rill erosion. The rate of erosion as estimated by RUSLE depends on six factors: (1) rainfall energy and intensity, (2) soil erodibility, (3) land slope steepness and length of slope, (4) soil surface cover conditions (such as grass, woodland, pavement, or no cover), and (5) land management practice used. These factors may be assigned quantitative values to be used in estimating soil loss. However, this method does not account for soil loss by gully erosion.

The Revised Universal Soil Loss Equation is:

$$A = R * K * (LS) * C * P \qquad [EQ. 5\text{-}2]$$

where

A = The estimated average annual soil loss from sheet and rill erosion caused by rainfall and its associated overland flow (in tons per acre). For volume estimates, Table 5.6 may be used to convert tons per acre to cubic yards based on soil textures.

R = The factor for annual rainfall erosivity - a measure of the erosive force of rainfall. R represents differences in erosivity among locations in the Caribbean area. For the Virgin Islands, the R factor is a constant of **250** for St. Croix and St. Thomas and **240** for St. John.

K = The soil erodibility factor. The K factor is based on soil type listed in the *1995 Revised Soil Survey of the Virgin Islands*. K values for the Virgin Islands are found in Table 5.1.

L = The slope length factor calculates the effect of slope length on erosion.

S = The slope steepness factor calculates the effect of soil steepness on erosion. The slope length and slope steepness are usually combined into a single topographic factor (LS) and computed from Tables 5.2.a - 5.2.c. Table 5.2.a is for low ratios of rill to interrill erosion, such as rangeland and other undisturbed soil conditions with cover. Table 5.2.b is for moderate ratios of rill to interrill erosion, such as row-cropped agricultural areas and other moderately consolidated soil conditions with little to moderate cover. Table 5.2.c is for high ratios of rill to interrill erosion, such as for freshly prepared construction sites and other highly disturbed areas with little or no cover. Table 5.2.a is typically used to estimate pre-development conditions, and Table 5.2.c to estimate conditions during construction.

C = The soil cover and management factor represents the effect of plants, soil cover, soil biomass, and soil disturbing activities on erosion. The C factor is also called the cover index and can be used to represent the effect of land cover or treatment that may be used to protect construction sites. The C factor zone for the Virgin Islands is **Southern Slopes**. The appropriate C factor can be selected from Table 5.5.

P = The management practice factor is the ratio of soil loss that occurs with certain conservation practices (like conservation tillage) compared to that of no practice. P factors for a combination of practices are computed as the product of P factors for the individual practices. Refer to Table 5.4 for P factors.

Table 5.6 provides the approximate soil weights of soil textures to convert tons per acre to cubic yards; and Table 5.7 provides USDA Texture Abbreviations.

5.3 EXAMPLES OF HOW THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) IS USED

A disturbed site of 15 acres near Christiansted, St. Croix. The soil is Glynn gravelly loam and the B horizon is completely exposed. The average slope is 8% and the length is 200 feet.

5.3.1 Example 1

Problem: Determine the estimated soil loss from this site if it was scraped up and down the slope with a bulldozer and remains unprotected for one year.

Solution: **The rainfall factor, R, for St. Croix is 250** (given on page 5-1). Refer to Table 5.1 and determine that the **K value for the B horizon of Glynn gravelly loam is 0.20**. Note that the K values are not always the same for the B and C horizons of some soils. (Table 5.7 provides texture and modifiers for abbreviations given in Table 5.1).

Refer to Table 5.2c to determine the topographic adjustment factor (LS) for length and percent of slope. The length and slope data are not multiplied together in the formula, but are developed mathematically from a complex equation. They may be obtained directly from Table 5.2. **Find 8% in the left-hand column and move horizontally to read 1.72 under slope length 200 feet.** To find quantities not included in Table 5.2, one may interpolate between gradients and slope lengths to estimate the required LS or use the closest factor.

Table 5.3 provides the cover index factor, C, for planning conditions. **Note that the C-factor for exposed soil is 1.0**. Increasing the cover or soil protection decreases the C-factor accordingly. Refer to Table 5.4 for the practice factor, P. **The P-factor for a compact, smooth, bulldozer-scraped surface is 1.3.**

To determine the annual soil loss on this site, enter the above underlined data into the RUSLE and compute the erosion for these conditions as follows:

A = RKLSCP = 250 x 0.20 x 1.72 x 1.0 x 1.3 = 111.8 tons per acre
A = 111.8 tons/acre x 15 acres = **1677 tons of soil lost on that site in one year!!!**

To convert this amount to volume, use Table 5.6. Note that for the loam texture of the Glynn soil, one cubic foot of material weighs approximately 90 pounds. Each ton of soil equals 0.82 cubic yards (yd^3). Thus, 1677 tons times 0.82 yd^3/ton = **1375 cubic yards of soil eroded in one year from the site.**

5.3.2 Example 2

Problem: Determine the soil loss from this site during the period from June 1 to September 1.

Solution: Refer to Table 5.5 to obtain the St. Croix adjustment, M, factor for the period. **During this period, 6 + 7 + 11 = 24% of the average annual soil loss for these conditions will occur.** Therefore, 24% of 1677 tons is calculated as:

A = 0.24 x 1677 = **402.5 tons eroded between June 1 and September 1**, or
A = 0.24 x 1375 = **330 cubic yards of soil eroded between June 1 and September 1.**

5.3.3 Example 3

Problem: Determine the soil loss from this site during the period from November 1 to March 30, when hay mulch at a rate of 2 tons per acre has been applied.

Solution: Refer to Table 5.3 for the **C-factor for hay mulch at 2 tons per acre (0.02), and Table 5.5 to obtain the M factor for this period (M = 14 + 9 + 5 + 4 + 4 = 36%)**. Use the USLE to calculate the soil loss:

A = RKLSCP = (250 x 0.20 x 1.72 x 0.02 x 1.3) x 0.36
A = **0.81 tons per acre for November 1 to March 30 with hay mulch protection**
A = 0.81 x 15 = **12.1 tons for November 1 to March 30 with hay mulch protection**
A = 12.1 tons x 0.82 yd^3/ton = **9.9 yd^3 for November 1 to March 30 with hay mulch**

5.3.4 Example 4

To determine soil loss from gullies, we cannot use the USLE but must compute soil loss by direct measurement.

Problem: A gully has formed that is 60 feet long and averages 2 feet wide by 1 foot deep.

Solution: A = 60 feet x 2 feet x 1 foot = **120** cubic feet of soil. For a gravelly loam, Table 5.6, we compute the weight to be 120 ft^3 x 90 lbs/ft^3 = 10,800 pounds. To convert to tons, divide by 2000 pounds/ton. Therefore, A = 10800 ÷ 2000 = **5.4 tons of soil eroded from the site**.

5.4 TABLES

Table 5.1. Soil Erodibility Factors (K), Soil Loss Tolerance Factors (T), and Hydrologic Soil Groups of the A, B and C Horizons, Virgin Islands Soil Series (USDA-NRCS, 1995).

U.S. Department of Agriculture
Natural Resources Conservation Service — CB Table 2 — 6/13/95

Survey Area: VIRGIN ISLANDS OF THE UNITED STATES — Soil Data for RUSLE

Map Unit Symbol	Component Name	Surface Texture	Percent of Map Unit	Hydrologic Group	Kf	T*	Rock Cover %
AcD	ANNABERG	GR-L	60	D	.12	1	30
AcD	CRAMER	GR-CL	20	C	.08	2	25
AcE	ANNABERG	GR-L	60	D	.12	1	30
AcE	CRAMER	GR-CL	20	C	.08	2	25
AcF	ANNABERG	GR-L	60	D	.12	1	30
AcF	CRAMER	GR-CL	20	C	.08	2	25
AcG	ANNABERG	GR-L	60	D	.12	1	30
AcG	CRAMER	GR-CL	20	C	.08	2	25
AmD	ANNABERG	GR-L	50	D	.12	1	30
AmD	MAHO BAY	GR-L	30	D	.22	2	15
AmE	ANNABERG	GR-L	50	D	.12	1	30
AmE	MAHO BAY	GR-L	30	D	.22	2	15
AmF	ANNABERG	GR-L	50	D	.12	1	30
AmF	MAHO BAY	GR-L	30	D	.22	2	15
AmG	ANNABERG	GR-L	50	D	.12	1	30
AmG	MAHO BAY	GR-L	30	D	.22	2	15
AqA	AQUENTS	VAR	90	D		5	NO DATA
ArB	ARAWAK	GR-L	85	B	.12	2	25

Map Unit Symbol	Component Name	Surface Texture	Percent of Map Unit	Hydrologic Group	Kf	T*	Rock Cover %
ArC	ARAWAK	GR-L	85	B	.12	2	25
ArD	ARAWAK	GR-L	85	B	.12	2	25
ArE	ARAWAK	GR-L	85	B	.12	2	25
ArF	ARAWAK	GR-L	85	B	.12	2	25
BrB	ROCK OUTCROP	UWB	90	D			NO DATA
BsB	BEACHES	S	90	D		5	10
BtB	BEACHES	STX-S	90	D		5	NO DATA
CaA	CARIB	CL	85	D	.26	5	5
CbB	CINNAMON BAY	L	85	B		5	5
CgC	CINNAMON BAY	GR-L	85	B	.17	5	10
CvC	CRAMER	CL	50	C	.08	2	15
CvC	VICTORY	L	30	B	.22	3	20
CvD	CRAMER	CL	50	C	.08	2	15
CvD	VICTORY	L	30	B	.22	3	20
CvE	CRAMER	CL	50	C	.08	2	15
CvE	VICTORY	L	30	B	.22	3	20
CvF	CRAMER	CL	50	C	.08	2	15
CvF	VICTORY	L	40	B	.22	3	20
DoE	DOROTHEA	CL	80	C	.17	5	10
DoE	SUSANNABERG	CL	15	D	.12	2	30
DoF	DOROTHEA	CL	80	C	.17	5	10
DoF	SUSANNABERG	CL	15	D	.12	2	30
DoG	DOROTHEA	CL	80	C	.17	5	10
DoG	SUSANNABERG	CL	15	D	.12	2	30
FsD	FREDRIKSDAL	GRV-CL	50	D	.22	1	35
FsD	SUSANNABERG	CL	30	D	.12	2	30
FsE	FREDRIKSDAL	GRV-CL	50	D	.22	1	35
FsE	SUSANNABERG	CL	30	D	.12	2	30
FsF	FREDRIKSDAL	GRV-CL	50	D	.22	1	35
FsF	SUSANNABERG	CL	30	D	.12	2	30
FsG	FREDRIKSDAL	GRV-CL	50	D	.22	1	35
FsG	SUSANNABERG	CL	30	D	12	2	30
GyA	GLYNN	GR-L	85	C	.20	5	10
GyB	GLYNN	GR-L	85	C	.20	5	10
GyC	GLYNN	GR-L	85	C	.20	5	10
HeA	HESSELBERG	C	85	D	.05	2	0
HeB	HESSELBERG	C	85	D	.05	2	0
HeC	HESSELBERG	C	85	D	o5	2	0
HgA	HOGENSBORG	CL	85	D	.26	5	0
HgB	HOGENSBORG	CL	85	D	.26	5	0
HgC	HOGENSBORG	CL	85	D	.26	5	0
JaB	JAUCAS	S	85	A	.08	5	0
JsD	JEALOUSY	GR-CL	50	C	.15	3	10
JsD	SOUTHGATE	GR-L	30	D	.22	1	25
JSE	JEALOUSY	GR-CL	50	C	.15	3	10
JSE	SOUTHGATE	GR-L	30	D	.22	1	25
JsF	JEALOUSY	GR-CL	50	C	.17	3	10
JsF	SOUTHGATE	GR-L	30	D	.22	1	25
LmC	LAMESHUR	GR-SL	85	A	.12	5	55

Map Unit Symbol	Component Name	Surface Texture	Percent of Map Unit	Hydrologic Group	Kf	T*	Rock Cover %
PaB	PARASOL	CL	85	B	.15	5	0
PaC	PARASOL	CL	85	B	.15	5	0
Pt	PITS	UWB	90				NO DATA
RdB	REDHOOK	STX-S	85	A	.08	5	65
SaA	SALT FLATS	SICL	90	D		5	No DATA
SbA	SANDY POINT	SCL	50	D	.20	5	0
SbA	SUGAR BEACH	MUCK	40	D		3	0
SiA	SION	C	85	B	.05	4	5
SiB	SION	C	85	B	.05	4	5
SoA	SOLITUDE	GR-FSL	85	D	.20	5	20
SrD	SOUTHGATE	GRV-L	45	D	.22	1	30
SrD	ROCK OUTCROP	UWS	40	D			No DATA
SrE	SOUTHGATE	GRV-L	45	D	.22	1	30
SrE	ROCK OUTCROP	UWB	40	D			No DATA
SrF	SOUTHGATE	GRV-L	45	D	.22	1	30
SrF	ROCK OUTCROP	UWB	40	D			No DATA
SrG	SOUTHGATE	GRV-L	45	D	.22	1	30
SrG	ROCK OUTCROP	UWB	40	D			NO DATA
UbD	URBAN LAND	VAR	90				No DATA
UcC	URBAN LAND	VAR	80				No DATA
UcC	CINNAMON BAY	L	15	B	.17	5	5
UgC	URBAN LAND	VAR	80				NO DATA
UgC	GLYNN	GR-L	15	C	.20	5	10
VsC	VICTORY	L	45	B	.22	3	20
VsC	SOUTHGATE	GR-L	40	D	.22	1	25
VsD	VICTORY	L	45	B	.22	3	20
VsD	SOUTHGATE	GR-L	40	D	.22	1	25
VsE	VICTORY	L	45	B	.22	3	20
VsE	SOUTHGATE	GR-L	40	D	.22	1	25
VsF	VICTORY	L	45	B	.22	3	20
VsF	SOUTHGATE	GR-L	40	D	.22	1	25

****The soil loss tolerance or permissible soil loss ("T" factor) is expressed in tons/acre/year.***

Table 5.2.a. Topographic Adjustment Factors (LS) for Slope Percent and Slope Length (USDA-NRCS Caribbean Area, 1995) for Rangeland.[1]

Slope (%)	Horizontal Slope Length (Feet)																
	< 3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.60	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

[1] *Such as for rangeland and other consolidated soil conditions with cover.*

Table 5.2. b. Topographic Adjustment Factors (LS) for Slope Percent and Slope Length (USDA-NRCS Caribbean Area, 1995) for Cropland.[1]

Slope (%)	Horizontal Slope Length (Feet)																
	< 3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10
1.0	0.11	0.11	0.11	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.20	0.20
2.0	0.17	0.17	0.17	0.17	0.17	0.19	0.22	0.25	0.27	0.29	0.37	0.33	0.35	0.37	0.41	0.44	0.47
3.0	0.22	0.22	0.22	0.22	0.22	0.25	0.32	0.36	0.39	0.44	0.48	0.52	0.55	0.60	0.68	0.75	0.80
4.0	0.26	0.26	0.26	0.26	0.26	0.31	0.40	0.47	0.52	0.60	0.67	0.72	0.77	0.86	0.99	1.10	1.19
5.0	0.30	0.30	0.30	0.30	0.30	0.37	0.49	0.58	0.65	0.76	0.85	0.93	1.01	1.13	1.33	1.49	1.63
6.0	0.34	0.34	0.34	0.34	0.34	0.43	0.58	0.69	0.78	0.93	1.05	1.16	1.25	1.42	1.69	1.91	2.11
8.0	0.42	0.42	0.42	0.42	0.42	0.53	0.74	0.91	1.04	1.26	1.45	1.62	1.77	2.03	2.47	2.83	3.15
10.0	0.46	0.48	0.50	0.51	0.52	0.67	0.97	1.19	1.38	1.71	1.98	2.22	2.44	2.84	3.50	4.06	4.56
12.0	0.47	0.53	0.58	0.61	0.64	0.84	1.23	1.53	1.79	2.23	2.61	2.95	3.26	3.81	4.75	5.56	6.28
14.0	0.48	0.58	0.65	0.70	0.75	1.00	1.48	1.86	2.19	2.76	3.25	3.69	4.09	4.82	6.07	7.15	8.11
16.0	0.49	0.63	0.72	0.79	0.85	1.15	1.73	2.20	2.60	3.30	3.90	4.45	4.95	5.86	7.43	8.79	10.02
20.0	0.52	0.71	0.85	0.96	1.06	1.45	2.22	2.85	3.40	4.36	5.21	5.97	6.68	7.97	10.23	12.20	13.99
25.0	0.56	0.80	1.00	1.16	1.30	1.81	2.82	3.65	4.39	5.69	6.83	7.88	8.86	10.65	13.80	16.58	19.13
30.0	0.59	0.89	1.13	1.34	1.53	2.15	3.39	4.42	5.34	6.98	8.43	9.76	11.01	13.30	17.37	20.99	24.31
40.0	0.65	1.05	1.38	1.68	1.95	2.77	4.45	5.87	7.14	9.43	11.47	13.37	15.14	18.43	24.32	29.60	34.48
50.0	0.71	1.18	1.59	1.97	2.32	3.32	5.40	7.17	8.78	11.66	14.26	16.67	18.94	23.17	30.78	37.65	44.02
60.0	0.76	1.30	1.78	2.23	2.65	3.81	6.24	8.33	10.23	13.65	16.76	19.64	22.36	27.45	36.63	44.96	52.70

[1] *Such as for row cropped agricultural and other moderately consolidated soil conditions with little-to-moderate cover.*

Table 5.2. c. Topographic Adjustment Factors (LS) for Slope Percent and Slope Length (USDA-NRCS Caribbean Area, 1995) for Construction Sites.[1]

Slope (%)	Horizontal Slope Length (Feet)																
	< 3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

[1] *Such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover.*

Table 5.3. Cover Index Factor (C) for Construction Sites (U.S. Department of Agriculture, Soil Conservation Service).

Type of Cover*		Factor C	Percent[1]
None (fallow or bare gr ound)		1.0	0.0
Temporary Seedings (90% stand)			
Ryegrass (perennial type)		0.05	95
Ryegrass (annuals)		0.10	90
Small grain		0.05	95
Millet or sudan grass		0.05	95
Permanent Seeding (90% stand)		0.01	99
Sod (laid immediately)		0.01	99
	Application Rate (tons/acre)		
Mulch			
Hay	0.50	0.25	75
Hay	1.00	0.13	87
Hay	1.50	0.07	93
Hay	2.00	0.02	98
Small grain straw	2.00	0.02	98
Wood chips	6.00	0.06	94
Wood cellulose	1.75	0.10	95
Fiberglass	0.50	0.05	95
Asphalt emulsion (1,250 gals/acre)		0.02	98

***** ***Fiber matting, excelsior, gravel and stone may also be used as protective cover.***
[1] ***Percent soil loss reduction as compared with fallow or bare ground.***

Table 5.4. Practice Factor (P) for Surface Condition for Construction Sites (U.S. Department of Agriculture, Soil Conservation Service).

Surface Condition With No Cover	P Factor[1]
Compact and smooth, scraped with bulldozer or scraper up and down hill	1.3
Same condition, except raked with bulldozer root rake up and down hill	1.2
Compact and smooth, scraped with bulldozer or scraper across the slope	1.2
Same condition, except raked with bulldozer root rake across the slope	0.9
Loose as a disked plow layer	1.0
Rough irregular surface equipment tracks in all directions	0.9
Loose with rough surface greater than 12" depth	0.8
Loose with smooth surface greater than 12" depth	0.9

[1] *Values based on estimates.*

Table 5.5. Adjustment Factors (M) for Estimating Monthly and Portions of Annual Soil Loss (U.S. Department of Agriculture, Soil Conservation Service).

	St. Croix & St. Thomas (R = 250)	St. John (R = 240)
Month	Percent	Percent
January	5	6
February	4	5
March	4	5
April	5	7
May	10	10
June	6	6
July	7	7
August	11	10
September	12	12
October	13	11
November	14	12
December	9	9
	100	100

Table 5.6. Approximate Soil Weights in Pounds per Cubic Foot and Conversion Factors (U.S. Department of Agriculture, Soil Conservation Service).

Soil Texture*	Volume Weight (lbs/ft^3)	Tons to Cubic Yards
Sands and loamy sands	110	0.67
Sandy loam	105	0.71
Fine sandy loam	100	0.74
Loam	90	0.82
Silt loam	85	0.87
Silty clay loam	80	0.93
Clay loam	75	0.99
Silty, sandy clay and clay	70	1.06
Aerated sediment	80**	0.93
Saturated sediment	60**	1.24

**** Less than 2 mm particle size (includes gravelly and stony textural modifiers).***
***** These are the approximate aerated and saturated weights to be used at damaged sites (streams or reservoirs).***

Table 5.7. USDA Texture Abbreviations (U.S. Department of Agriculture, Soil Conservation Service).

Texture Modifiers	
CB - Cobbly	GRV - Very gravelly
CN - Channery	MK - Mucky
CNV - Very Channery	SR - Stratified
GR - Gravelly	ST - Stony
STV - Very stony	STX - Extremely stony
Textures	
G - Gravel	SL - Sandy loam
COS - Coarse Sand	FSL - Fine sandy loam
S - Sand	VSFL - Very fine sandy loam
FS - Fine sand	L - Loam
VFS - Very fine sand	SIL - Silt loam
LCOS - Loamy coarse sand	SI - Silt
LS - Loamy sand	CL - Clay loam
LFS - Loamy fine sand	SICL - Silty clay loam
LVFS - Loamy very fine sand	SIC - Silty clay
COSL - Coarse sandy loam	C - Clay
MUCK - Muck	

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CHAPTER 6: ESTIMATING RUNOFF AND STORMWATER DISCHARGE
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CHAPTER 6: ESTIMATING RUNOFF AND STORMWATER DISCHARGE

6.1 INTRODUCTION

Runoff occurs whenever there is precipitation in excess of that which can be absorbed by pervious materials (soils, etc.). Land cover types and changes to land cover types affect the amount of runoff and stormwater discharge that occurs in conjunction with a storm event. The conversion of rural land and open spaces to urban land uses usually increases soil erosion and the discharge and volume of stormwater runoff within a watershed. These increases are due to pervious surfaces being converted to impervious surfaces, natural water flow patterns being altered, and to other changes that occur to watersheds in response to precipitation.

This chapter provides information to assist the developer, planner, landowner or regulator in estimating the amount of runoff and stormwater discharge from a watershed and the amounts of runoff and stormwater discharge due to changes to a watershed. The information in this chapter is taken from *Urban Hydrology for Small Watersheds, U.S. Department of Agriculture Soil Conservation Service Engineering Technical Release 55 (TR-55)* (USDA-SCS, 1986). Information in this chapter was compiled by Mario A. Morales, USDA Natural Resources Conservation Service (NRCS), Resource Conservation and Development Coordinator for the Virgin Islands. For more information, contact the Virgin Islands' USDA-NRCS Field Office or your local Cooperative Extension Service office.

6.2 ESTIMATING RUNOFF - THE SCS CURVE NUMBER METHOD

The SCS Curve Number (CN) Method is described in detail in USDA-SCS (1985). The equation used by the curve number method is of the form:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad \textbf{[Eq. 6-1]}$$

where

Q	=	runoff (inches)
P	=	rainfall (inches)
S	=	potential maximum retention after runoff begins (inches)
I_a	=	initial abstraction (inches)

The initial abstraction term (I_a) encompasses all losses that occur before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evapotranspiration, and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2 * S \quad \textbf{[Eq. 6-2]}$$

By removing I_a as an independent parameter, this approximation allows the use of a combination of S and P to produce a unique runoff amount. Substituting equation 6-2 into equation 6-1 yields:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad \textbf{[Eq. 6-3]}$$

S is related to the soil and cover conditions of the watershed through a **Curve Number (CN)**. CN has a range of 0 to 100, and S is related to CN by the equation:

$$S = \frac{100}{CN} - 10 \quad \text{[Eq. 6-4]}$$

Figure 6.1 and Table 6.1 solve equations 6-3 and 6-4 for a range of curve numbers and rainfall amounts.

6.2.1 Factors Considered in Determining Runoff Curve Numbers

The primary factors that determine CN are the hydrologic soil group (HSG), cover type, hydrologic condition, and antecedent runoff condition (ARC). Another factor to consider is whether impervious areas outlet directly to the stormwater drainage system (**connected**) or whether the flow spreads over pervious areas before entering the drainage system (**unconnected**). Figure 6-2 is provided to aid in selecting the appropriate figure or table for determining curve numbers.

Curve numbers in Tables 6-2 (a-d) represent average antecedent runoff conditions for urban land uses, cultivated and other agricultural land uses, and arid and semiarid rangeland uses. Tables 6-2 assume impervious areas are directly connected. The following sections explain how to determine curve numbers and how to modify them for use with non-agricultural conditions.

6.2.1.a Hydrologic Soil Groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four Hydrologic Soil Groups – A, B, C, and D (see Table 6.3) – according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Table 6.3 defines these groups and provides the hydrologic group classification for soils in the U.S. Virgin Islands.

Most urban areas are only partially covered by impervious surfaces, thus, soils remain an important factor in runoff estimates. The effect of urbanization on runoff is greater in watersheds that have soils with high infiltration rates (sands and gravels) than in watersheds with predominately silt and clay soils, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change infiltration characteristics. With urbanization, native soil profiles may be mixed or removed, or fill material from other areas may be introduced. Assistance in determining HSG for altered soils is available from the Natural Resources Conservation Service Field Office on St. Croix. The soils in the watershed of interest may be identified from the revised U.S. Virgin Islands Soil Survey (USDA-NRCS, 1995), which can be obtained from the USDA Service Center in Gallows Bay, St. Croix, from the UVI Conservation Data Center, St. Thomas (on CD-ROM), or from the UVI Cooperative Extension Service, St. Thomas. The text of the Soil Survey can also be downloaded in pdf format from www.statlab.iastate.edu/soils/soildiv/surveys/virgnis.pdf.

6.2.1.b Cover Type

Tables 6.2 (a-d) address most cover types found in urbanizing areas, such as vegetation, bare soil, and impervious surfaces. There are a number of methods that can be used to determine cover type. The most common are field and aerial reconnaissance, photographs, and land use maps.

6.2.1.c Treatment

Treatment is a modifier for cover type (used only in Table 6.2 (b)) that describes the management of cultivated agricultural lands. It includes mechanical practices, such as contouring and terracing, and management practices, such as crop rotations and reduced or no tillage.

6.2.1.d Hydrologic Condition

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff, and is generally estimated from plant density and residue cover on sample areas. Good hydrologic condition indicates that the soil usually has a low runoff potential for that specific hydrologic soil group, cover type, and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are: canopy or density of lawns, crops or other vegetative areas; amount of year-round cover; amount of grass; percent of residue cover; and degree of surface roughness.

6.2.1.e Antecedent Runoff Condition

The index of runoff potential before a storm event is the **antecedent runoff condition** (ARC). ARC is an attempt to account for the variation in curve number at a site from storm to storm. The curve number for the average ARC at a site is the median value as taken from sample rainfall and runoff data. The curve numbers in Tables 6.2 are for the average ARC, which is used primarily for design applications. See USDA-SCS (1985) and Rallison and Miller (1981) for a more detailed discussion of storm-to-storm variation and a demonstration of upper and lower enveloping curves.

6.2.1.f Urban Impervious Area Modifications

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the stormwater drainage system, should be considered in computing the curve number for urban areas (Rawls et. al., 1981). For example, do the impervious areas connect directly to the drainage system or do they outlet onto lawns or other pervious areas where infiltration can occur?

6.2.1.g Connected Impervious Areas

An impervious area is considered connected if runoff from that area flows directly into the stormwater drainage system. It is also considered connected if runoff from the area occurs as concentrated shallow flow that runs over a pervious area and then into a drainage system. Urban curve numbers (Table 6.2(a)) were developed for typical land use relationships based on specific assumed percentages of impervious area. These curve number values were developed on the assumptions that pervious urban areas are equivalent to pasture in good hydrologic condition and impervious areas have a curve number of 98 and are directly connected to the stormwater drainage system. Some assumed percentages of impervious area are shown in Table 6.2(a).

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages or the pervious land use assumptions in Table 6.2(a) are not applicable, use Figure 6.3 to compute a composite curve number. For example, Table 6.2(a) gives a curve number of 70 for a ½-acre lot in hydrologic soil group B with an assumed impervious area of 25%. However, if the lot has only 20% impervious area and a pervious area curve number of 61, then the composite curve number obtained from Figure 6.3 is 68. The decrease in curve number from 70 to 68 reflects the smaller percentage of impervious area for that parcel.

6.2.1.h Unconnected Impervious Areas

Runoff from these areas is spread over a pervious area as sheet flow. To determine curve number when all or part of the impervious area is not directly connected to the drainage system, use Figure 6.4 if total impervious area is less than 30 percent or use Figure 6.3 if the total impervious area is greater than 30 percent, because the absorptive capacity of the remaining pervious areas will not significantly affect runoff.

When impervious area is less than 30 percent, obtain the Composite Curve Number by entering the right half of Figure 6.4 with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area. Then move left to the appropriate pervious curve number and read down to find the composite curve number. For example, for a ½-acre lot with 20 percent total impervious area (75 percent of which is unconnected) and pervious curve number of 61, the composite curve number from Figure 6.4 is 66. If all of the impervious area is connected, the resulting curve number (from Figure 6.3) would be 68.

6.2.1.i Rainfall

The highest peak discharges from small watersheds are usually caused by intense, brief rainfall that occurs as a distinct event or as a part of a longer storm. These rainfall events have intensities that vary greatly and normally do not extend over a very large area. Because of the great variability in storm events and the need for design information, synthetic (a typical storm event as calculated by NRCS) rainfall distributions have been developed by the USDA Natural Resources Conservation Service using U.S. National Weather Service data for typical storms. The twenty-four (24) hour storm, while longer than that needed to determine peaks for small drainage areas, is appropriate for determining runoff volumes. Therefore, a single storm duration and associated synthetic rainfall distribution can be used to represent not only peak discharge but also runoff volumes. The following twenty-four hour rainfall distribution charts are presented in Figures 6.5 through 6.11: the one-year, two-year, five-year, ten-year, twenty five-year, fifty-year, and one hundred-year storms.

6.2.1.i Runoff

When curve number and the amount of rainfall (P) have been determined for the watershed, runoff can be determined by using Figure 6.1, Table 6.1 or equations 6-3 and 6-4. The runoff amount calculated is usually rounded to the nearest hundredth of an inch.

6.2.2 Limitations

- Curve numbers describe average conditions that are useful for design purposes. If the rainfall event used is a historical storm, the modeling accuracy decreases.

- Use the runoff curve number equation with caution when recreating specific features of an actual storm. The equation does not contain an expression for time, and therefore, does not account for rainfall duration and intensity.

- The user should understand the assumption reflected in the initial abstraction term (I_a) and should ascertain that the assumption applies to the situation. I_a – which consists of interception, initial infiltration, surface depression storage, evapotranspiration, and other factors – was generalized as 0.2S based on data from agricultural watersheds (S is the potential maximum retention after runoff begins). This approximation can be especially important in an urban application because the combination of impervious areas with pervious areas can imply a significant initial loss that may not actually take place. The opposite effect – a greater initial loss – can occur if the impervious areas have surface depressions that store some runoff. To use a relationship other than $I_a = 0.2S$, one must re-calculate equation 6-3,

Figure 6.1, Table 6.1, and Tables 6.2 by using the original rainfall-runoff data to establish new S or CN relationships for each cover and hydrologic soil group.

- The curve number procedure is less accurate when runoff is less than 0.5 inches. A different procedure should be used to verify runoff accuracy in this case.

- The SCS runoff procedures apply only to direct surface runoff: do not overlook large sources of subsurface flow or high groundwater levels that contribute to runoff. These conditions are often related to hydrologic soil group A soils and wooded areas that have been assigned relatively low curve numbers in Tables 6.2. Good judgement and experience based on stream gage records are needed to adjust curve numbers as conditions warrant.

- When the weighted curve number is less than 40, use another procedure to determine runoff.

6.2.3 Examples

Four examples illustrate the procedure for computing runoff curve numbers (CN) and runoff (Q) in inches. A blank copy of TR-55 Worksheet 2 (used to compute CN and Q) is provided at the end of this chapter. Two of the four examples are based on an imaginary watershed on St. Thomas and the other two are based on a different imaginary watershed on St. Croix. Both examples are based on a 25-year, 24-hour storm event. The examples on St. Thomas calculate runoff based on acreage. The examples on St. Croix calculate runoff based on the percentage of acreage of soil types that comprise the watershed. Section 6.5 contains the completed TR-55 Worksheets for examples 1 through 4.

6.2.3.a Example 1

The site covers eighteen (18) acres at Bordeaux Hills, on the western end of St. Thomas. The acreage is classified as a Cramer soil, which is in hydrologic soil group C (see Table 6.3). A 25-year, 24-hour storm event produces a total rainfall (P) of 6.2 inches (see Figure 6.9).

Problem: Determine the curve number (CN) and volume of runoff (Q) for this site for the present cover condition of brush in fair hydrologic condition.

Solution: Refer to Table 6.2(c) to find a **curve number** of **70** for brush in fair hydrologic condition. Because this location has only one hydrologic soil group and cover type, Worksheet 2 is not needed. However, should a location have more than one hydrologic soil group or cover type, TR-55 Worksheet 2 should be used to calculate a **weighted curve number**.

To determine **direct runoff (Q)**, refer to Figure 6.9, which depicts the rainfall distribution for a 25-year, 24-hour storm event. For the western end of St. Thomas, the **rainfall (P)** is **6.2** inches. Next, refer to Figure 6.1 and locate 6.2 inches on the P axis (horizontal), and follow that line up the chart to the line that represents curve number 70. Trace the curve number 70 line left towards the Q axis (vertical) to find the **runoff volume of 2.95 inches**. (See completed Worksheet for this example in section 6.5.)

6.2.3.b Example 2

Problem: Determine the weighted curve number (CN) and volume of runoff (Q) for the same site but with a different cover type. The 18-acre site has been cleared for a housing development. Four (4) acres will remain in open space in good hydrologic condition. The remaining fourteen (14) acres will be developed into quarter-acre lots with thirty-eight percent (38%) impervious area.

Solution: First, refer to Table 6.2(a) to determine the curve number for each cover type. For open space with good hydrologic condition, the corresponding **curve number** is **74**. The **curve number** for quarter-acre lots with 38% impervious area is **83**. Each of these curve numbers is multiplied by its corresponding area and then averaged to obtain a weighted curve number:

$$CN = \frac{(74 * 4 \; acres) + (83 * 14 \; acres)}{18 \; acres} = 81 \quad (use \; 80)$$

The **rainfall value (P)** is the same as in Example 1 – **6.2 inches**. Next, refer to Figure 6.1, locate 6.2 inches on the horizontal (P) axis, follow the line up to the line representing curve number 80, and then move horizontally to the left to determine runoff from the vertical (Q) axis. This example yields a **direct runoff (Q) of four (4.1) inches**. (See worksheet for this example in section 6.5.)

6.2.3.c Example 3

The site covers twenty-five (25) acres at Villa La Reine Estates, mid-island St. Croix. Fifty-eight percent (58%) of the site has Arawak soils, hydrologic soil group B (see Table 6.3), and forty-two percent (42%) of the site is classified as a Cramer soil, which is in hydrologic soil group C (see Table 6.3). A 25-year, 24-hour storm event produces a total rainfall (P) of 8 inches (see Figure 6.9).

Problem: Determine the weighted curve number (CN) and runoff volume (Q) from this site for a fair cover condition in pasture on the Arawak soil.

Solution: Referring to Table 6.2(c), the curve number for fair pasture condition in hydrologic soil group B is **69**. The Cramer soil has good pasture condition. The curve number of good pasture condition in hydrologic soil group C is **74**. The **weighted curve number** for this site is obtained by multiplying each above curve number by its corresponding percentage of acreage as follows:

$$CN = \frac{(69 * 58\%) + (74 * 42\%)}{100\%} = 71.1 = 71 \quad (use \; 70)$$

The **rainfall value (P)** is determined to be **8.0** inches for the central area of St. Croix by referring to Figure 6.9. Next, refer to Figure 6.1 and locate 8 on the horizontal axis (P), follow the line up to the line representing curve number 70, then move horizontally to the vertical axis (Q) to determine a **runoff volume of 4.4 inches**. (See Worksheet for this example in section 6.5.)

6.2.3.d Example 4

Problem: Using the information in Example 3 (above), determine the weighted curve number and runoff volume for the Villa La Reine Estates site for a post-development scenario of forty-seven percent (47%) of the Arawak soil having quarter-acre lots with thirty-eight percent (38%) impervious area, eleven percent (11%) of the Arawak soil in open space with fair condition, thirty-six percent (36%) of the Cramer soil in quarter-acre lots with thirty-eight percent (38%) impervious area, and six percent (6%) of the Cramer soil in open space with good condition.

Solution: Referring to Table 6.2(a), we find the following curve numbers:

Soil, Group, Cover & Condition	Curve Number	Percent of Total Area
Arawak (B), 1/4-acre, 38% imperv.	75	47%
Arawak (B), open space, fair	69	11%
Cramer (C), 1/4-acre, 38% imperv.	83	36%
Cramer (C), open space, good	74	6%

The **weighted curve number** for this site (refer to example above) is:

$$CN = \frac{(75 * 47\%) + (69 * 11\%) + (83 * 36\%) + (74 * 6\%)}{100\%} = 77.16 \simeq 77$$

Using the **rainfall value** of **8.0**, refer to Figure 6.1, locate 8.0 along the horizontal axis (P), follow this line up to approximately 77 curve number, follow that left to the vertical axis (Q) to determine the **direct runoff volume of 5.2 inches**. (See worksheet for this example in Section 6.5.)

6.3 TIME OF CONCENTRATION AND TRAVEL TIME

Travel time (T_t) is the time it takes stormwater to travel from one location to another in a watershed. T_t is a component of **time of concentration (T_c)**, which is the time it takes for runoff to travel from the hydraulically-most-distant point of the watershed to a point of interest within the watershed. T_c is computed by summing all the travel time for consecutive components of the stormwater drainage system.

T_c influences the shape and peak of the runoff hydrograph (**def**). Urbanization usually increases T_c, thereby increasing the peak discharge (**def**). T_c can also be increased as a result of ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or reduction of land slope through grading.

6.3.1 Factors Affecting Time of Concentration and Travel Time

6.3.1.a Surface Roughness

One of the most significant effects of urban development on stormwater velocity is the decrease in flow retardance. In undeveloped areas, stormwater runoff moves slowly as shallow overland flow through vegetation and over rough surfaces. When these areas are modified by urban development, stormwater moves much more rapidly over smooth, impervious paved areas and through gutters and storm drains. This leads to a significant decrease in the travel time of stormwater runoff through the watershed.

6.3.1.b Channel Shape and Flow Patterns

In small, non-urban watersheds, much of the total travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow distances by conveying storm runoff into a channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

6.3.1.c Slope

Slopes may be increased or decreased by urbanization, depending upon the amount of site grading or the extent to which storm drains and ditches are used in the design of the stormwater management system. Slopes generally tend to increase when channels are straightened and decrease when overland flow is directed through storm drains, street gutters and swales, and diversions.

6.3.2 Computation of Travel Time and Time of Concentration

Stormwater moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type of flow that occurs is a function of the type of conveyance system and is best determined by field inspection.

Travel time (T_t) is the ratio of flow length to flow velocity:

$$T_t = \frac{L}{3600\ V} \qquad \textbf{[Eq. 6-5]}$$

where

T_t	=	travel time (hours)
L	=	flow length (feet)
V	=	average velocity (feet/second)
3600		is a conversion factor from seconds to hours

Time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments:

$$T_t = T_{t1} + T_{t2} + \ldots + T_{tm} \qquad \textbf{[Eq. 6-6]}$$

where

T_c	=	time of concentration (hours)
m	=	number of flow segments

6.3.3 Sheet flow

Sheet flow is flow over level surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (**Manning's n**) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These "n" values are for very shallow flow depths of about one tenth (0.1) of a foot (1.2 inches). Table 6.4 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows, 1976) to compute T_t:

$$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}} \quad \text{[Eq. 6-7]}$$

where

T_t	=	travel time (hours)
n	=	Manning's roughness coefficient (see Table 6.4)
L	=	flow length (feet)
P_2	=	2-year, 24-hour rainfall (inches)
s	=	slope of hydraulic grade line (land slope, feet/feet)

This simplified form of the Manning's kinematic solution is based on the following assumptions: shallow steady uniform flow; constant intensity of rainfall excess (that part of a rain available for runoff); rainfall duration of 24 hours; and minor effect of infiltration on travel time.

6.3.4 Shallow Concentrated Flow

After traveling a maximum distance of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from Figure 6.12, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, compute velocity using the following equations:

$$\textit{Unpaved}:\ V = 16.1345\ (s)^{0.5}$$
$$\textit{Paved}:\ V = 20.3282\ (s)^{0.5} \quad \text{[Eq. 6-8]}$$

where

V	=	average velocity (ft/s)
s	=	slope of hydraulic grade line (watercourse slope, ft/ft)

After determining average velocity in Figure 6.12, use equation 6-5 to estimate travel time for the shallow concentrated flow segment.

6.3.5 Open Channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating permanent or intermittent streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

Manning's equation is:

$$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n} \quad \text{[Eq. 6-9]}$$

where

V	=	average velocity (ft/s)
r	=	hydraulic radius (ft) and is equal to a/p_w
p_w	=	wetted perimeter (ft)
a	=	cross sectional flow area (ft^2)
s	=	slope of the hydraulic grade line (channel slope, ft/ft)

n = Manning's roughness coefficient for open channel flow

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982). After average velocity is computed using equation 6-9, T_t for the channel segment can be estimated using equation 6-5.

6.3.6 Reservoirs, Lakes or Ponds

Sometimes it is necessary to estimate the velocity of flow through a reservoir, lake or pond at the outlet of a watershed. This travel time is normally very small and can be assumed to be zero.

6.3.7 Limitations

C Manning's kinematic solution should not be used for sheet flow longer than 300 feet. Equation 6-7 was developed for use with the four standard rainfall intensity-duration relationships.

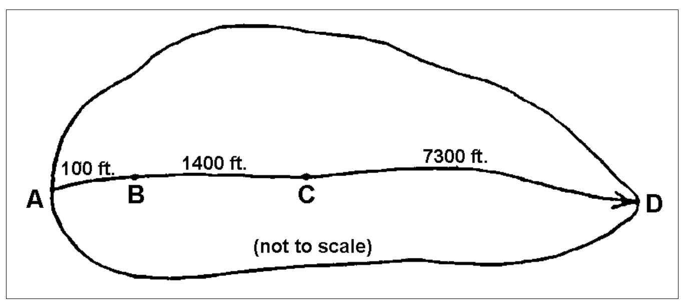
C In a watershed with storm drains, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm drains generally handle only a small portion of a large event. The rest of the peak flow travels over streets, lawns, etc. to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or non-pressure flow.

C The minimum T_c used in TR-55 is 0.1 hour.

C A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. The procedures in TR-55 can be used to determine the peak flow upstream of the culvert. Detailed storage routing procedures should be used to determine the outflow through the culvert.

6.3.8 Example 5

The sketch on the right shows a hypothetical watershed on St. Croix. The problem is to compute T_c at the outlet of the watershed (point D). The 2-year, 24-hour rainfall depth is 3.6 inches. All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:



St. Croix watershed for Example 5.

Segment AB: Sheet flow, dense grass cover, slope (s) = 0.01 ft/ft, and length (L) = 100 feet.
Segment BC: Shallow concentrated flow, unpaved, s = 0.01 ft/ft, and L = 1400 feet.
Segment CD: Channel flow, Manning's n = 0.05, flow area (a) = 27 ft^2, wetted perimeter (p_w = 28.2 feet, s = 0.005 ft/ft, and L = 7300 feet.

TR-55 Worksheet 3 is used to compute T_c. TR-55 Worksheet 3 is completed to solve Example 5 in section 6.5. A blank copy of TR-55 Worksheet 3 is provided for the user at the end of this Chapter.

6.4 GRAPHICAL PEAK DISCHARGE METHOD

This section presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The graphical method was developed from hydrograph analyses using TR-20 "*Computer Program for Project Formulation - Hydrology*" (SCS, 1983). The peak discharge equation used is:

$$q_p = q_u A_m Q F_p \qquad \textbf{[Eq. 6-10]}$$

where

q_p	=	peak discharge (cfs)
q_u	=	unit peak discharge (csm/in)
Q	=	runoff (in)
A_m	=	drainage area (mi^2)
F_p	=	pond and swamp adjustment factor

The input requirements for the Graphical method are the T_c (hr); the drainage area (mi^2); the appropriate rainfall distribution (Type III for the Virgin Islands); the 24-hour rainfall (in); and the curve number. If pond and/or swamp areas are spread throughout the watershed and are not considered in the T_c computation, then an adjustment for pond and swamp areas is also required.

6.4.1 Peak Discharge Computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from Figures 6.5 to 6.11 or more detailed local precipitation maps. Curve number (CN) and direct runoff (Q) for the watershed are computed according to the methods outlined in Section 6.2. The curve number is used to determine the initial abstraction (I_a) from Table 6.5, and the I_a/P is then computed.

Peak discharge per square mile per inch of runoff (q_u) is obtained from Figure 6.13 by using T_c (see Section 6.3), rainfall distribution type, and I_a/P ratio. The pond and swamp adjustment factor is obtained from Table 6.6 (rounded to the nearest Table value). Use TR-55 Worksheet 4 provided at the end of this chapter to aid in computing the peak discharge using the Graphical method.

6.4.2 Limitations

The Graphical method provides a determination of peak discharge only. If a hydrograph is needed or watershed subdivision is required, use the Tabular Hydrograph method described in Chapter 5 of TR-55 (SCS, 1986). Use TR-20 if the watershed is very complex or if a higher degree of accuracy is required.

C The watershed must be hydrologically homogenous, that is, describable by one curve number. Land use, soils, and cover are distributed uniformly throughout the watershed.

C The watershed may have only one main drainage channel (stream or gut) or, if more than one, the branches must have nearly equal T_c's.

C This method cannot perform valley or reservoir routing.

C The F_p factor can be applied only for ponds or swamps that are not in the T_c flow path.

- Accuracy of peak discharge estimated by this method will be reduced if I_a/P values are used that are outside the range given in Figure 6.15. The limiting I_a/P values are recommended for use in this case.

- This method should be used only if the weighted curve number is greater than 40.

- When this method is used to develop estimates of peak discharge for both present and developed conditions of a watershed, use the same procedure for estimating T_c.

- T_c values with this method may range from 0.1 to 10 hours.

6.4.3 Example 6

Compute the 25-year peak discharge for the 25-acre watershed described in examples 3 and 5. Worksheet 4 in section 6.5 shows how q_p is computed for this example.

6.5 TR-55 WORKSHEET SOLUTIONS TO EXAMPLES

The following worksheets detail the computation of CN and Q for examples 1 through 4, the computation of T_c for example 5, and the computation of q_p for example 6.

Solution to Example 1.

Worksheet 2: Runoff curve number and runoff

Project: Bordeaux Hill By: MAM Date: 10/01/01

Location: St. Thomas Checked: JJS Date: 10/01/01

Circle One: (Present) Developed

1. Runoff Curve Number (CN)

Soil Name and Hydrologic Group (Appendix A)	Cover Description (cover type, treatment and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/			Area ☒ acres ☐ mi2 ☐ %	Product of CN x Area
		Table 6-2	Fig. 6-3	Fig. 6-4		
Cramer, C	Brush (Bush), Fair condition	70			18	1260
				Totals =	18	1260

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1260}{18} = 70$; Use CN = 70

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	6.2		
Runoff, Q	in	2.95		

(Use P and CN with Table 6-1, Figure 6-1 or Equations 6-3 and 6-4)

Solution to Example 2.

Worksheet 2: Runoff curve number and runoff

Project Bordeaux Hill By MAM Date 10/01/01

Location St. Thomas Checked JJS Date 10/01/01

Circle One: Present (Developed)

1. Runoff Curve Number (CN)

Soil Name and Hydrologic Group (Appendix A)	Cover Description (cover type, treatment and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/			Area ☒ acres ☐ mi2 ☐ %	Product of CN x Area
		Table 6-2	Fig. 6-3	Fig. 6-4		
Cramer, C	Open Space, Good Condition	74			4	296
Cramer, C	1/4 acre lots, 38% impervious	83			14	1162
				Totals =	18	1458

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1458}{18} = 80$; Use CN = 80

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	6.2		
Runoff, Q	in	4.0		

(Use P and CN with Table 6-1, Figure 6-1 or Equations 6-3 and 6-4)

Solution to Example 3.

Worksheet 2: Runoff curve number and runoff

Project: Villa La Reine Estates — By: MAM — Date: 10/01/01

Location: St. Croix, VI — Checked: JJS — Date: 10/01/01

Circle One: (Present) Developed

1. Runoff Curve Number (CN)

Soil Name and Hydrologic Group (Appendix A)	Cover Description (cover type, treatment and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 6-2	CN 1/ Fig. 6-3	CN 1/ Fig. 6-4	Area ☒ acres ☐ mi2 ☐ %	Product of CN x Area
Arawak, B	Pasture, Fair Condition	69			58	4002
Cramer, C	Pasture, Good Condition	74			42	3108
				Totals =	100	7110

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{7110}{100} = 71.1$; Use CN = 70

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	8.0		
Runoff, Q	in	4.4		

(Use P and CN with Table 6-1, Figure 6-1 or Equations 6-3 and 6-4)

Solution to Example 4.

Worksheet 2: Runoff curve number and runoff

Project: Villa La Reine Estates By: MAM Date: 10/01/01

Location: St. Croix, VI Checked: JJS Date: 10/01/01

Circle One: Present (Developed)

1. Runoff Curve Number (CN)

Soil Name and Hydrologic Group (Appendix A)	Cover Description (cover type, treatment and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 6-2	CN 1/ Fig. 6-3	CN 1/ Fig. 6-4	Area ☒ acres ☐ mi2 ☐ %	Product of CN x Area
Arawak, B	1/4 acre lots, 38% impervious	75			47	3525
Arawak, B	Open Space, Fair Condition	69			11	759
Cramer, C	1/4 acre lots, 38% Impervious	83			36	2988
Cramer, C	Open Space, Good Condition	74			6	444
				Totals =	100	7716

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{7716}{100} = 77.16$; Use CN = 77

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	8.0		
Runoff, Q	in	5.0		

(Use P and CN with Table 6-1, Figure 6-1 or Equations 6-3 and 6-4)

Solution to Example 5.

Worksheet 3: Time of Concentration (Tc) or Travel Time (Tt)

Project: Villa La Reine Estates **By:** MAM **Date** 10/01/01

Location: St. Croix, VI **Checked** JJS **Date** 10/01/01

Circle one: Present (Developed)

Circle one: Tc Tt through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to Tc only)

Segment ID		AB		
1. Surface description (Table 6-4)		Dense Grass		
2. Manning's roughness coefficient, n (Table 6-4)		0.24		
3. Flow length, L, (total L ≤ 300 ft)	ft	100		
4. Two-year 24-hour rainfall, P_2	in	3.6		
5. Land slope, s	ft/ft	0.01		
6. $Tt = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$ Compute Tt	hr	0.3	+	= 0.3

Shallow Concentrated Flow

Segment ID		BC		
7. Surface description (paved or unpaved)		U		
8. Flow length, L	ft	1400		
9. Watercourse slope, s	ft/ft	0.01		
10. Average velocity, V (Figure 6-12)	ft/s	1.6		
11. $Tt = \frac{L}{3600\,V}$ Compute Tt	hr	0.24	+	= 0.24

Channel Flow

Segment ID		CD		
12. Cross sectional flow area, a	ft^2	27		
13. Wetted perimeter, p_w	ft	28.2		
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	0.957		
15. Channel slope, s	ft/ft	0.005		
16. Manning's roughness coefficient, n		0.05		
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	2.05		
18. Flow length, L	ft	7300		
19. $Tt = \frac{L}{3600\,V}$ Compute Tt	hr	0.99	+	= 0.99
20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)	hr			1.53

Solution to Example 6.

Worksheet 4: Graphical Peak Discharge Method

Project Villa La Reine Estates By MAM Date 10/01/01

Location St. Croix, VI Checked JJS Date 10/01/01

Circle one: (Present) Developed ________________

1. Data:

Drainage Area .... A_m = 0.039 mi^2 (acres/640)

Runoff curve number .... CN = 70 (from Worksheet 2)

Time of concentration .. Tc = 1.53 hr (from Worksheet 3)

Rainfall distribution type = III (I, IA, II, III)

Pond and swamp areas spread throughout watershed ...... = - percent of A_m (- acres or mi^2 covere

2. Frequency	yr	25		
3. Rainfall, P (24-hour)	in	8.0		
4. Initial abstraction, I_a (Use CN with table 6-5)	in	0.857		
5. Compute I_a/P		0.11		
6. Unit peak discharge, q_u (Use Tc and I_a/P with Figure 6-13)	csm/in	230		
7. Runoff, Q (From Worksheet 2)	in	4.4		
8. Pond and swamp adjustmetn factor, F_p (Use percent pond and swamp area with Table 6-6. Factor is 1.0 for zero percent pond and swamp area.)		1.0		
9. Peak discharge, q_p (Where $q_p = q_u A_m Q F_p$)	cfm	39.47		

6.6 FIGURES AND TABLES

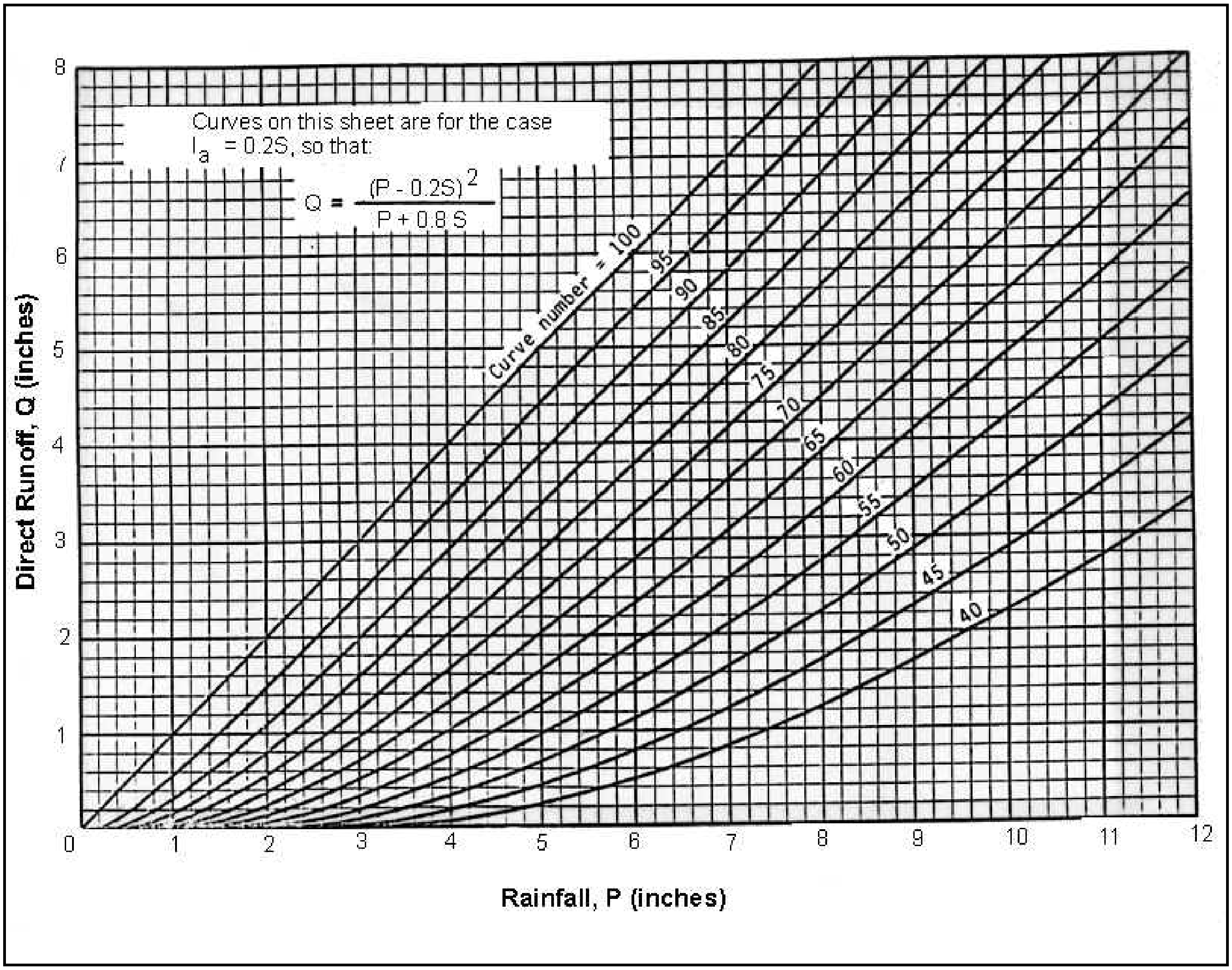


Figure 6.1. Solution of runoff equation for SCS curve number method (USDA-SCS, 1986).

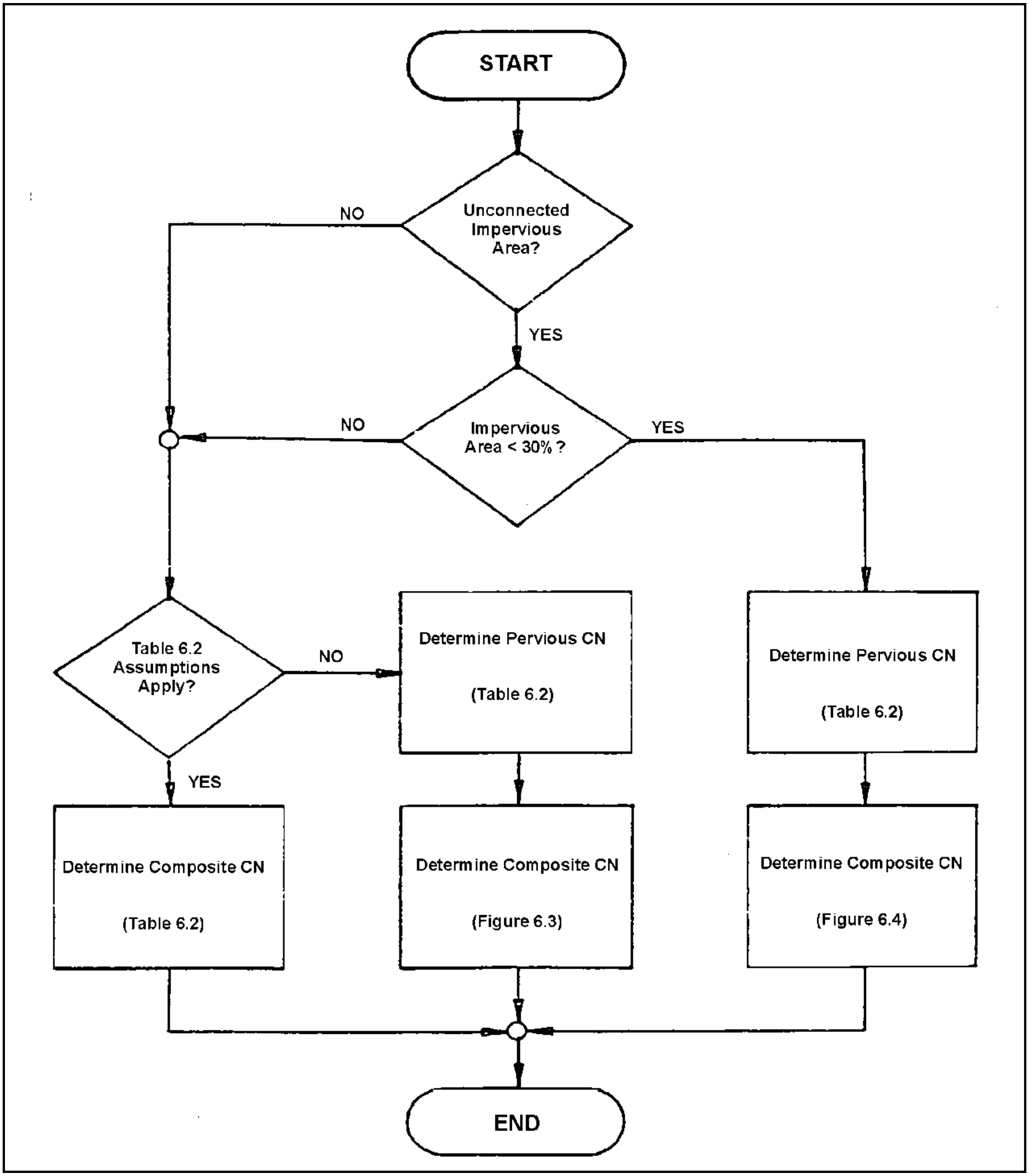


Figure 6.2. Flow chart for selecting the appropriate figure or table for determining runoff curve numbers (USDA-SCS, 1986).

Table 6.1. Runoff depth for selected CN's and rainfall amounts[1] (USDA-SCS, 1986).

	Runoff depth for curve number of --												
Rain-fall	40	45	50	55	60	65	70	75	80	85	90	95	98
	---inches---												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.15	0.27	0.46	0.74	0.99
1.4	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.13	0.24	0.39	0.61	0.92	1.18
1.6	0.00	0.00	0.00	0.00	0.01	0.05	0.11	0.20	0.34	0.52	0.76	1.11	1.38
1.8	0.00	0.00	0.00	0.00	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.29	1.58
2.0	0.00	0.00	0.00	0.02	0.06	0.14	0.24	0.38	0.56	0.80	1.09	1.48	1.77
2.5	0.00	0.00	0.02	0.08	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.96	2.27
3.0	0.00	0.02	0.09	0.19	0.33	0.51	0.71	0.96	1.25	1.59	1.98	2.45	2.77
3.5	0.02	0.08	0.20	0.35	0.53	0.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	0.06	0.18	0.33	0.53	0.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	0.14	0.30	0.50	0.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	0.24	0.44	0.69	0.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	0.50	0.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	0.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.89	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

[1] Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Table 6.2.a. Runoff curve numbers for urban areas[1] (USDA-SCS, 1986).

Cover description		Curve numbers for hydrologic soil group --			
Cover type and hydrologic condition	**Average percent impervious area[2]**	**A**	**B**	**C**	**D**
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)					
Fair condition (grass cover 50% to 75%)		68	79	86	89
Good condition (grass cover > 75%)		49	69	79	84
		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm drains (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)					
Gravel (including right-of-way)		83	89	92	93
Dirt (including right-of-way)		76	85	89	91
		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in Table 2.2(c))					

1 Average runoff condition, and $I_a = 0.2S$.

2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using Figures 6.3 or 6.4.

3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4 Composite CN's for natural desert landscaping should be computed using Figures 6.3 or 6.4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using Figures 6.3 or 6.4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 6.2.b. Runoff curve numbers for cultivated agricultural lands[1] (USDA-SCS, 1986).

Cover description			Curve numbers for hydrologic soil group --			
Cover type	**Treatment**[2]	**Hydrologic Condition**[3]	**A**	**B**	**C**	**D**
Fallow	Bare soil	--	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	86
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small Grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and $I_a = 0.2S$.

2 *Crop residue cover* applies only if residue is on at least 5% of the surface throughout the year.

3 Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of reside cover on the land surface (good > 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 6.2.c. Runoff curve numbers for other agricultural lands[1] (USDA-SCS, 1986).

Cover description		Curve numbers for hydrologic soil group --			
Cover type	**Hydrologic Condition**	**A**	**B**	**C**	**D**
Pasture, grassland or range -- continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow -- continuous grass, protected from grazing and generally mowed for hay.	--	30	58	71	80
Brush -- brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods -- grass combination (orchard or tree farm)[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads -- buildings, lanes, driveways, and surrounding lots	--	59	74	82	86

1 Average runoff condition, and I_a = 0.2S.

2 *Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50% to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

3 *Poor:* <50% ground cover.
Fair: 50% to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use CN = 30 for runoff computations.

5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 6.2.d. Runoff curve numbers for arid and semi-arid rangelands[1] (USDA-SCS, 1986).

Cover description		Curve numbers for hydrologic soil group --			
Cover type	**Hydrologic Condition[2]**	**A[3]**	**B**	**C**	**D**
Herbaceous -- mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen -- mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper -- pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub -- major plants include salt bush, greasewood, creosote bush, black brush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition, and $I_a = 0.2S$. For range in humid regions, use Table 6.2.c.

2 *Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30% to 70% ground cover.
Good: >70% ground cover.

3 Curve numbers for group A have been developed only for desert shrub.

Table 6.3. Hydrologic soil groups of the U.S. Virgin Islands (USDA-NRCS, 1995).

Group			
A	**B**	**C**	**D**
Jaucas	Arawak	Cramer	Annaberg
Lameshur	Cinnamon Bay	Dorothea	Aquents
Redhook	Parasol	Glynn	Beaches
	Sion	Jealousy	Carib
	Victory		Fredriksdal
			Hesselburg
			Hogensborg
			Maho Bay
			Rock Outcrop
			Salt Flats
			Sandy Point
			Solitude
			Southgate
			Sugar Beach
			Susannaberg

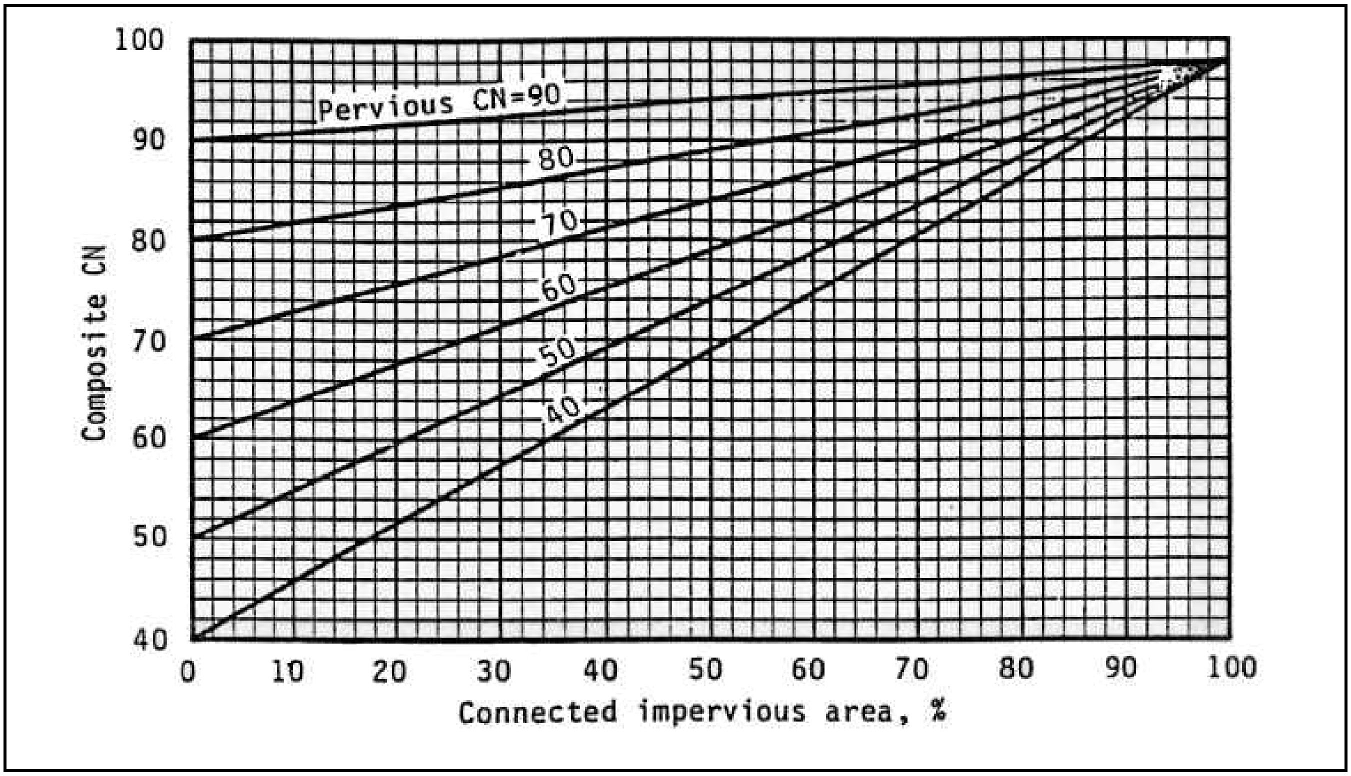


Figure 6.3. Composite CN with connected impervious area (USDA-SCS, 1986).

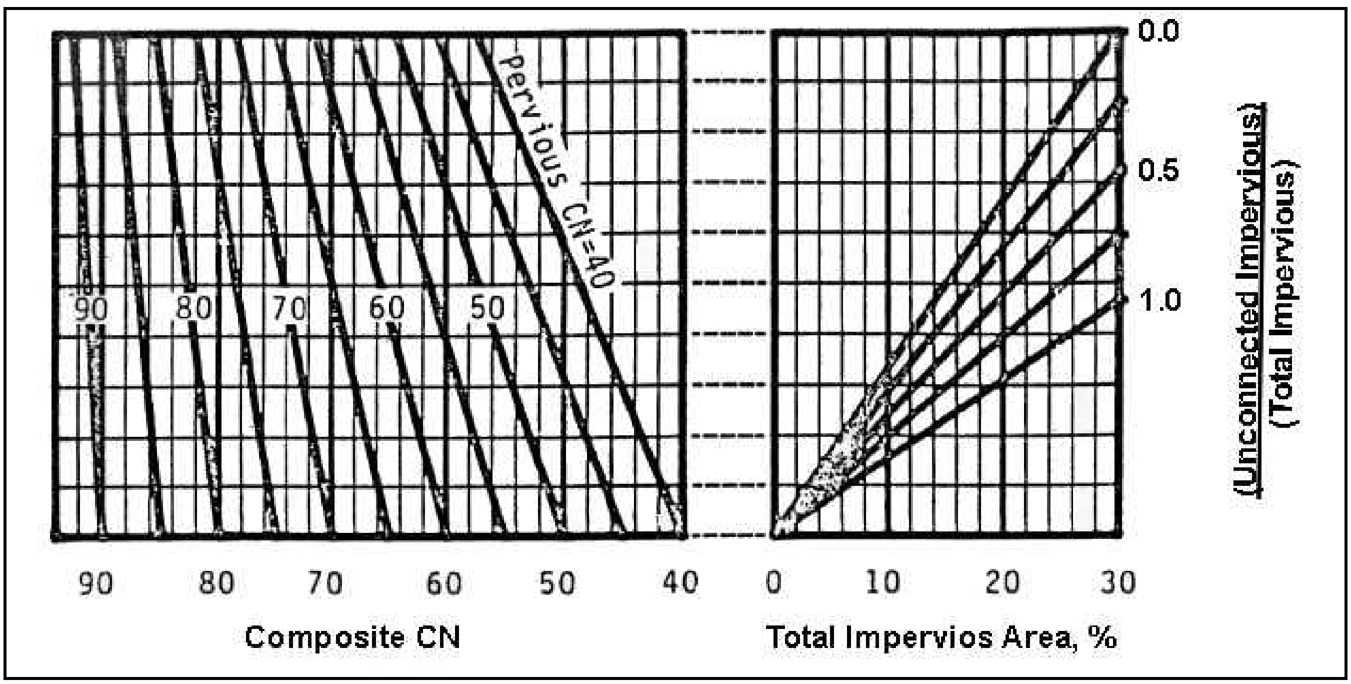


Figure 6.4. Composite CN with unconnected impervious areas and total impervious area less than 30% (USDA-SCS, 1986).

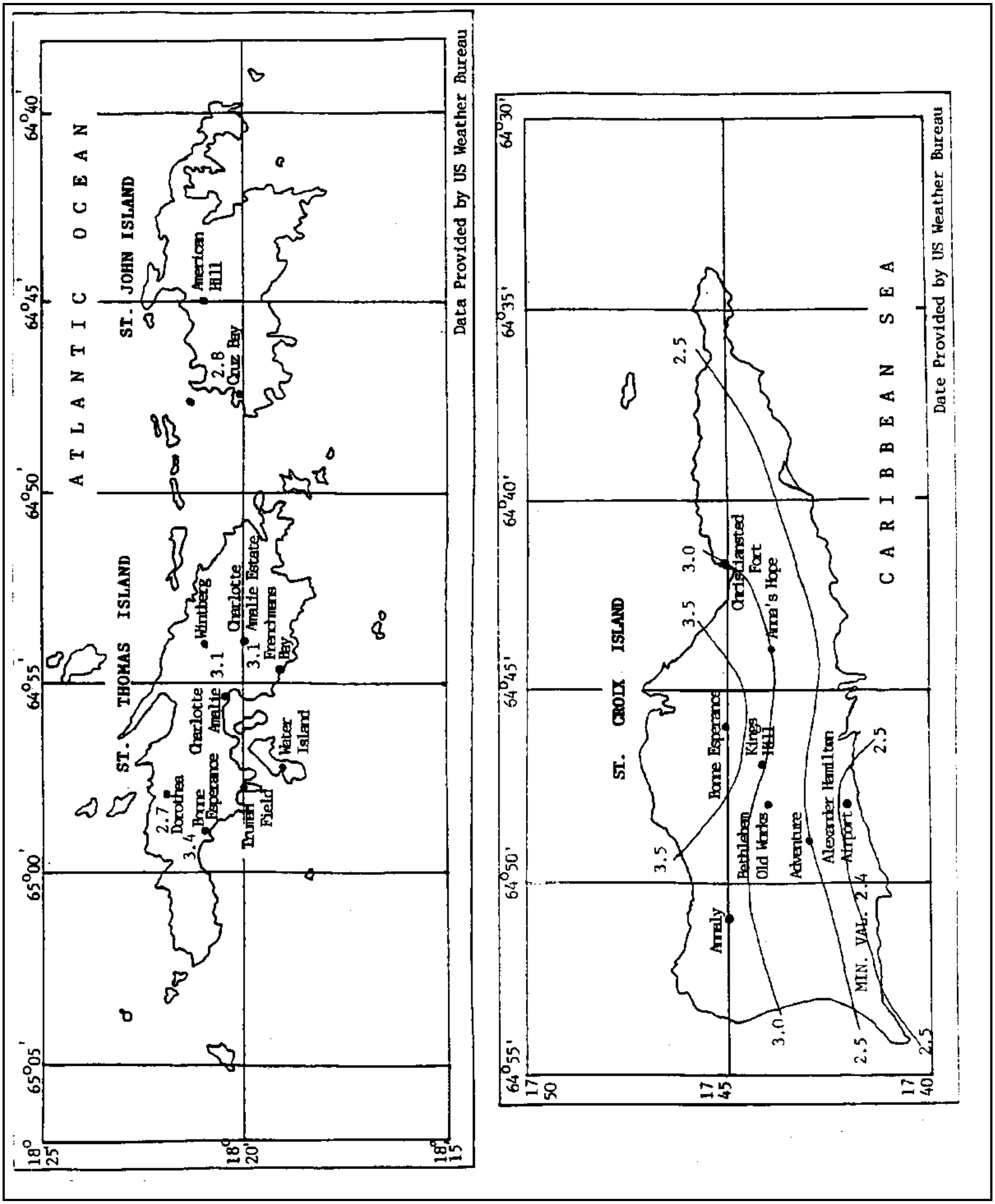


Figure 6.5. 1-year, 24-hour rainfall for the U.S. Virgin Islands (in.) (USDA-SCS, 1986).

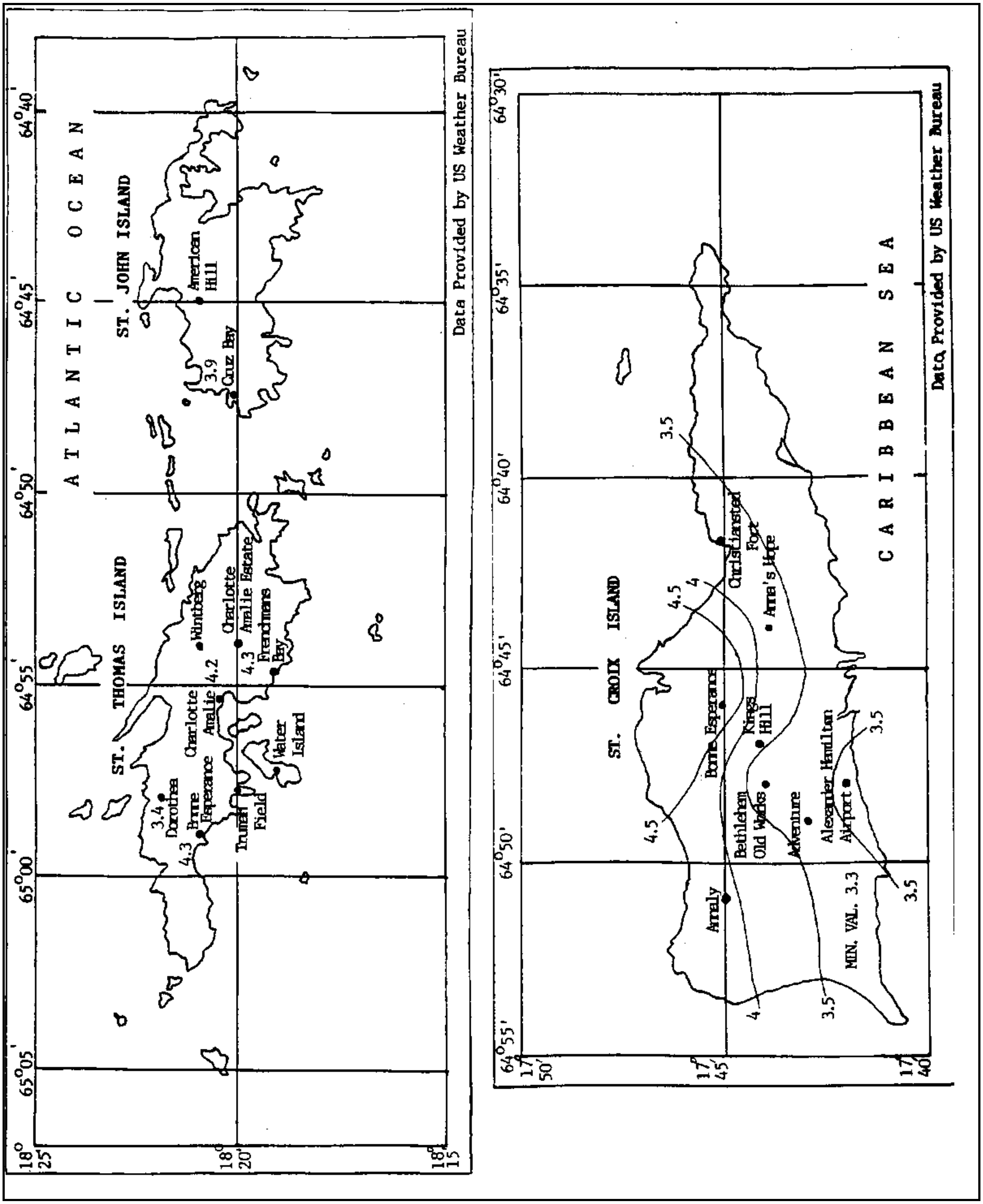


Figure 6.6. 2-year, 24-hour rainfall for the U.S. Virgin Islands (in.) (USDA-SCS, 1986).

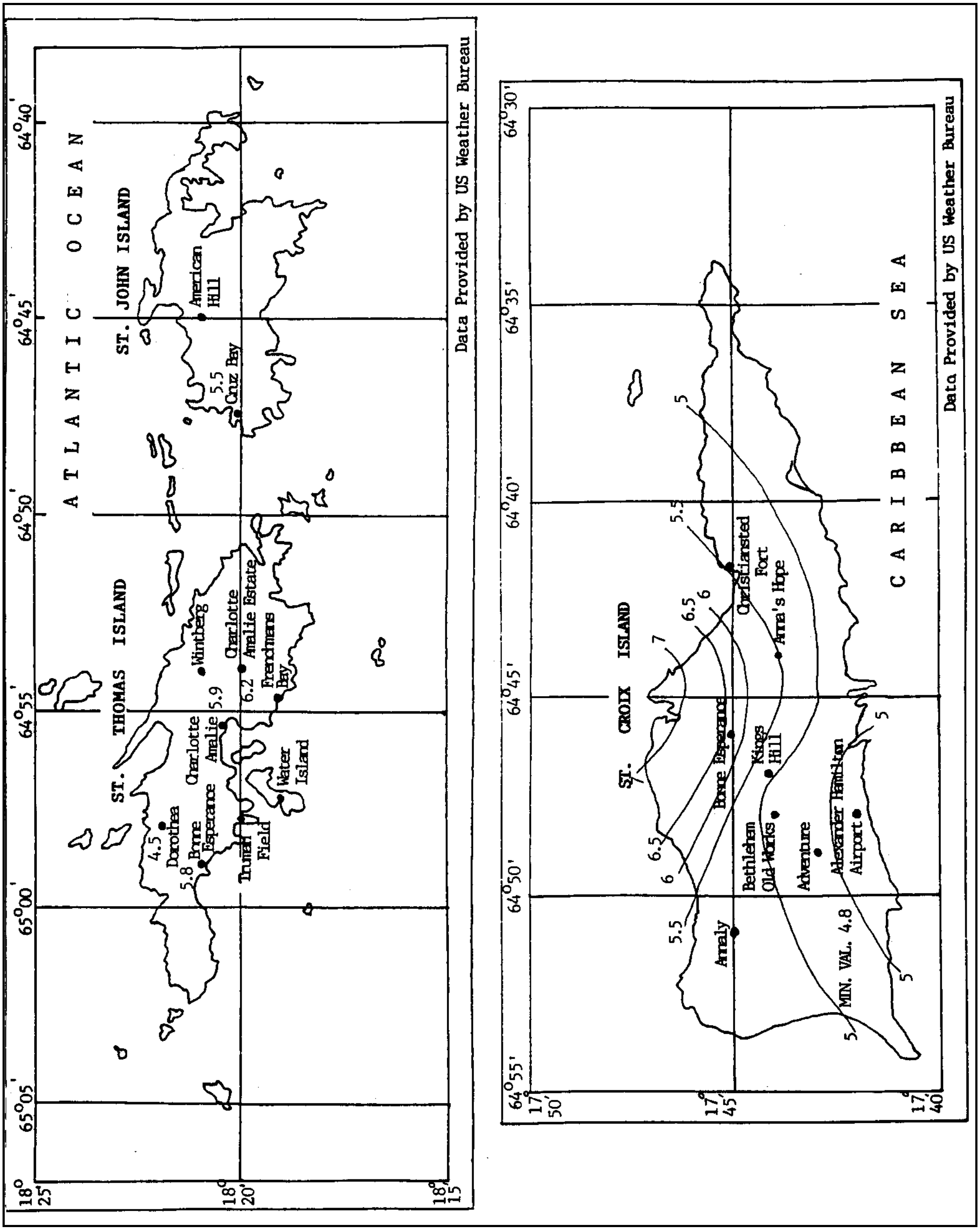


Figure 6.7. 5-year, 24-hour rainfall for the U.S. Virgin Islands (in.) (USDA-SCS, 1986).

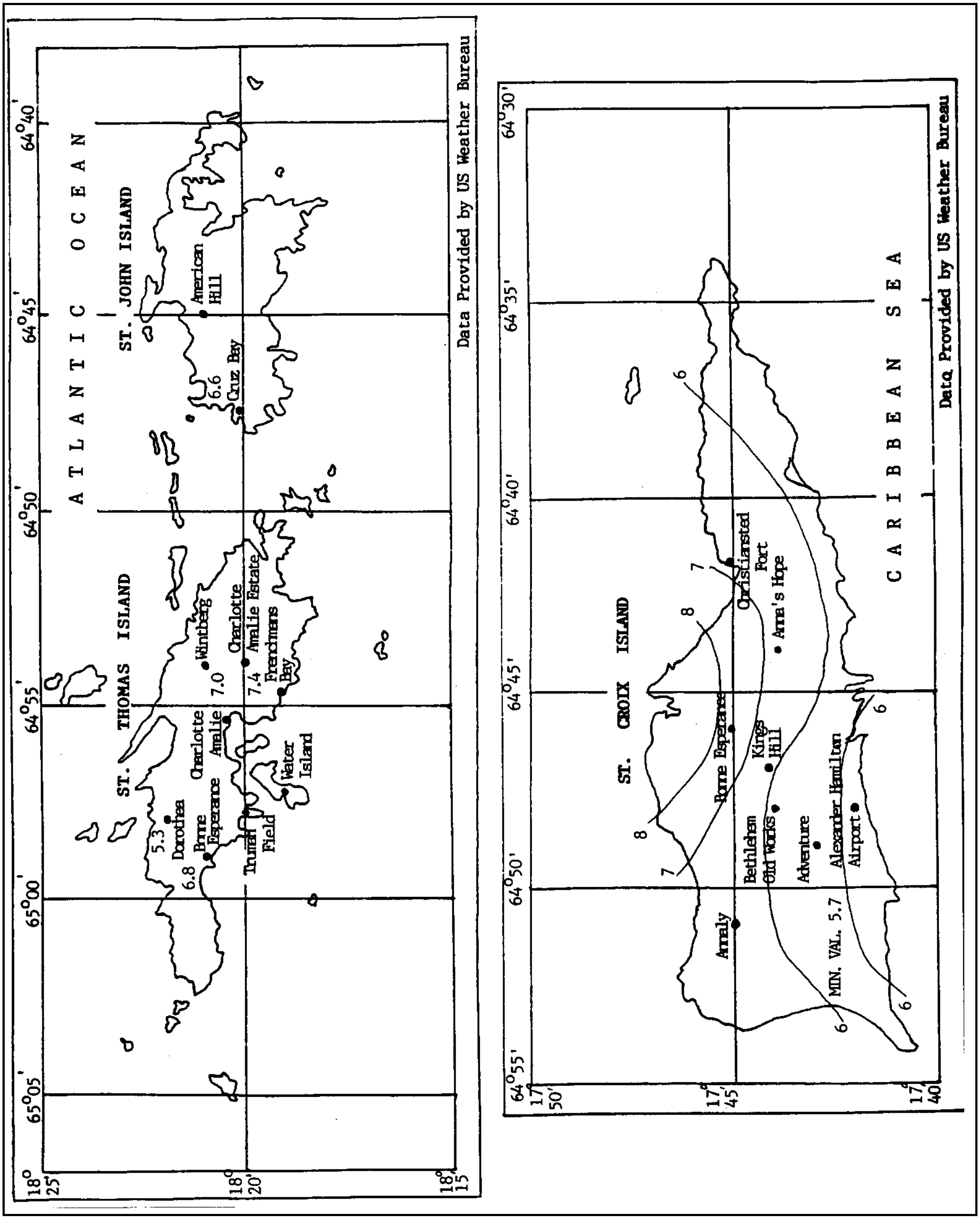


Figure 6.8. 10-year, 24-hour rainfall for the U.S. Virgin Islands (in.) (USDA-SCS, 1986).

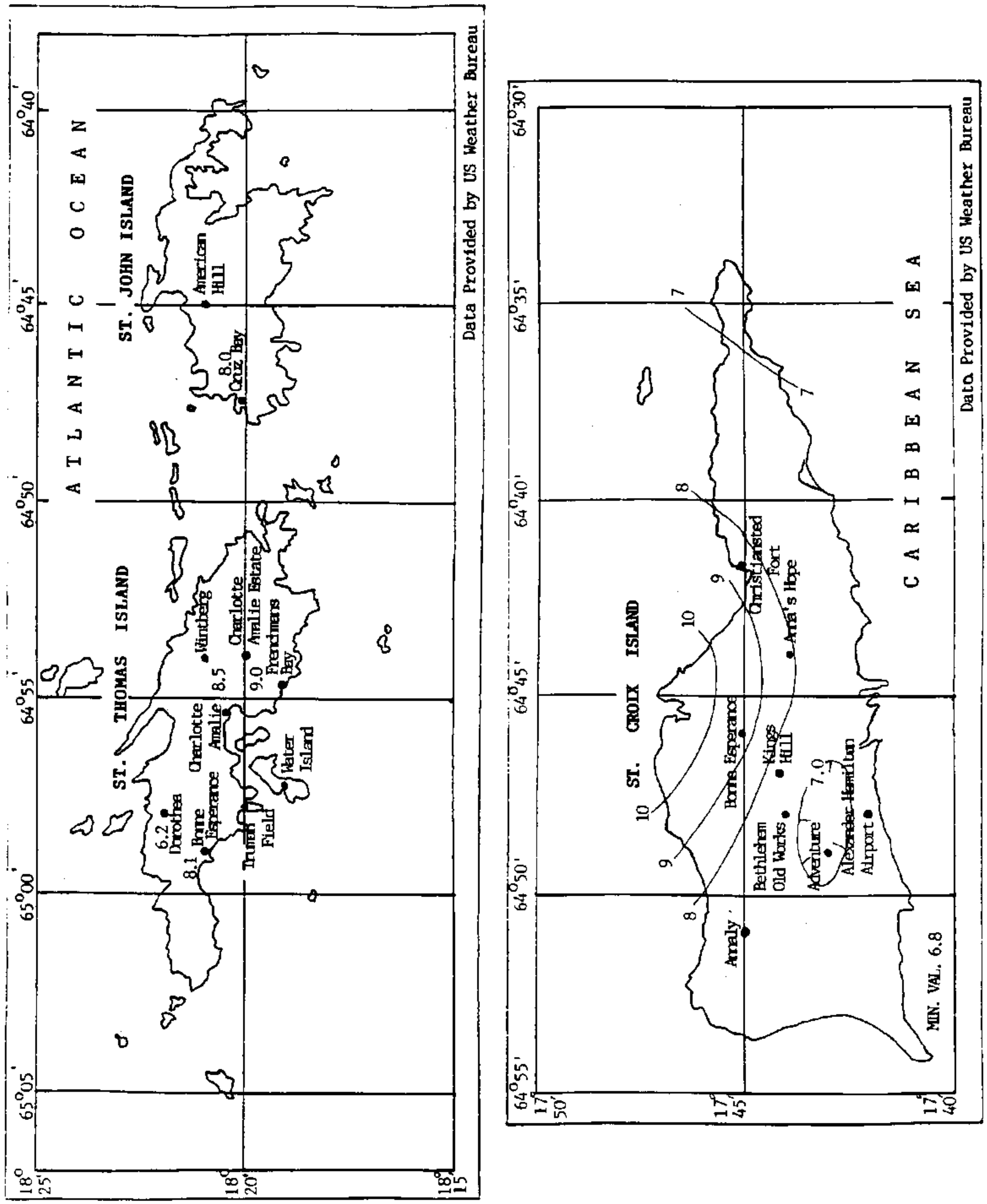


Figure 6.9. 25-year, 24-hour rainfall for the U.S. Virgin Islands (in.) (USDA-SCS, 1986).

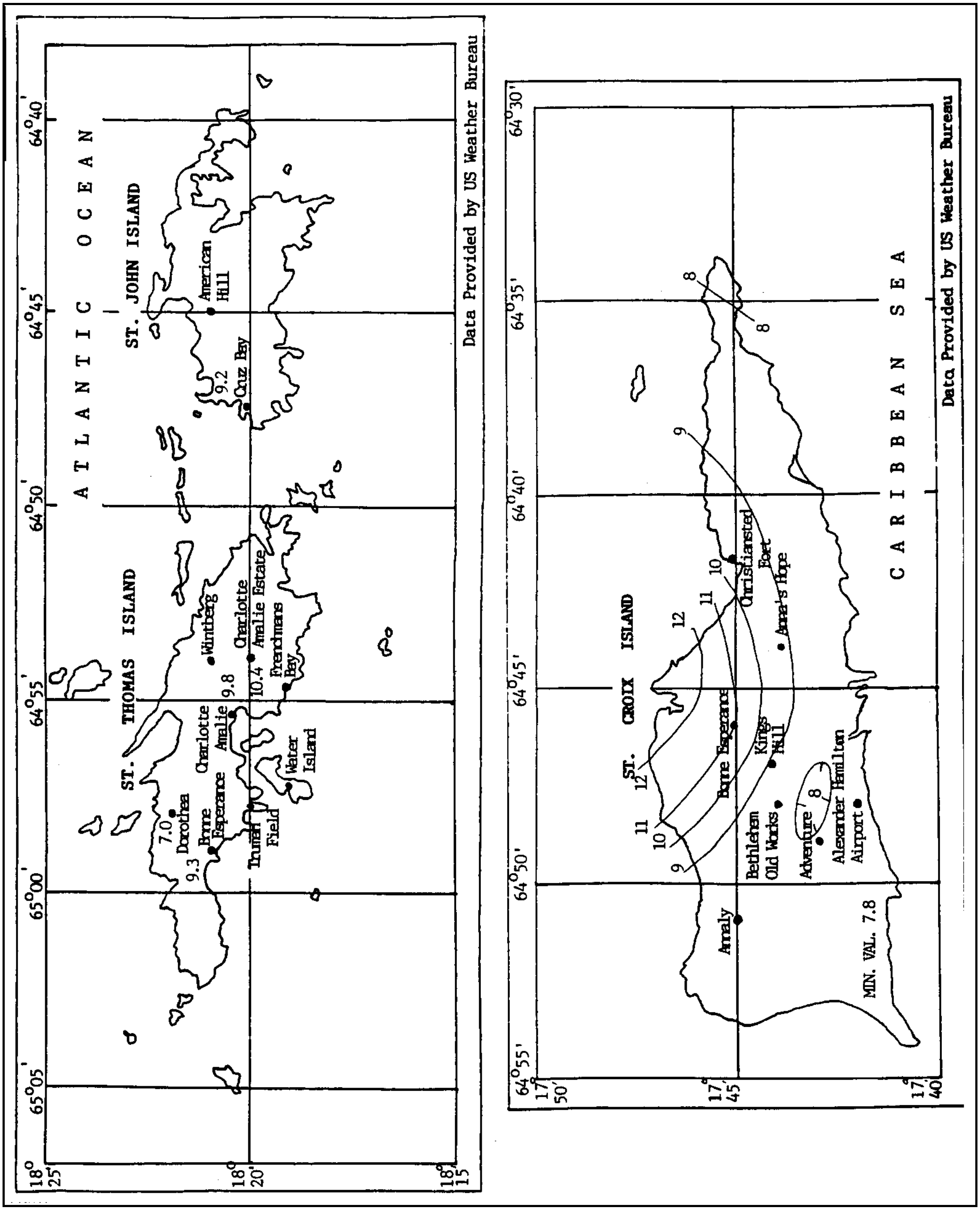


Figure 6.10. 50-year, 24-hour rainfall for the U.S. Virgin Islands (in.) (USDA-SCS, 1986).

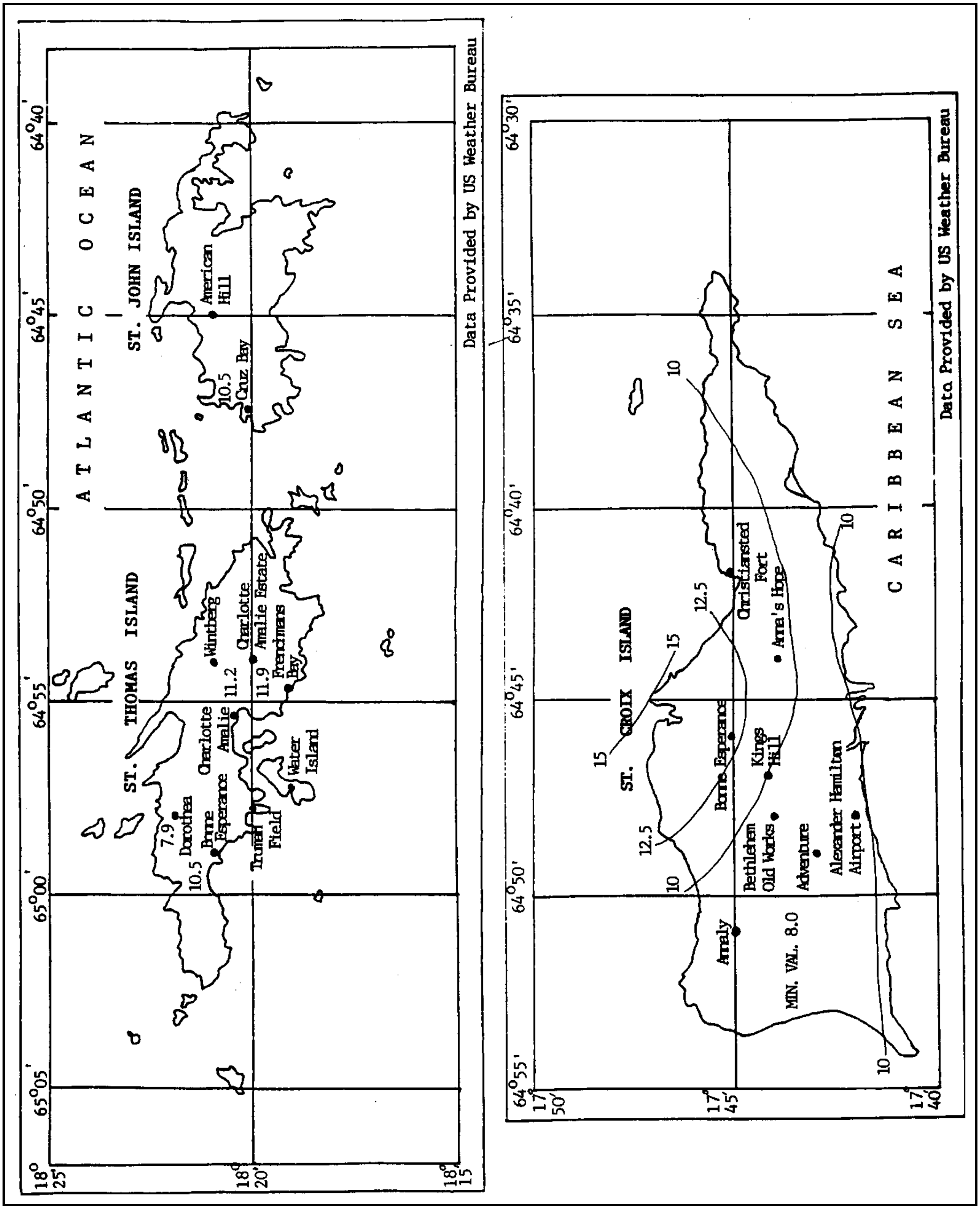


Figure 6.11. 100-year, 24-hour rainfall for the U.S. Virgin Islands (in.) (USDA-SCS, 1986).

Table 6.5. Roughness coefficients (Manning's n) for sheet flow (USDA-SCS, 1986).

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover < 20%	0.06
Residue cover $ 20%	0.17
Grass:	
Short grass	0.15
Dense grasses[2]	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

1 *THE N VALUES ARE A COMPOSITE OF INFORMATION COMPILED BY ENGMAN (1986).*
2 *INCLUDES SPECIES SUCH AS WEEPING LOVEGRASS, BLUEGRASS, BUFFALO GRASS, BLUE GRAMA GRASS, AND NATIVE GRA*
3 *WHEN SELECTING N, CONSIDER COVER TO A HEIGHT OF ABOUT 0.1 FT. THIS IS THE ONLY PART OF THE PLANT COVE*

Table 6.4. I_a values for runoff curve numbers (USDA-SCS, 1986).

Curve number	I_a	Curve number	I_a
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

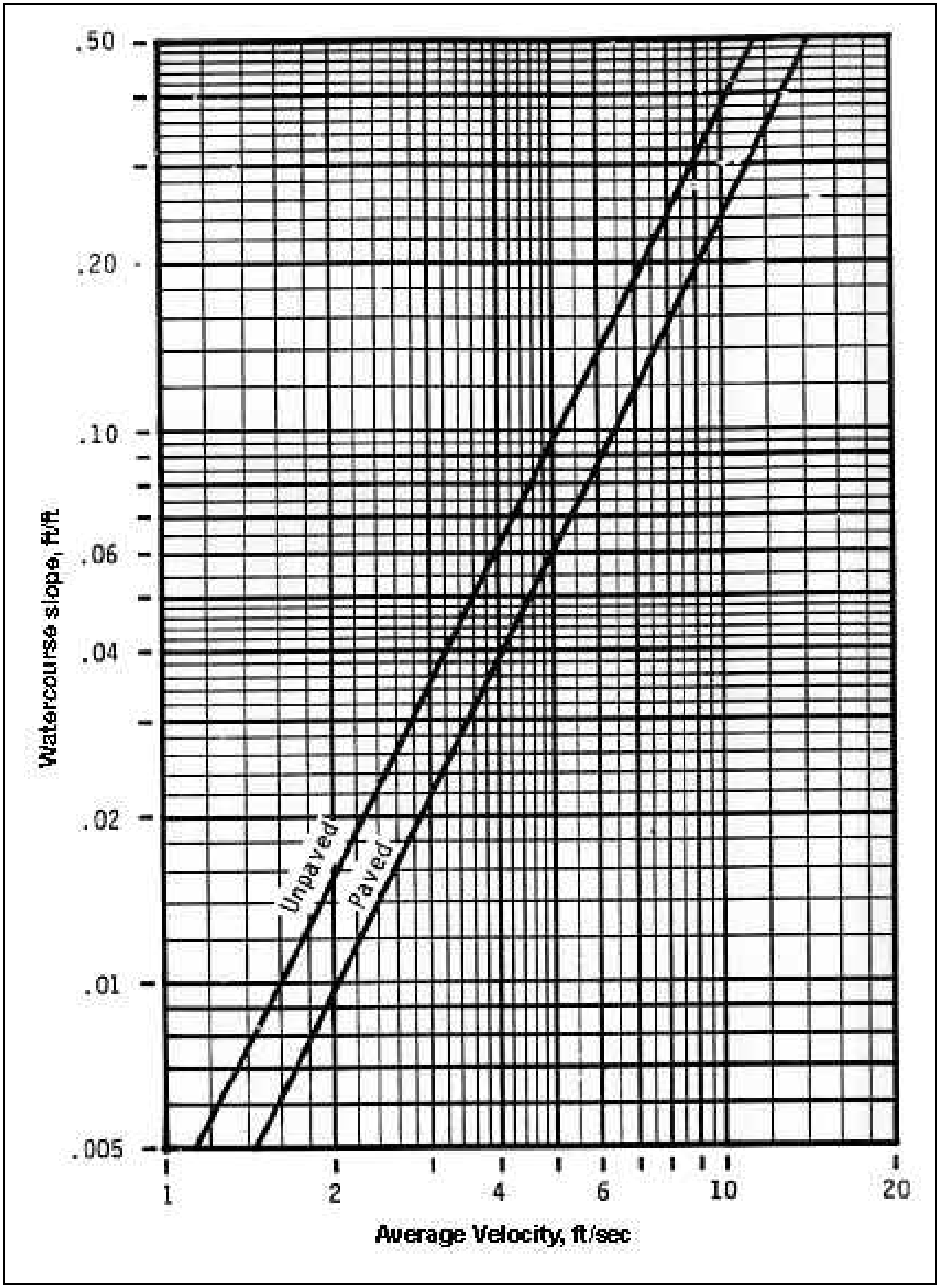


Figure 6.12. Average velocities for estimating travel time for shallow concentrated flow (USDA-SCS, 1986).

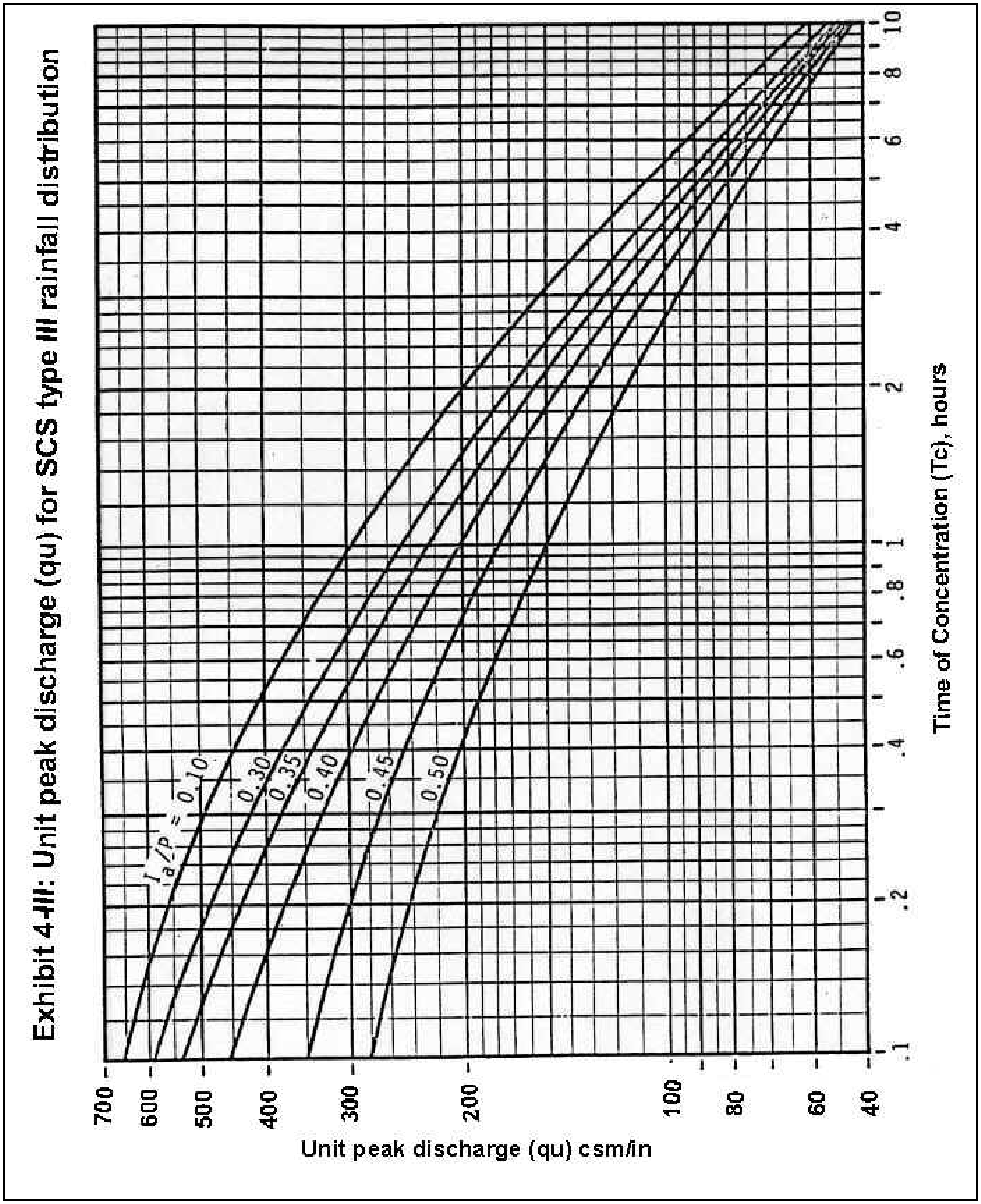


Figure 6.13. Unit peak discharge (q_u) for SCS Type-III rainfall distribution (the type that occurs in the U.S. Virgin Islands) (USDA-SCS, 1986).

Table 6.6. Adjustment factor (F_p) for pond and swamp areas that are spread throughout the watershed (USDA-SCS, 1986).

Percentage of pond and swamp areas	F_p
0.0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

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Worksheet 2: Runoff curve number and runoff

Project ______________________ By _____ Date ________

Location ______________________ Checked _____ Date ________

Circle One: Present Developed ______________________

1. Runoff Curve Number (CN)

Soil Name and Hydrologic Group (Appendix A)	Cover Description (cover type, treatment and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 6-2	CN 1/ Fig. 6-3	CN 1/ Fig. 6-4	Area ☒ acres ☐ mi2 ☐ %	Product of CN x Area
				Totals =	18	1260

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1260}{18} =$ 70 ; Use CN = 70

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	6.2		
Runoff, Q	in	2.95		

(Use P and CN with Table 6-1, Figure 6-1 or Equations 6-3 and 6-4)

Worksheet 3: Time of Concentration (Tc) or Travel Time (Tt)

Project: ______________________________ **By:** ______ **Date** ________

Location: ______________________________ **Checked** ______ **Date** ________

Circle one: Present Developed ______________________________

Circle one: Tc Tt through subarea ______________________________

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to Tc only)	Units	Segment ID			
1. Surface description (Table 6-4)					
2. Manning's roughness coefficient, n (Table 6-4) ..					
3. Flow length, L, (total $L \leq 300$ ft)	ft				
4. Two-year 24-hour rainfall, P_2	in				
5. Land slope, s	ft/ft				
6. $Tt = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute Tt	hr		+		=

Shallow Concentrated Flow	Units	Segment ID			
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (Figure 6-12)	ft/s				
11. $Tt = \frac{L}{3600\,V}$ Compute Tt	hr		+		=

Channel Flow	Units	Segment ID			
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft				
16. Manning's roughness coefficient, n					
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $Tt = \frac{L}{3600\,V}$ Compute Tt	hr		+		=

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19) .... hr ________

Worksheet 4: Graphical Peak Discharge Method

Project ______________________ By _____ Date _______

Location _____________________ Checked _____ Date _______

Circle one: (Present) Developed ______________________

1. Data:

Drainage Area .... A_m = ________ mi^2 (acres/640)

Runoff curve number .... CN = ________ (from Worksheet 2)

Time of concentration .. Tc = ________ hr (from Worksheet 3)

Rainfall distribution type = ________ (I, IA, II, III)

Pond and swamp areas spread throughout watershed ...... = ________ percent of A_m (____ acres or mi^2 covere

2. Frequency	yr			
3. Rainfall, P (24-hour)	in			
4. Initial abstraction, I_a (Use CN with table 6-5)	in			
5. Compute I_a/P				
6. Unit peak discharge, q_u (Use Tc and I_a/P with Figure 6-13)	csm/in			
7. Runoff, Q (From Worksheet 2)	in			
8. Pond and swamp adjustmetn factor, F_p (Use percent pond and swamp area with Table 6-6. Factor is 1.0 for zero percent pond and swamp area.)				
9. Peak discharge, q_p (Where $q_p = q_u A_m Q F_p$)	cfm			

LIST OF APPENDICES

APPENDIX A: GLOSSARY

aesthetics: an approach dealing with the beautiful and with judgements of beauty.

anoxic: a condition where there is a lack of oxygen, eg., anoxic water is water lacking enough oxygen for organisms to live.

anti-vortex trash rack: a type of trash screen that does not cause whirlpools to form in a pond or outlet.

aquatic ecosystems: an underwater community of plants and animals and their surroundings.

arid: excessively dry.

aspect: the direction a slope faces--a physiographic feature of steep slopes that influences plant growth and adaptation.

anti-vortex device: a device, usually a vertical or horizontal plane, carefully designed and placed at the entrance of a pipe to prevent the formation of a whirlpool in the water at the pipe entrance.

backfill: soil used to fill a trench or an excavation.

baseflow: The portion of water flow in a stream or gut that is due to groundwater seepage into the channel.

bearing capacity: the amount of force or pressure that a structure can withstand.

benthic community or organisms: organisms or a community of organisms that live on or in the bottom of a body of water.

berm: an earthen mound used to direct the flow of runoff around or through a structure; a shelf that breaks the continuity of a slope.

biochemical oxygen demand (BOD): the amount of oxygen used by microorganisms in water that is rich in organic matter (such as water polluted with sewage).

biodegradable: the ability to break down or decompose under natural conditions and processes.

buffer strip or zone: strips of grass or other erosion-resistant vegetation between a waterbody and an area of more intensive land use; a strip of vegetated land that separates a disturbed site from its surroundings.

channel: a natural stream that conveys water; a ditch or channel excavated for the flow of water.

chronic: long-term or recurring effects resulting from exposure to pollution or pollutants.

chute: a high velocity, open channel that conveys water to a lower level without erosion.

cluster development: the concentration of development or construction activities on a limited portion of a site, leaving the remaining portion undisturbed.

concentrated stormwater runoff: runoff collected from a large area that is diverted into a small space such as a drainage channel.

conduit: any channel or pipe for transporting the flow of water.

contamination: a state of being polluted or impure, used here to indicate chemical, sediment or bacteriological impurities in water.

contour: an imaginary line on the land connecting points of the same elevation; a line drawn on a map to show the location of points of the same elevation; a series of such contours serving to delineate the topography of the land.

contributing watershed: the area contributing stormwater runoff to a treatment practice such as a detention basin or infiltration trench.

conveyance: any natural or manmade channel or pipe in which concentrated water flows.

culvert: a covered channel or a large-diameter pipe that directs water flow below the ground level.

debris: broken remains of rocks, plants, and other objects that form trash or remains and are transportable by guts or floods.

denuded: land stripped of vegetation or land that has had vegetation worn down due to impacts from the elements or humans.

deposition: the accumulation of material dropped out of the transporting agent (water or wind) due to the slowing of the travel of that agent.

design storm: a rainfall event of specified size and return frequency (e.g., a storm that occurs only once every two years) that is used to calculate the runoff volume and peak discharge rate to a control practice.

detention: the temporary impoundment of runoff to minimize runoff speed and volume generated in a given time period and to settle and retain suspended solids and associated pollutants.

development: a tract of land with houses or a community built on it, or the process of building on a tract of land.

dike: an earthen ridge or embankment constructed to channel or confine stormwater.

discharge: a release or flow of stormwater or other substance from a conveyance or storage container (expressed as cubic feet per second, million gallons per day, gallons per minute, or cubic meters per second).

disturbed area: an area where the natural vegetative and soil cover has been removed or alter and is, therefore, susceptible to erosion.

diversion: a channel, with or without a supporting ridge on the lower side, constructed across or at the bottom of a slope to divert water runoff.

dripline: the outer limit of a trees roots or branches.

embankment: a bank (of earth or riprap) used to keep back water.

emergent plant: an aquatic plant that is rooted in the sediment of a wetland but whose leaves are at or above the water surface. such wetland plants provide habitat for wildlife and waterfowl in addition to removing stormwater pollutants.

erodibility: the susceptibility of a given soil to the erosive forces of wind and water.

erosion: the wearing away of the land surface by wind or water; erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or commercial development, or road building.

erosion rate: the amount of soil eroded from a parcel per unit area (measured as tons/acre or kilograms/hectare).

eutrophication: the process by which a body of water becomes rich in dissolved nutrients (specifically nitrogen and phosphorus) promoting the overgrowth of aquatic vegetation leading to a subsequent deficiency in dissolved oxygen.

excavation: the process of removing earth, stone, or other materials.

exotic plants: plant species not native to the Virgin Islands.

fertilizer: materials such as nitrogen and phosphorus that provide nutrients for plants.

filter fabric: textile of relatively small mesh or pre size that is used to (a) allow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment from passing through (impermeable).

filter strip: usually long, relatively narrow area of undisturbed or planted vegetation used to retard or collect sediment to protect water bodies and adjacent properties.

filtration: treatment of stormwater runoff with either vegetation or sand or gravel to filter (or strain) pollutants out of the water.

final stabilization: the point at which all soil disturbing activities at the site have been completed, and a uniform perennial vegetative cover with a density of 70% of the cover for unpaved areas and areas not covered by permanent structures has been established or equivalent permanent stabilization measures (such as retaining walls or gabions) have been used.

flood plain: nearly level land made up of sediment deposited by guts and subject to flooding unless artificially protected.

forb: an herb other than grass.

Gabion basket/mattress: a galvanized-wire basket filled with stone used for structural purposes. When fastened together, they are used as retaining walls and for slope protection.

geotextiles: fabric-like materials made of natural or synthetic fibers used as blankets or ground coverings to prevent surface erosion.

grade/gradient: (n) 1. the slope of a road, channel, or natural ground. 2. the finished surface of a roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction, such as paving or laying pipe. (v) 3. To finish the surface of a roadbed, top of embankment, or bottom of excavation.

grading: the cutting and/or filling of the land surface to a desired slope or elevation.

ground cover: plants that are low growing and provide a thick gowth that protects the soil as well as providing some beautification of the area occupied by the plants.

gully erosion: the eroding of a miniature valley (or gully) with steep sides by running water. A gully is deep enough that it wouldn't be eliminated by normal tillage practices.

gut: a natural drainage channel, perennial or intermittent, similar to a perennial or intermittent stream, that conveys stormwater over the land surface to the sea.

hazardous substance: 1. any material that poses a threat to human health and/or the environment. Hazardous substances can be toxic, corrosive, ignitable, explosive, or chemically reactive. 2. any substance required by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

head: pressure; the height of water above any plane of reference; the difference in elevation between two points in a stream, gut, drainage way, or groundwater aquifer.

herbaceous: a plant that remains succulent and does not develop woody tissue.

humus: the fraction of the soil organic matter remaining after the decomposition of plant and animal materials -- usually of a dark color.

hydraulic impacts: impacts or effects on the flow of water through a channel, drainage ditch, gut or other structure.

hydrocarbons: chemicals or material derived from petroleum-based products, such as oil, grease, cleaning agents, and other chemicals.

hydrology: the natural water movement and cycling process of a given area.

hydroseeder: a machine that mixes water and various combinations of seed, fertilizer and mulch in a tank to form a slurry that is sprayed under high pressure over the area to be seeded.

impervious: surfaces or land forms that are unable to absorb water, causing the water to run over the surface.

infiltration: 1. the penetration of water through the ground surface into sub-surface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls.

infiltration rate: a soil characteristic describing the maximum rate at which water can enter the soil under specific conditions.

infrastructure: the installations and framework necessary for communities to function properly, including power and water lines, sewage system, roads, and stormwater drainage system.

inlet: an entrance into a ditch, storm sewer, basin, or other structure or waterbody.

invertebrate: an animal or organism that does not have a spinal column.

jute: a plant fiber used to make rope, mulch, netting, or matting.

landscape: the image or picture that the sum of the landforms, vegetation, water, and structures in a given area produces.

load: the forces that a structure is subjected to by a weight or mass (of earth or water) or to wind pressure on the vertical surfaces.

microclimate: the essentially uniform local climate of a small site or habitat (such as a rainforest, wetland, etc.).

microorganisms: an organism or animal that is of minute or microscopic size.

mulch: a natural or artificial layer of plant residue or other materials covering the land surface to conserve moisture, hold soils in place, aid in establishing plant cover, and minimize temperature fluctuations.

nonpoint source pollution: pollution that results from land runoff, drainage or seepage during and following a rainfall event. This type of pollution generally does not come from one particular source, or point (such as a pipe) but results from the action of rainfall running over and through the land picking up pollutants and carrying them to receiving waters.

nutrients: a substance that nourishes or promotes growth of a plant or animal (typical nutrients that can become pollutants are nitrogen and phosphorus).

oil and grease traps: devices that collect oil and grease, removing them from stormwater.

orifice: an opening in a pipe or structure through which water and associated substances passes.

organic pollutants: substances that contain carbon that can cause pollution problems in receiving waters.

outfall: the mouth of a channel, drain, sewer or other structure; the point, location, or structure where stormwater discharges from a pipe ditch, or the conveyance to a receiving water.

outlet: the point where stormwater runoff can be released into a gut, drainage channel, or other artificial drain of adequate capacity without causing scour or erosion.

pathogen: a harmful organism, such as a bacteria or virus.

peak runoff discharge: the maximum volume of water flowing out of a channel, structure or gut into any other receiving water or area.

permeability: the ability of a soil or other material (such as concrete or gravel) to transmit water through it.

pervious: permeable.

photodegradable: a product or object that can be broken down by the energy of sunlight.

plunge pool: a basin used to slow flowing water either at the inlet to or outlet from a control practice; the pool may be protected from erosion by various lining materials.

point source pollution: pollution that comes from a particular source or point (as in a stormwater drainage pipe, a sewage outfall pipe, or an industrial outfall pipe).

pollutant export: the transport of pollutants from one site to another, usually by stormwater runoff or groundwater flow.

porosity: the amount of space in a soil profile not occupied by soil particles or other material. Or the percentage of pore space in a material (soil or filter fabric) that can pass through air or water.

rainfall intensity: the amount of rainfall that falls in a given time period (as in inches per hour or centimeters per hour) that measure the amount of force or energy of the rain.

receiving waters: the waterbodies that stormwater runoff flows into, such as guts, salt ponds, bays, lagoons and other coastal areas.

retention: the holding of runoff in a basin without release except by evaporation, infiltration or emergency bypass.

rhizome: an underground, horizontal stem of a plant, by which that plant spreads across the land surface.

ripable rock: rock that is easily broken.

riser: a vertical water pipe.

runoff: the part of rainfall that runs off the land into guts or other surface waters. it can carry pollutants from the air and land into the receiving waters.

runoff velocity: the speed at which stormwater runoff flows (measured as cubic feet per second or cubic meters per second).

safety factor: the ratio of the ultimate load that a structure can withstand to the strength required to withstand a specific load. A safety factor is used to over-design a structure so that it will not fail even if loads somewhat exceed its design capacity.

scour: the clearing and digging action of flowing water, especially the downward erosion caused by running water in sweeping away mud and silt from the channel bed and outside bank of a curved channel.

sedimentation: the process by which sediment particles carried in stormwater runoff are deposited onto the land surface or into waterbodies and settling to the bottom of those waterbodies.

seep: a spot where water oozes slowly to the ground surface to form a wet area, pool or stream.

serration: notches dug into a slope or grade to lessen erosion. The profile of the grade should resemble the teeth of a saw.

setback: a strip of vegetated land that separates a disturbed site from its surroundings. The amount of space that must be left undisturbed between a construction activity and an adjacent feature (such as a roadway, gut, wetland, coastline, cistern, etc.).

shallow slope failure: landslide or slippage. the downward sliding or falling of either a dry or wet mass of earth, rock or a mixture of the two.

shrink-swell potential: susceptibility to volume change due to loss or gain in moisture content (usually refers to clay soils).

site fingerprinting: placing a development away from environmentally-sensitive areas and limiting ground disturbance to those areas where structures or roads will exist at the completion of construction.

slippage: landslide or shallow slope failure. the downward sliding or falling of either a dry or wet mass of earth, rock or a mixture of the two.

sloughing: the moving of unstabilized soil layers down a slope due to excess water in the soils.

soil: the consolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of plants.

soil texture: the limits of the amounts of sand, silt and clay contained in a soil.

soil bioengineering: the combination of mechanical, biological and ecological concepts to stop and/or prevent landslides and erosion.

soluble pollutants: pollutants that dissolve in water or other liquids.

spillway: a passage for surplus water to run over or around an obstruction.

storm drain: a slotted opening leading to an underground pipe or an open ditch for carrying stormwater runoff.

stormwater runoff: the amount of rainwater not absorbed into the ground that runs over the land surface to receiving waters.

subsidence: a lowering of the land elevation caused by solution and collapse of underlying soluble deposits, settling of underlying soil materials, reduction of fluid pressures in a groundwater aquifer, or decomposition of organic soils.

subsoil: the bed or layer of earth lying below the surface soil.

sump: a pit or tank that catches liquid runoff for drainage or disposal.

surface water: all water naturally open to the atmosphere (streams, guts, ponds, estuaries, bays, etc.).

suspended sediment: soil or sediment particles suspended in stormwater runoff or in the waters of a gut, pond, estuary, bay or other waterbody.

swale: a grassed or otherwise stabilized ditch designed to carry stormwater runoff away from a site.

tarp: a sheet of waterproof canvas or other material used to cover and protect materials, equipment or vehicles.

terrestrial: living on or in or growing from land. of or relating to land.

toe (of slope): where the slope stops or levels out; the bottom of a slope.

topography: the physical features of a surface area including its relief (or slope), relative elevations, and the position of natural and manmade features.

trash rack: a grill, grate or other device at the intake of a channel, pipe, drain or spillway that prevents oversize debris from entering the structure.

turbidity: the cloudiness of water used as a measure of the amount of particles (suspended sediment and other particles) in that waterbody.

urbanization: the conversion of rural areas or open spaces to suburban, commercial, industrial or urban land uses.

visual resource: the appearance of a landscape.

visual resource quality: how appealing a given landscape is to an observer.

waterbody: any body of water on the surface of the earth: gut, stream, pond, bay, lagoon, ocean, etc.

watershed: the area of land that drains water, sediment, and dissolved materials to a common outlet along the coastline (bay, lagoon, salt pond, or other coastal area).

watershed management plan: a comprehensive approach or plan to address the needs of a watershed, including land use; stormwater runoff, erosion, and sediment control practices; pollutant reduction strategies; and pollution prevention techniques.

wetland: an area or parcel of land that possesses three essential characteristics: (1) hydrophytic vegetation--plant life that grows in water, soil, or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content; (2) hydric soils--soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper layer; and (3) wetland hydrology--permanent or periodic inundation, or soil saturation to the surface, at least seasonally. The presence of water for a week or more during the growing season. examples include: swamps, bogs, fens, marshes, mangrove lagoons, and estuaries.

xeriscaping: a landscaping method that maximizes water conservation by using drought-tolerant native plant species.

APPENDIX B: EROSION AND SEDIMENT CONTROL PRACTICE SPECIFICATIONS

Preservation & Protection of Natural Vegetation

Planning

1. Gather property boundary, topography, vegetation and soil information. Identify potentially high erosion areas, areas with tree wind-throw potential, etc. Sketch a vegetative cover type map on a copy of a topographic map that shows other natural and manmade features. Identify on map vegetation desirable for preservation because of value for screening, shade, erosion control, endangered species, freedom from disease or rot, long life-span, space needed for future growth, and aesthetics.
2. Avoid construction on steep slopes (slopes > 40%), highly erodible soils, wetlands and guts. Delineate clearing limits on engineering plans.
3. Identify areas to be seeded and planted. Remaining vegetation shall blend with surroundings and/or provide special function such as a filter strip, buffer zone or screen.
4. Mark trees to be cut on the plans. Trees that may be a hazard to people, personal property or utilities shall be designated for removal.

Tree Protection Measures

1. Limit soil placement over existing tree and shrub roots to a maximum of 3 inches.
2. Caution heavy equipment operators to avoid damage to existing tree trunks and roots during land-leveling operations.
3. Tree and shrub roots can be protected when lowering grades by using retaining walls and terraces. Lowered grades shall start no closer than the dripline of the tree (Figure B.1). For narrow-canopied trees and shrubs, the stem diameter in inches is converted to feet and doubled, such that a 10-inch tree shall be protected to 20 feet.
4. Trenching across tree root systems shall be the same minimum distance as for lowered grades. Tunnels under root systems for underground utilities shall start 18 inches or deeper below the normal ground surface. Tree roots that must be cut shall be cut clean.
5. Construct sturdy fences, wood or steel barriers, or other devices around valuable vegetation to protect it from construction equipment. Barriers shall be placed far enough from trees so that tall equipment such as backhoes and dump trucks do not contact tree branches (Figure B.2).
6. Identify and clearly mark construction limits for equipment exclusion.
7. Avoid spilling oil, gas and other contaminants.
8. Prune obstructive and broken branches properly. The branch collar on all branches, living or dead, shall not be damaged. (Contact the UVI Cooperative Extension Service for more information on proper pruning.)
9. Do not nail boards to trees.

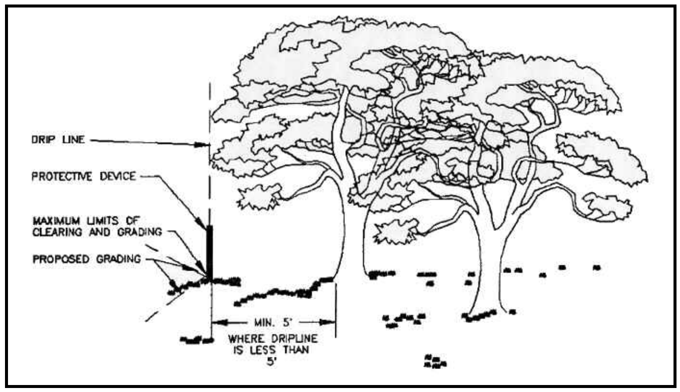


Figure B.1. Construction operations relative to the location of protected trees (*CH2M Hill, 1998, adapted from Virginia*).

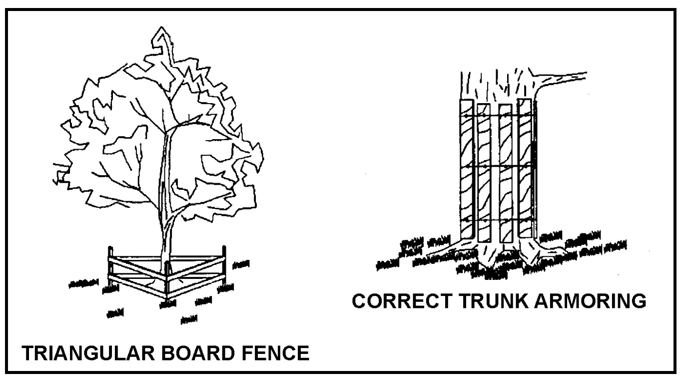


Figure B.2. Tree fencing and armoring (*CH2M Hill, 1998, adapted from Virginia*).

Filter Strips

Planning Considerations

Filter strips consist of close-growing grasses or other dense vegetation at the perimeter of cleared, disturbed or impervious areas to intercept runoff in sheet flow and remove sediment and other particulate contaminants (Figure B.3). In designing filter strips, the type and quantity of pollution must be determined. Slopes, soils, vegetation, construction timing, water needs, and operation and maintenance methods must be considered. A filter strip will not function properly if installed on slopes steeper than 10%. Outlet flow from the filter strip must be non-erosive.

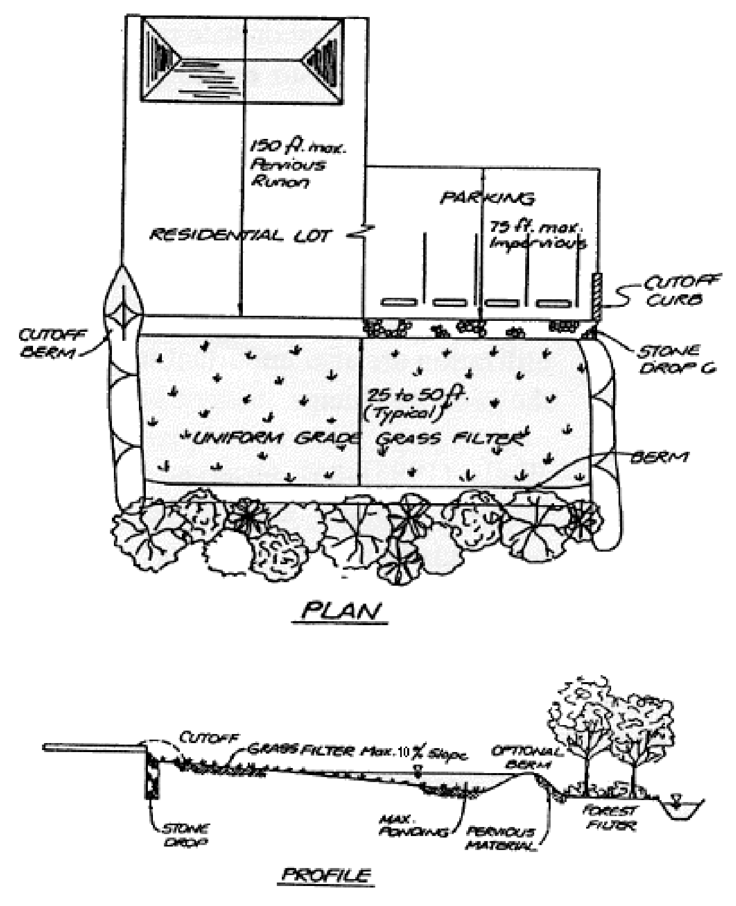


Figure B.3. Up to 75 feet of parking lot can be treated in a filter strip. A key design principle is to allow a drop from the parking lot to the grass filter to avoid sediment buildup at the edge (*Schueler, 1995*).

Design Criteria

The filter strip must have a level spreading device. A shallow stone trench can be used as a level spreader at the top of the strip to distribute water flow evenly. It will also serve to protect the strip from man-induced damage. The top edge of the filter strip should follow across the same elevational contour and should directly adjoin the contributing impervious area. Otherwise, runoff may travel along the top of the filter strip instead of through it. If a section of the top edge of the strip dips below the contour, it is likely that runoff will eventually form a channel toward the low spot. Berms can be placed at 50-100 foot intervals perpendicular to the top edge of the strip to prevent runoff from bypassing the strip.

Wooded filter and buffer strips are preferable to grassed strips. If an existing wooded belt cannot be preserved at the site, plant and manage a grassed strip to gradually become wooded. Densely vegetate the strip with a mix of erosion-resistant plant species that effectively hold the soil in place (see list of recommended species below). If grass is used, the stems of the grass species must be able to stand upright during any design flow. For flow depths of 0.1 ft. or less use n = 0.04. Where flow will be up to 0.5 ft. use n = 0.07.

For the Caribbean area, the following plants are suggested for grassed filter strips: Napier types (elephant, mott, merker, supermerker; *Pennisetum purpureum*); Pangola grass (*Digitaria decumbens*); Star grasses (*Cynodon nlemfuensis/plectostachyum*); Brunswick grass (*Paspalum nicorae*); and Uva grass (*Gynerium sagittatum*) (USDA-SCS Caribbean Area, 1992).

Construction Specifications

Construction should occur during the dry season, when soil moisture is low (Delaware DNREC, 1997). For grass filter strips, remove all trees, stumps, roots, rocks, brush, and similar materials that can interfere with filter strip installation. Vegetative materials removed can be chipped/shredded and used for mulch or composted. Grade the filter strip to a uniform, even and relatively shallow slope. Be careful to avoid compacting the soil, so that the maximum amount of water will infiltrate in the strip. On steeper slopes, erosion control materials such as erosion control mats or mulches should be used to stabilize the strip until vegetation can be established (see Chapter 3, ***Mulches, Mats & Geotextiles***).

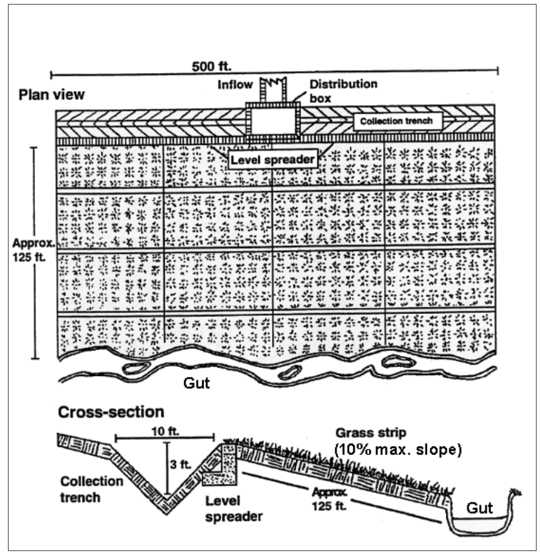


Figure B.4. Schematic design of a vegetated filter strip (*Delaware DNREC, 1997*).

Absolute minimum length for a filter strip is at least 20 feet, however, strip length usually ranges from 50-75 feet, plus an additional four feet per each one percent of slope at the site (particularly if it is a forested strip, Figure B.4). In any case, the strip should be at least as long as the contributing runoff area. The level spreader at the top of the strip (Figure B.4) should be at least 1 foot wide and 3 inches deep. Seed the strip according to seed manufacturer's recommendations. Seeding can be done either by hand-broadcasting or hydroseeding (see Chapter 3, ***Permanent Seeding and Planting***).

Maintenance

Corrective maintenance is needed around the edge of the strip to prevent concentrated flows from forming. Shorter strips need to be managed as lawns or meadows and mowed 2 - 3 times per year to suppress weeds and keep back bush. Spot repairs may be needed to maintain a dense vigorous vegetative growth. Accumulated sediments near the top of the strip will need to be manually removed over time to keep the original grade.

Inspect strips annually and examine for damage by foot or vehicle traffic, encroachment, gully erosion and evidence of concentrated flows through or around strip.

Land Grading

Design Criteria

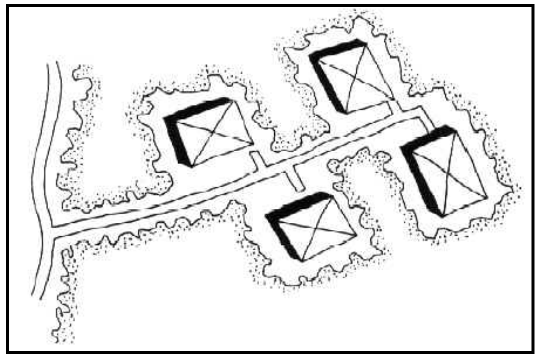


Figure B.5. Example of site fingerprinting - clearing only the area needed for construction (*CWP, 2001e*).

1. Base grading plan on adequate surveys and investigations. Plan must show location, slope, and elevation of surfaces to be graded, and drainage practices and diversion required. Location and magnitude of cuts and fills will be included where exact finished grades are required. Minimize clearing to only those areas required for construction (building, septic, driveway footprints, Figure B.5).
2. Side slopes of fills and cuts to be vegetated may be no steeper than 2:1 (horizontal:vertical). Design slopes will vary in accordance with the stability of the soil. Side slopes of cuts in rock or unerodible material may be at the angle of repose for the material.
3. The finished grade surface shall have a continuous slope, without grade reversals, to an outlet to facilitate drainage. The length and degree of designed slope shall be within limits suitable to the soil type without causing erosion or ponding.
4. Cut and fill slopes that are to be stabilized with grasses shall not be steeper than 2:1. Slopes exceeding 2:1 require special design and stabilization considerations. Reverse benches shall be provided whenever the height of any 2:1 slope exceeds 20 feet; for 3:1 slopes, it shall be increased to 30 feet and for 4:1 slopes to 40 feet. Use benches to divide the slope face as equally as possible and convey runoff to a stable outlet (Figure B.6).

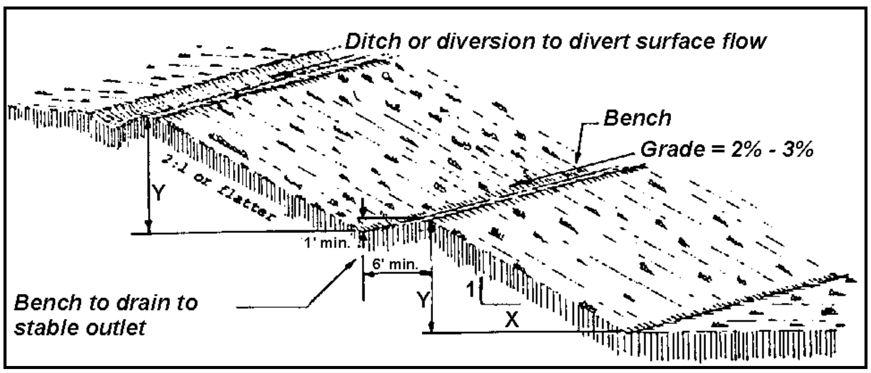


Figure B.6. Land grading — benched slope details *(Maryland Department of the Environment, 1994)*.

5. Benches shall be a minimum of 6 feet wide for easy maintenance. They shall have a reverse slope of 6:1 or flatter to the toe of the upper slope and be a minimum of one foot deep. The gradient of the bench to the outlet shall be between 2 and 3 percent. The flow length in a bench shall not exceed 800 feet. Figure B.6 details benched slopes and Figure B.7 depicts the cross section of a serrated cut slope.

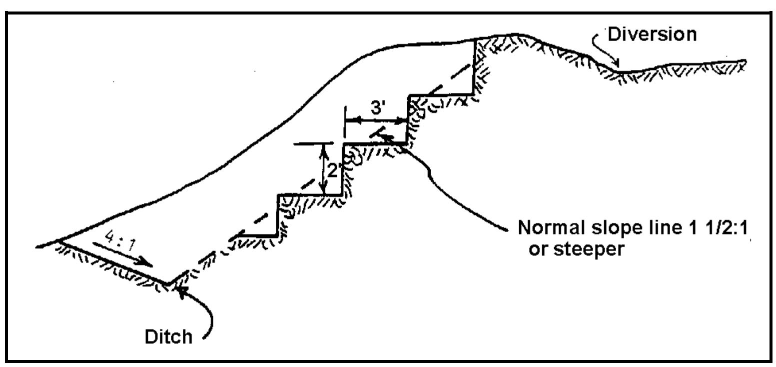


Figure B.7. Typical section of a serrated cut slope (*Empire State Chapter Soil & Water Conservation Society, 1991*).

Construction Specifications

1. Protect all graded or disturbed areas, including slopes, during clearing and construction in accordance with the approved sediment control plan and until they are permanently stabilized.
2. Construct, apply and maintain all sediment control practices and measures in accordance with the approved sediment control plan and the standards and specifications for Erosion and Sediment Control Practices as detailed in this Handbook.
3. Stockpile topsoil required for vegetation establishment in an amount necessary to complete finished grading of all exposed areas.
4. Clear, grub, and strip topsoil from all areas to be filled in order to remove trees, vegetation, roots or other objectionable material. Run the bulldozer up and down the slope to create grooves perpendicular to the slope (Figure B.8). This will minimize erosion by channeling water laterally across the slope instead of in grooves, or gullies, up and down the slope.
5. Compact all fills as required to reduce erosion, slippage, settlement, subsidence or other related problems. Fill intended to support buildings, structures, etc. shall be compacted in accordance with the V.I. building code.

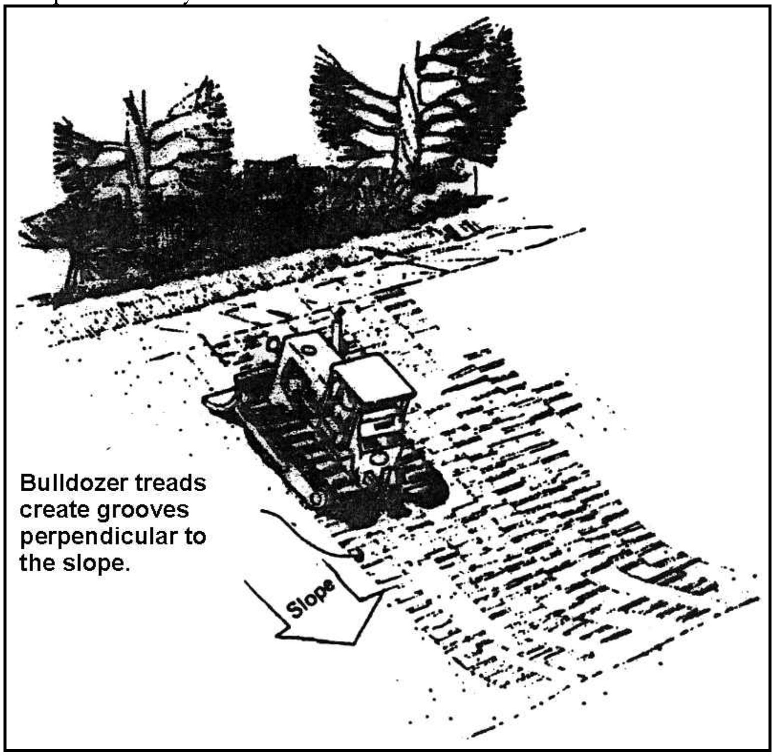


Figure B.8. Bulldozer treads create grooves perpendicular to the slope.

6. Fill material must be free of brush, rubbish, rocks, logs, stumps, building debris, and other objectionable materials that would interfere with or prevent construction of satisfactory fills.
7. Do not incorporate soft or highly compressible materials into fill slopes or structural fills.
8. Keep all benches free of sediment during all phases of development.
9. Provide adequate drainage for seeps or springs encountered during construction so that excess water does not cause slope failure.
10. Permanently stabilize all graded areas immediately following finished grading.
11. Show all stockpiles, borrow areas, and spoil areas on the plans and stabilize according to the provisions of this Handbook.

Surface Roughening

Design Criteria

Selection of the appropriate method of surface roughening depends on the type of slope. The methods used include tracking, grooving and stair-stepping (Figure B.9). Steepness, mowing requirements, and a cut or fill slope operation are all factors considered in determining roughening method.

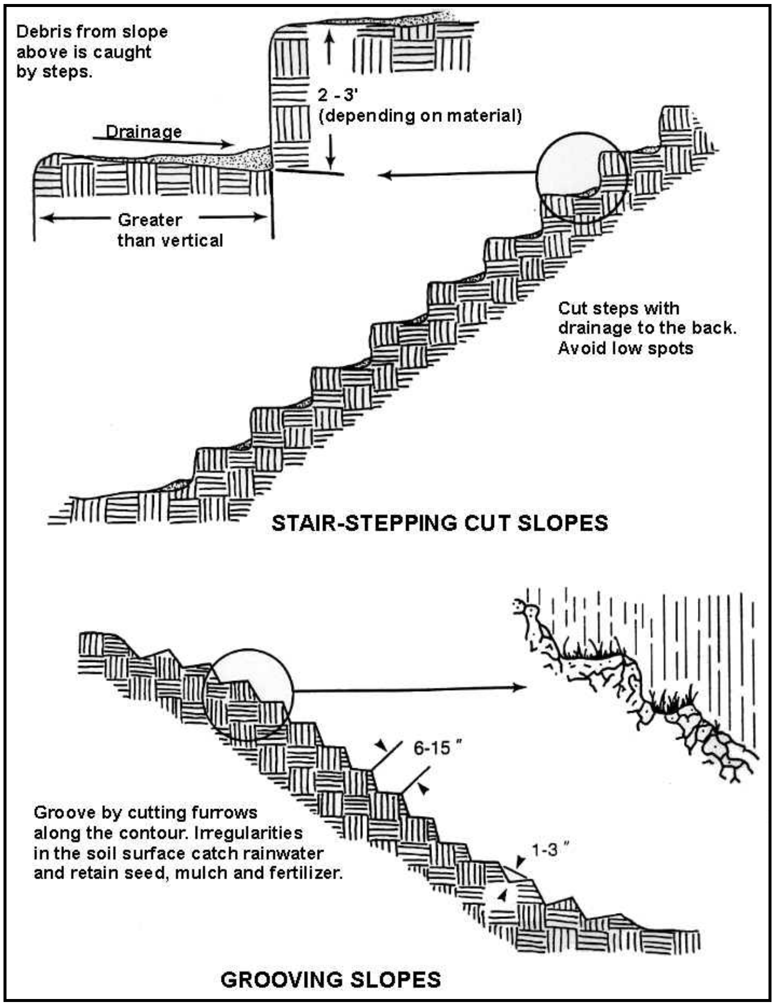


Figure B.9. Surface roughening details *(Empire State Chapter Soil & Water Conservation Society, 1991*).

Construction Specifications

Cut slope, no mowing

1. Stair-step grade or groove cut slopes with a gradient steeper than 3:1.
2. Use stair-step grading on any erodible material soft enough to be ripped with a bulldozer. Slopes of soft rock with some soil are particularly suited to stair-step grading.
3. Make the vertical cut distance less than the horizontal distance, and slightly slope the horizontal position of the step to the vertical wall.
4. Do not make vertical cuts more than 2 feet in soft materials or 3 feet in rocky materials.

Grooving uses machinery to make a series of ridges and depressions that run across the slope on the contour. Grooving can be done with disks, tillers, spring harrows, or the teeth of a front end loader bucket. Do not make the grooves less than 3 inches deep or more than 15 inches apart.

Fill slope, no mowing

1. Place fill to create slopes with a gradient steeper than 3:1 in lifts 9 inches or less and properly compacted. Ensure the face of the slope consists of loose, uncompacted fill 4 to 6 inches deep. Use grooving as described above to roughen the slope, if necessary.
2. Do not blade or scrape the final slope face.

Cuts/Fills, Mowed Maintenance

1. Make mowed slopes no steeper than 3:1.
2. Roughen these areas to shallow grooves by normal tilling, disking, harrowing, or use of cultipacker-seeder. Make the final pass of such tillage equipment on the contour.

3. Make grooves at least 1 inch deep and a maximum of 10 inches apart.
4. Excessive roughness is undesirable where mowing is planned.

Use tracking mainly in sandy soils to avoid compaction of the soil surface. It is not as effective as the other roughening methods.

Temporary Seeding

Design Criteria & Installation Specifications

Site Preparation – On sites where construction is currently underway, disturb as little of the site as possible and protect trees and other vegetation according to specifications for ***Natural Vegetation Preservation*** in this Handbook. Annual grasses such as rye or fescue can be used to provide temporary cover. Common bermuda or bahia grass (perennials) can also be added to the seed mix to provide temporary stabilization on bare soils that will be disturbed again before construction is complete, but not for a considerable amount of time.

On sites to be graded, strip and stock pile the topsoil. After grading is completed, spread the topsoil evenly over the area. On un-graded areas where the exposed soil is unsuitable for growing of vegetation, spread a 2- to 6-inch layer of good topsoil before planting. The topsoil should be fertile, free of litter, rocks, and objectionable weeds, and contain no toxic substances. A pH of 5.0 to 7.5 is most desirable, and soluble salts should not exceed 500 parts per million (ppm). Ordinarily, a topsoil depth of 3 to 6 inches, after settling, is considered adequate for establishing grasses. Table B.1 provides guidelines for the volume of topsoil required for application.

Table B.1. Volume of topsoil required for application to various depths *(USDA-SCS, 1990b)*.

Depth (inches)	Cubic yards per 1000 square feet	Cubic yards per acre
1	3.1	134
2	6.2	269
3	9.3	403
4	12.4	538
5	15.5	672
6	18.6	807

The surface grade should be at least 1 percent or more away from buildings. The grade and slope should permit the use of regular maintenance equipment. The best slopes for grass maintenance are 3:1 or flatter. Steep, vegetated slopes may also require structural stabilization, such as retaining walls or bench terraces.

Seedbed Preparation – Scarify if compacted. Remove all debris, such as rocks, stumps, scrap lumber, mortar or concrete, and rocks. If possible, disturb these areas as little as possible, especially on very steep slopes. After applying topsoil, if required, loosen the soil to a depth of several inches. Perform all tillage operations across the slope to reduce erosion hazard.

Seeding – Plant grasses during the rainy season and according to manufacturer's specifications (see Table B.2 for grass seeding and planting information). It may be necessary to increase the seed rate to account for loss to birds and pests. On steeper slopes or highly erodible soils, it will be necessary to hold the soil and seed in place with mulch and tackifier (for Hydroseeding applications) or erosion control mats (see ***Mulches, Mats & Geotextiles*** in this Handbook) to prevent erosion and loss of seed. Table B.3 provides a comparison of

Table B.2. Suitable grass species for seeding and planting in the Caribbean *(USDA-SCS, 1990b)*.

Plant Species	Propagation	Adaptation
	-------*Widely Adapted Grasses*-------	
Carpetgrass	8 lbs. per acre	Wet and shaded areas
Common bermuda grass	80 lbs. per acre	Throughout the island
Guinea grass	30 pounds per acre or vegetative	Dry areas & alkaline soils; shady areas; Intolerant to wet and acid soils
Paragrass	Vegetative	Throughout the island, especially wetlands and other wet areas
Pangolagrass	Vegetative	Throughout islands, except dry areas
Vetiver	Vegetative	Especially adapted to granitic soils
	-------*Grasses Especially Adapted to Dry Sites*-------	
Angleton grass	Natural seeding	All dry sites
Buffel grass	4 lbs. per acre	All dry sites
	-------*Grasses Especially Adapted to Saline Sites*-------	
Beach Grass (*Sporobolus virginicus*)	Vegetative	

lawn grasses for use in the Virgin Islands. Do **NOT** allow livestock to graze the grass. Also do not allow equipment to travel over the newly vegetated area to the point that the practice is destroyed.

Hydroseeding

1. **Seeds** – Virtually any lawn seed, or roadside seed, can be used in the system. Consult the seed manufacturer's recommendation for the amount of seed required for the targeted coverage. If that is not available use the following guideline and modify depending on the results you are getting:
   50 gallon = 4 pounds
   100 gallon = 8 pounds
   150 gallon = 12 pounds
   300 gallon (1/8 acre) = 25 pounds
   500 gallon = 40 pounds
   750 gallon (1/4 acre) = 75 pounds

   Pre-germinated seed may be used in the system. Several methods of pregerminating seeds exist. An easy to use system is to soak the seed in a container of clear water over night, the night before use. A garbage can or drum is ideal. Fill the container about 2/3 full of seed, then add water to the top of the seed. By morning the seed would have swelled, and the container will be full. The seed can then be dumped in the hydroseeder tank as needed. Pre-germinated grass seed will normally germinate in about half the normal time. Also, grass seed will only germinate at certain temperatures. By pre-germinating the seeds, it is less necessary to worry if the ground will be cool enough for the seed to germinate. If faster germination is desired, seeds may be soaked for 24 hours on the basis of 4 hours in water, followed by 4 hours out, and so forth for 24 hours. This system is good for athletic fields when the fastest possible germination is desired.

2. **Mulch** – Cellulose mulch is recommended for general use in the hydroseeder. Cellulose mulch is made from chopped up newspaper, with a green coloring agent, and anti-foaming agents. Mulch usually comes in 50 pound bales. The recommended amounts for use are:

   50 gallon = ¼ bale (12.5 lbs)
   100 gallon = ½ bale (25 lbs)
   150 gallon = ¾ bale (37.5 lbs)
   300 gallon = 1 ½ bales (75 lbs)
   500 gallon = 2 ½ bales (125 lbs)
   750 gallon = 3 ½ - 4 bales (175 - 200 lbs)

   These amounts are not necessarily the maximum. Ideally, the seed, mulch & water slurry should have about the consistency of apple sauce. If the spray has very little coloring, the mulch is too thin. If the spray has very little power, the mulch is too thick. Break up the mulch as much as possible as it is added to the tank. Clumps can be pulled through the hydroseeder before it has a chance to break them up, causing clogging problems.

3. **Fertilizer** – Most fertilizers intended for lawn applications can be used, including granular types. For new seeding, a starter fertilizer may be needed. Starter fertilizers are generally high in phosphorus (the middle number on a fertilizer bag, such as 5-10-5). Phosphorus will stimulate grass root growth. Use the fertilizer amount recommended by the manufacturer for the desired coverage. High nitrogen fertilizers are not recommend for seeding.

4. **Tackifier** – An optional ingredient in the hydroseeding mix is a tackifier. It is a blend of gelling, hardening, and loading agents designed to hold seed in place. Tackifier is used in adverse weather or on steep slopes. Some tackifiers

also lubricate the hydroseeder and reduce clogging. Most mulch manufacturers also manufacture tackifier. Start with a lower than suggested amount of tackifier and work up to avoid possible clogging. If a build up at the top of the tank is observed, reduce the application rate. Tackifier should not be added to the tank until right before spraying. In some instances, tackifier can is already mixed in with the mulch.

5. **Lime** – Lime is not recommended for use in a hydroseeder. There are liquid products available that alter pH and produce the same results as lime.

Maintenance

Proper maintenance of vegetative practices will insure erosion protection and improve the appearance of the site. Plan maintenance activities as preventative treatment to avoid serious problems in the future. Common vegetation maintenance activities include:

1. Repair small areas of unsatisfactory vegetation by reseeding and/or mulching. Regular attention to small areas will save on future large costs.
2. Mow grassed areas frequently to control weeds and unwanted woody vegetation. Mowing height should be at least 3 inches (height should be higher during the dry season and times of drought). Pay special attention to herbaceous vegetation in outlets and waterways and turf areas such as lawns and playgrounds.
3. New vegetation may need fertilization the first 2 or 3 years after establishment to maintain density and improve vigor. Fertilize according to soil test recommendations.
4. Use herbicides as directed by manufacturer and according to Territorial and Federal rules and regulations (contact DPNR or UVI Cooperative Extension Service for herbicide information).

Table B.3. A tabular comparison of lawn grasses (*USDA-SCS, 1990b*).

Grass	Texture	Maintenance Frequency		Soil Type	Tolerance to:		Resistance to:		Establishment		Mower type	Mowing Height (inches)	Insect Problems	Disease Problems
		Mowing	Fertilizer (times/year)		Shade	Salt	Drought	Wear	Method	Rate				
St. Augustine grass	medium to coarse	weekly	3 to 4	Alkaline	Good	Good	Poor	Good	Vegetative	Medium to fast	reel or rotary	1½ - 2½	Chinch bugs Armyworms Mole-crickets	Brown patch Grey leafspot
Centipede grass	medium	bimonthly	1	acid	fair	poor	good	poor	vegetative	medium	reel or rotary	1¼ - 2	Ground pearls Armyworms Spittle bugs Mole-crickets	Brown patch
Zoysia grass	fine to medium	weekly to bimonthly	3 to 4	wide range	good	good	good	good	vegetative	slow	reel	½ - 1¼	Armyworms Billbugs Mole-crickets	Brown patch Dollar spot
Improved bermuda grass	fine	1-3/week	4 to 12	wide range	very poor	fair	poor	good	vegetative	very fast	reel	½ - 1	Armyworms Scale insects Mole-crickets	Dollar spot Brown patch Helminthosporium
Seeded bermuda grass	medium fine	1-2/week	4 to 12	wide range	very poor	fair	fair	good	seed or vegetative	very fast	reel or rotary	½ - 1	Armyworms Scale insects Mole-crickets	Dollar spot Brown patch Helminthosporium
Bahia grass	medium to coarse	weekly	1 to 2	acid	fair to good	poor	fair	good	seed or vegetative	medium	rotary	2½ - 3	Armyworms Mole-crickets	Brown patch
Carpet grass	medium	weekly	1	wet, poorly drained, acid	good	poor	very poor	fair	seed or vegetative	medium	rotary	1¼ - 2	Armyworms Mole-crickets	Brown patch

Permanent Seeding & Planting

Design Criteria & Installation Specifications

Design criteria and installation specifications for permanent seeding and planting are similar to those for temporary seeding. Establish permanent grass by seeding or sodding as soon as possible after seedbed preparation is completed. Many lawn grasses used in the Caribbean area are planted with vegetative material, except for common bermuda grass, bahia grass, and some varieties of zoysia. See Tables B.2 and B.3 for information on lawn grasses appropriate for use in the Virgin Islands.

Apply seed uniformly by hand, cyclone seeder, drill cultipacker seeder, or hydroseeder. If seeding on steep (>15%) slopes or during the rainy season, protect the seed and soil with mulch or erosion control matting (see ***Mulches, Mats & Geotextiles*** sections of this Handbook).

Sod pieces or plugs are planted on 12 inch centers. On erodible slopes and other critical areas, it is best to use sod strips. The following information applies specifically to sod strips that require intensive treatment measures. However, some information may be applicable to other types of sod planting.

1. Sod strips should be laid on the contour, never up and down the slope, starting at the bottom of the slope and working up.
2. Place sod strips with snug, even joints and stagger the joints from strip to strip.
3. Roll or tamp sod immediately following placement to ensure that the roots are in solid contact with the soil surface. Do not overlap sod. All joints should be butted tight to prevent voids that would cause air drying of the roots.
4. On steep slopes, secure sod to surface soil with wooden pegs or wire staples.
5. Immediately following planting, sod should be watered until moisture penetrates the soil layer beneath the sod to encourage quick root growth. Maintain optimum moisture for at least 2 weeks. Watering to a 6-inch depth is more effective than frequent light watering. As sodding is completed, the entire area should be rolled or tamped.

Mulches, Mats & Geotextiles

Mulching — Application Specifications

Mulching is the application of shredded/chipped plant residues or other materials to the soil surface in order to reduce runoff and erosion, prevent surface compaction, conserve moisture and control weeds. It should be used on severely eroded areas; on cleared areas such as newly constructed waterways, channel banks and outlets; and all cuts and fills resulting from construction. It is a temporary erosion control measure and can be used alone or in conjunction with temporary seeding or permanent seeding and planting.

Table B.4 provides guidelines for mulch rates and slope length limits for some different types of mulch materials that may be used on construction sites.

Table B.4. Mulch rates and length limits for construction slopes (*USDA-SCS, 1993*).

Mulch Material	Mulch Rate (tons/acre)	Land Slope (percent)	Length Limit (feet)
Straw or hay, anchored or tacked down	1.5	1-5	300
	1.5	6-10	150
	2.0	1-5	400
	2.0	6-10	200
	2.0	11-15	150
	2.0	16-20	100
	2.0	21-25	75
	2.0	26-33	50
	2.0	34-50	35
Crushed Stone (¼ to 1½ inch)	135	< 16	200
	135	16-20	150
	135	21-33	100
	135	34-50	75
	240	< 21	300
	240	21-33	200
	240	34-50	150
Wood Chips	7	< 16	75
	7	16-20	50
	12	< 16	150
	12	16-20	100
	12	21-33	75
	25	< 16	200
	25	16-20	150
	25	21-33	100
	25	34-50	75

NOTE: Maximum slope length for which the specified mulch rate is considered effective. When this limit is exceeded, either a higher application rate or mechanical shortening of the effective slope length is required.

Types of Mulch

1. Straw or hay: 1½ - 2 tons per acre with seeding. 3 tons per acre used alone.
2. Wood fiber (jute): 1,000 to 2,000 pounds per acre.
3. Mulch netting with excelsior, straw, coconut fiber (coir), nylon, or paper woven into it. Used for waterways, slopes that are difficult to vegetate, areas subject to wind, or areas where other mulches are not available.
4. Crushed stone: 135 to 240 tons per acre.
5. Wood chips: 7 to 25 tons per acre.

Types of Mulch Anchoring

1. Straw or Hay Mulch
   - Mulch netting made of plastic or jute and stapled into place.
   -Chemical anchoring solution sprayed on at manufacturer's recommended rates (for mulches applied hydraulically).
   - Mulch anchoring tool.
2. Wood Fiber Mulch – Chemical anchoring solution sprayed on at manufacturer's recommendation (for mulches applied hydraulically).
3. Mulch Netting – Staples installed at manufacturers's recommendation.

Types of Application Equipment

1. Straw or hay mulch: mulch blower or by hand.
2. Wood fiber mulch: hydroseeder.
3. Mulch netting: by hand.
4. Crushed stone: by hand.
5. Wood chips: by hand.

Erosion Control Mats

An erosion control mat is a blanket made of straw, coconut fiber (coir), polyethylene, nylon, vinyl, or any combination that is specifically manufactured for erosion control applications. Erosion control mats (or blankets) are designed for immediate to long-term erosion protection and vegetation establishment on moderate to severe slopes, channels and shorelines where conventional loose and hydraulically applied mulches often fail. Some materials are also used for permanent vegetation reinforcement on steep slopes, channels or shorelines. The type of erosion control mat to be used on a site depends on the purpose of the mat (permanent turf reinforcement mat, 100% biodegradable mat (or blanket), extended or long-term degradable mat, or short-term photodegradable mat) and the area where it will be installed (slope, channel or shoreline). Some mats or blankets incorporate coconut fibers and/or long lasting, UV stabilized netting to provide a higher degree of erosion protection, durability and longevity than single and double net short term products. Installation specifications vary by manufacturer and designated use of the mat. Selection of type of mat (straw, coconut, synthetic, or some combination) depends on the steepness of the slope, the velocity of water to be flowing over the mat, and the intended duration of the installation. Refer to manufacturer specifications to determine the appropriate material to use for each site.

Installation Specifications

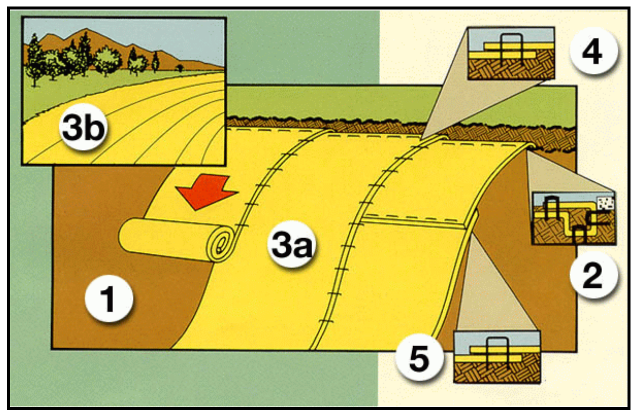


Figure B.10. Erosion control mat slope installation example (*North American Green, 2002*).

Divert runoff away from the application area. Remove tree stumps, rocks and debris to prepare a smooth surface. Fill holes and depressions; grade and compact area (for permanent stabilization). The mat may also be installed and covered with one inch of topsoil before seed application.

Slope Installations (Figure B.10)

1. For areas that will be seeded, prepare the seed bed and fertilize before applying mat.
2. Begin at the top of the slope by anchoring the mat in a 6" (15 cm) deep by 6" (15 cm) wide trench with approximately 12" (30 cm) of mat extended beyond the up-slope portion of the trench. Anchor the mat with a row of metal staples (Figure B.11) or stakes approximately 12" (30 cm) apart in the bottom of the trench. Backfill and compact the trench after stapling. Apply seed to compacted soil and fold remaining 12" (30 cm) portion of mat back over seed and compacted soil. Secure mat over compacted soil with a row of staples or stakes spaced approximately 12" (30 cm) apart across the width of the mat.
3. Roll the mats (a) down or (b) horizontally across the slope. Mats will unroll with appropriate side against soil surface. All mats must be securely fastened to soil surface by placing staples/stakes in appropriate locations as shown in the manufacturer's staple pattern guide.
4. The edges of parallel mats must be stapled with a 3" - 6" (7.5 cm - 15 cm) overlap, depending on mat type.
5. Consecutive mats spliced down the slope must be placed end over end (shingle style) with an approximate 3" - 6" (7.5 cm - 15 cm) overlap. Staple through overlapped area, approximately 12" (30 cm) apart across entire mat width.

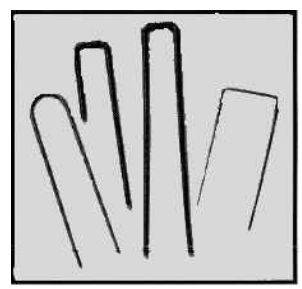


Figure B.11. Different types of staples used to anchor erosion control mats.

<u>Note:</u> in loose soil conditions, staple or stake lengths greater than 6" (15 cm) may be necessary to properly secure the mats.

Channel Installations (Figure B.12)

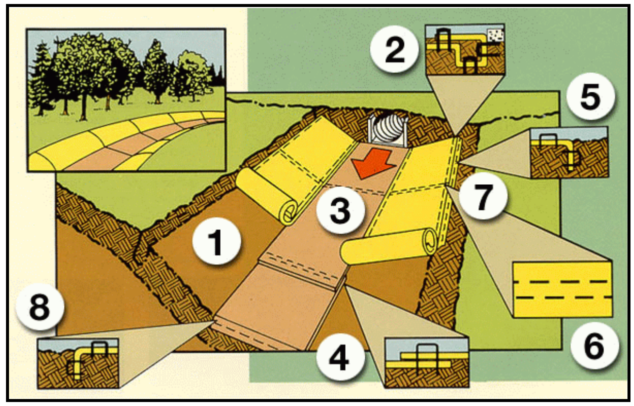


Figure B.12. Example erosion control mat installation in a channel or drainage swale (*North American Green, 2002*).

1. Prepare soil before installing mats, including any necessary application of fertilizer and seed.
2. Install mat in the direction of water flow and ensure that it is in constant contact with the ground (to prevent erosion under the mat). Begin at the top of the channel by anchoring the top end of the mat in a 6" (15 cm) deep X 6" (15 cm) wide trench with approximately 12" (30 cm) of mat extended beyond the up-slope portion of the trench. Anchor the mat with a row of staples or stakes approximately 12" (30 cm) apart in the bottom of the trench. Backfill and compact the trench after stapling. Apply seed to compacted soil and fold remaining 12" (30 cm) portion of mat back over seed and compacted soil. Secure mat over compacted soil with a row of staples/stakes spaced approximately 12" (30 cm) apart across the width of the mat.
3. Roll center mat in direction of water flow in the bottom of the channel. Mats will unroll with appropriate side against the soil surface. All mats must be securely fastened to soil surface by placing staples or stakes in appropriate locations as shown in the staple pattern guide provided by the manufacturer.
4. Place consecutive mats end over end (shingle style) with a 4" - 6" (10 cm - 15 cm) overlap. Use a double row of staples staggered 4" (10 cm) apart and 4" (10 cm) on center to secure mats.
5. Full length edge of mats at top of side slopes must be anchored with a row of staples/stakes approximately 12" (30 cm) apart in a 6" (15 cm) deep X 6" (15 cm) wide trench. Backfill and compact the trench after stapling.
6. Adjacent mats must be overlapped approximately 3" - 6" (7.5 cm - 15 cm) (depending on mat type) and stapled.
7. In high flow channel applications, a staple check slot is recommended at 30 to 40 foot (9m - 12m) intervals. Use a double row of staples staggered 4" (10 cm) apart and 4" (10 cm) on center over entire width of the channel.
8. The downstream ends of the mats must be anchored with a row of staples/stakes approximately 12" (30 cm) apart in a 6" (15 cm) deep X 6" (15 cm) wide trench. Backfill and compact the trench after stapling.

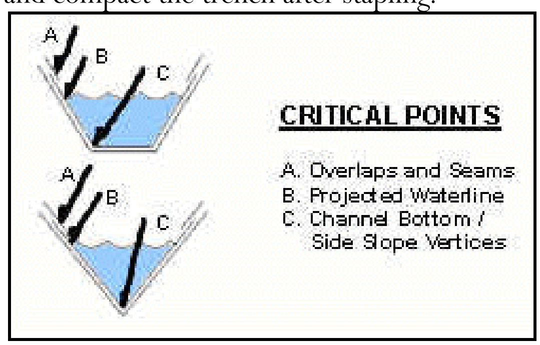


Figure B.13. Critical stress points for erosion control mat applications in channels *(North American Green, 2002*).

Notes: horizontal staple spacing should be altered if necessary to allow staples to secure the critical points (Figure B.12) along the channel surface. In loose soil conditions, the use of staple or stake lengths greater than 6" (15 cm) may be necessary to properly anchor the mats.

Shore Installations (Figure B.13)

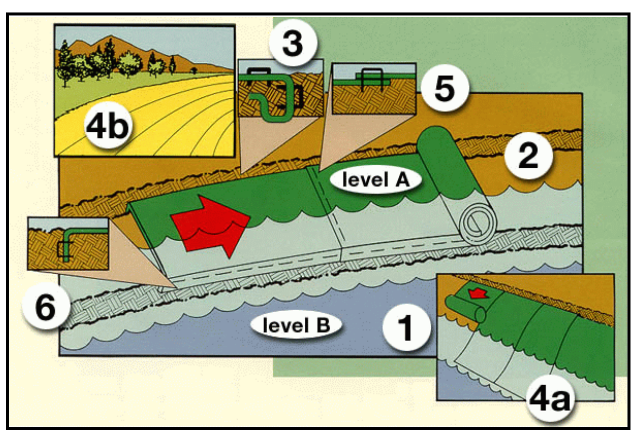


Figure B.14. Example erosion control mat installation for shorelines (*North American Green, 2002*).

1. For easier installation, lower the water level from level A to level B before installation.
2. Prepare soil before installing mats, including any necessary application of fertilizer and seed.
3. Begin at top of the shoreline by anchoring the mat in a 6" (15 cm) deep by 6" (15 cm) wide trench with approximately 12" (30 cm) of mat extended beyond the up-slope portion of the trench. Anchor the mat with a row of staples or stakes approximately 12" (30 cm) apart in the bottom of the trench. Backfill and compact the trench after

stapling. Apply seed to compacted soil and fold remaining 12" (30 cm) portion of mat back over seed and compacted soil. Secure the mat over compacted soil with a row of staples or stakes spaced approximately 12" (30 cm) apart across the width of the mat.

4. Roll the mats either (a) down the shoreline for long banks, (top to bottom) or (b) horizontally across the shoreline slope. Mats will unroll with the appropriate side against the soil surface. All mats must be securely fastened to the soil surface by placing staples or stakes in appropriate locations as shown in the staple pattern guide.
5. The edges of all horizontal and vertical mat seams must be stapled with approximately 3"- 6" (7.5 cm - 15 cm) overlap. Secure all overlaps with staples spaced 12" (30 cm) apart.
6. The edge of the mat at or below normal water level must be anchored by placing the mat in a 12" (30 cm) deep by 6" (15 cm) wide anchor trench. Anchor the mat with a row of staples or stakes spaced approximately 12" (30 cm) apart in the trench. Backfill and compact the trench after stapling (stone or soil may be used as backfill).

Note: in loose soil conditions, the use of staple or stake lengths greater than 6" (15 cm) may be necessary to properly anchor the mats.

Soil Retaining Walls

Design Criteria

1. **Bearing Capacity:** Maintain a minimum safety factor of 1.5 as the ratio of the ultimate bearing capacity to the designed unit loading.

2. **Sliding:** Maintain a minimum safety factor of 2.0 against sliding.

3. **Overturning:** Use a minimum safety factor of 1.5 as the ratio of the resisting force (that which tends to keep the wall in place) to the overturning force.

4. **Drainage:** Unless adequate provisions are made to control surface and groundwater behind the wall, a significant increase in pressure that can tend to slide or overturn the wall will result. Provide surface drainage when backfill is sloped down to a retaining wall. Install drainage systems with adequate outlets behind retaining walls placed in cohesive soils. Grade or protect drains with filters so that soil will not move through the drainfill.

5. **Load systems:** Several different loads or combination of loads need to be considered when designing a retaining wall. The minimum load is the level backfill that the wall is being constructed to retain. The unit weight will vary depending on composition. Additional loads such as line loads, surcharge loads, or slope fills will add to the composite design load system for the retaining wall.

Construction Specifications

**** Consult with a structural engineer to ensure that bearing capacities and loadings can be contained****
See Figures B.15 through B.18 and Tables B.5 through B.8 for design and construction specifications.

Concrete Walls

1. Prepare foundation by excavating to the lines and grades shown on the engineering drawing and removing all objectionable material.
2. Compact the subgrade and keep it moist at least 2 hours prior to placement of concrete.
3. Use steel reinforcement in accordance with the schedule on the engineering drawing and keep steel free of rust, scale and dirt.
4. Cut a ¾-inch groove (or furrow) into exposed edges.
5. Grade drainfill according to engineering drawings.
6. Provide weep holes for drainage outlets as shown on engineering drawings.
7. Pour and cure concrete in accordance with American Concrete Institute (ACI) specifications.

Pre-cast Units

1. Prepare foundation by excavating to the lines and grades shown on the engineering drawings.
2. Compact and trim subgrade to receive the leveling beam.
3. Place pre-cast units in accordance with manufacturer's recommendations.
4. Place granular fill in the pre-cast bins in 3-foot lifts, leveled off and compacted with a plate vibrator.

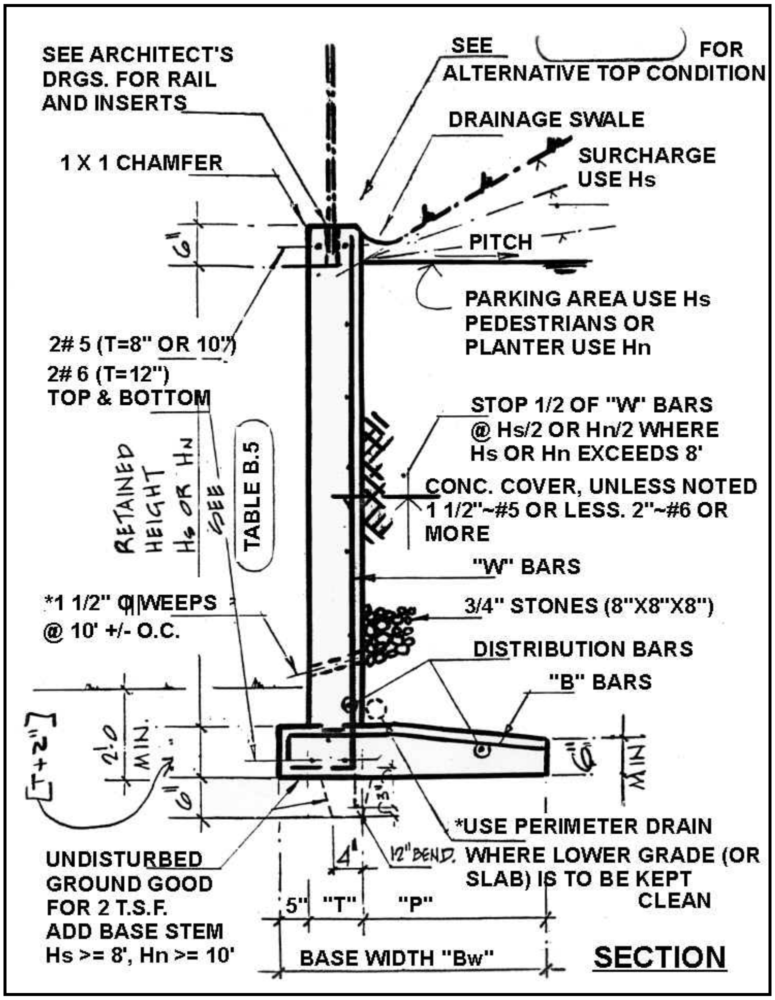


Figure B.15. Concrete cantilever retaining wall, toe in. Height = 4 to 14 feet (*Bernier, 1995*).

Table B.5. Concrete cantilever retaining wall, toe in. Height = 4 to 14 feet (*Bernier, 1995*).

Retained Height		Base Width	Thickness	Base Projection	Main Reinforcement	
					Wall	Base
H_s*	H_N*	B_W	T	P	W bars	B bars
2	4	1'-6"	8"	0-5"	SIM. S11 ~21-09	
4	6	2'-6"	8"	1'-5"	#4 @ 18"	#3 @ 18"
6	8	3'-6"	8"	2'-5"	#4 @ 12"	#4 @ 18"
8	10	5'-0"	8"	3"-11"	#5 @ 12"	#5 @ 12"
10	12	6'-6"	10"	5'-3"	#6 @ 12"	#6 @ 12"
12	14	8'-0"	12"	6'-7"	#6 @ 8"	#6 @ 8"

* H_S or H_N = actual grade difference plus 1' - 4' U.N.

NOTES:
1. Concrete f'c = 3000 psi @ 28 days.
2. Reinforcement fy = 60,000 psi.
3. Re-bar can be substituted as follows:
   a. #4 @ 8" may replace #5 @ 12"
   b. #4 @ 4" or #5 @ 6" may replace #6 @ 8".
4. Distribution bars shall be one size less and 1½ times the spacing of main reinforcing (i.e., distribution to #5 @ 12" shall be #4 @ 18") except that minimum distribution bars shall not be less than #3 @ 18".
5. For relevant wall section, see Figure B.10.
6. For expansion and crack control joints see Figures B. and B.??
7. H_S use for 33° (max) surcharge or car parking. Not suitable for full highway loading. H_N = level backfill with pedestrian load only.
8. No footing or wall shall be poured without prior approval of the engineer.

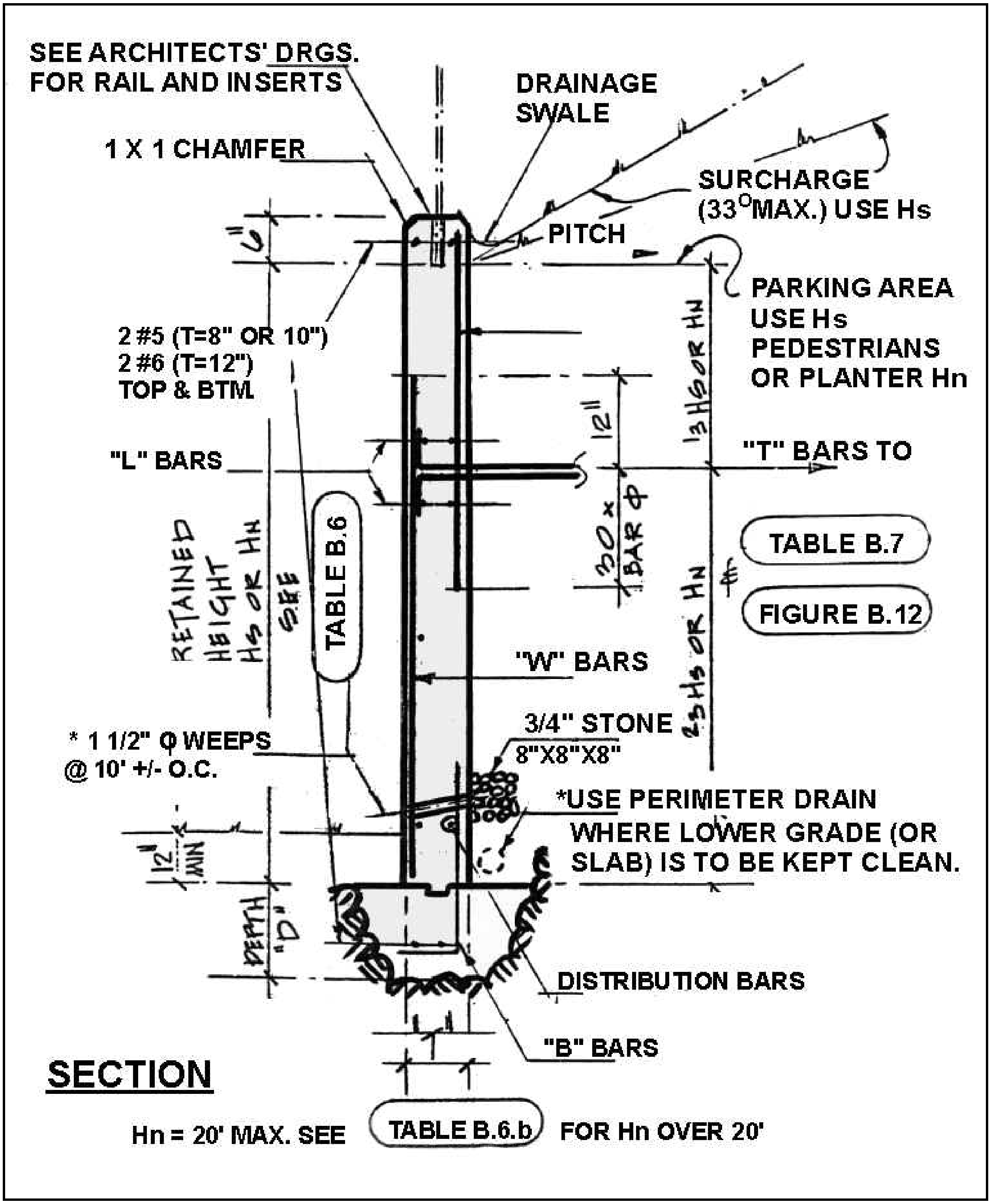


Figure B.16. Concrete retaining wall with tie-back to anchor. H = 0 to 16 feet (*Bernier, 1995*).

Table B.6. Concrete retaining wall with tie-back to anchor, H = 0 to 32 feet (*Bernier, 1995*).

Retained Height		Depth	Thickness	Main Reinforcement Dowels	Main Reinforcement Wall	Main Reinforcement Wall
H_S	H_N	D	T	B bars	W bars	C bars
			Table B.6.a			
2'	4	12"	8"	NONE	#4 @ 18"	NONE
4'	6	12"	8"	"	#4 @ 18"	"
6'	8	12"	8"	"	#4 @ 16"	#3 @ 18"
8'	10	12"	8"	#3 @ 16"	#5 @ 16"	#3 @ 18"
10'	12	12"	10"	#3 @ 16"	#5 @ 12"	#3 @ 18"
12'	14	12"	10"	#4 @ 16"	#5 @ 8"	#4 @ 18"
14'	16	1'-3"	12"	#5 @ 16"	#6 @ 8"	#4 @ 18"
16'	18	1'-6"	12"	#6 @ 16"	#7 @ 8"	#4 @ 18"
18'	20	1'-9"	12"	#6 @ 12"	#8 @ 10"	#4 @ 12"
			Table B.6.b			
20'	22	2'-0"				
22'	24	2'-6"				
24'	26	3'-0"				
26'	28	3'-6"				
28'	30	4'-0"				
30'	32	4'-6"				

NOTES:
1. See Table B.5 for additional notes.
2. "D" shall be into undisturbed natural ground having a safe bearing capacity of 2.T.S.F.
3. "D" may be halved in rock, but not less than 12" (inches).

Table B.7. Concrete retaining wall with tie-back to anchor, H = 0 to 32 feet (*Bernier, 1995*).

Retained Height		Anchor Size	Wall Beam	Ties Wall to Anchor
H_S	H_N	A x L	L bars	T bars
		Table B.7.a		
2	4	1'-6" x 1'-6"	4 #4	#4 @ 20'
4	6	1'-6" x 1'-6"	4 #4	#4 @ 10'
6	8	1'-6" x 1'-6"	4 #4	#4 @ 5'
8	10	1'-8" x 1'-8"	4 #4	2 #4 @ 6'
10	12	1'-10" x 1'-10"	4 #4	2 #4 @ 5'
12	14	2'-2" x 2'-2"	4 #4	3 #4 @ 5'
14	16	2'-6" x 2'-6"	4 #4	4 #4 @ 5'
16	18	2'-10" x 2'-10"	4 #5	3 #5 @ 5'
18	20	3'-0" x 3'-4"	4 #5	4 #5 @ 5'
		Table B.7.b		
20	22	3'-0" cont.		5 #5 @ 5'
22	24	3'-6" "		4 #6 @ 5'
24	26	4'-0" "		5 #6 @ 5'
26	28	4'-6" "		6 #6 @ 5'
28	30	5'-0" "		7 #6 @ 5'
30	32			8 #6 @ 5'

NOTES:
1. Tie bars shall be well greased and wrapped with a heavy-duty, moisture-proof tape or shall be surrounded with 4" minimum of concrete during backfilling.

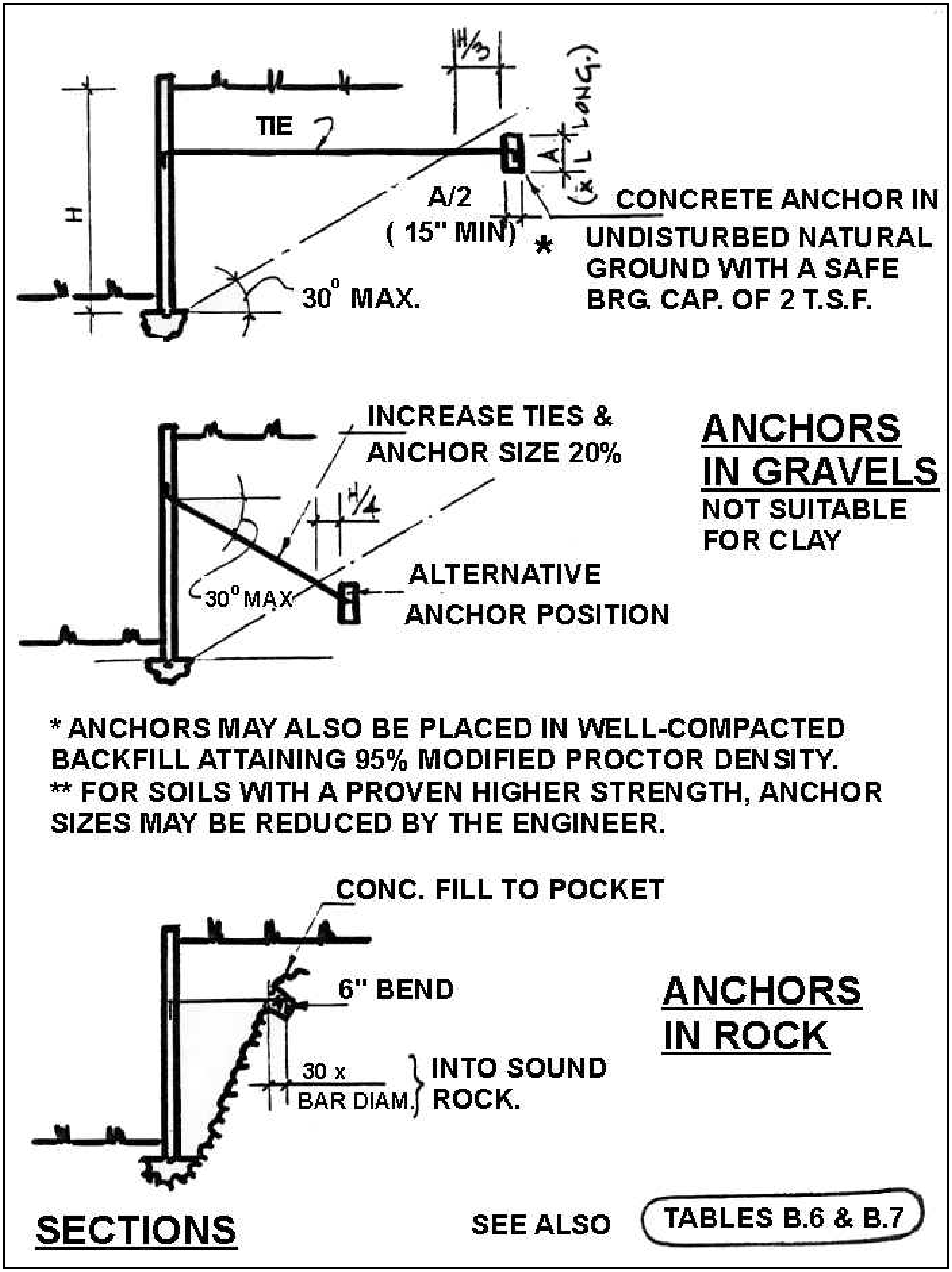


Figure B.17. Concrete retaining wall with tie-back to anchor, H = 0 to 32 feet (*Bernier, 1995*).

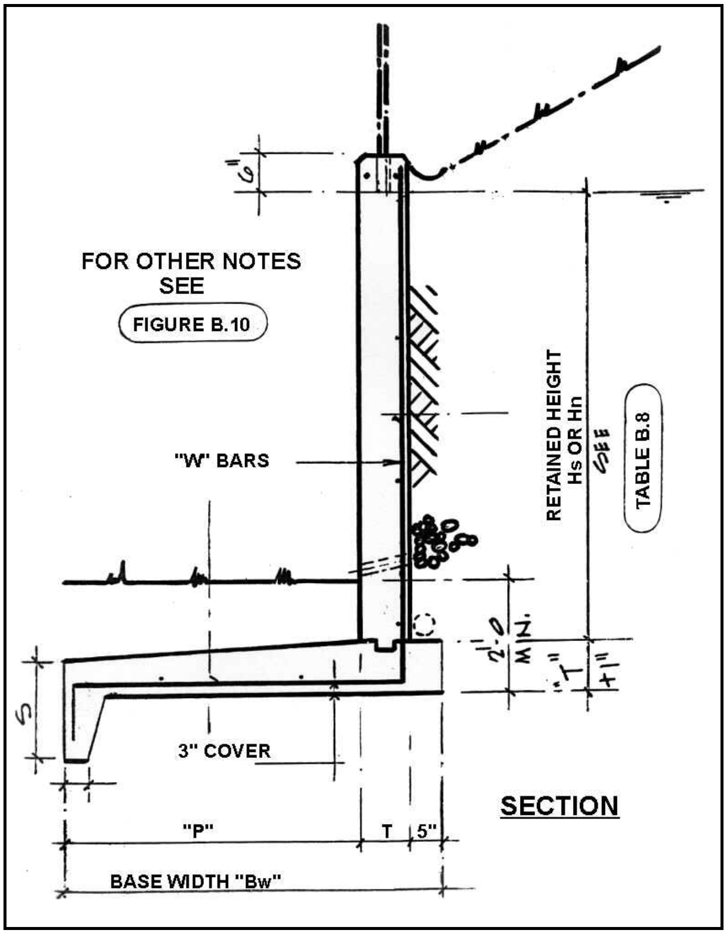


Figure B.18. Concrete cantilever retaining wall, toe out, H = 4' to 14 feet (*Bernier, 1995*).

Table B.8. Concrete cantilever retaining wall, toe out H = 4 to 14 feet (*Bernier, 1995*).

Retained Height		Base Width	Thickness	Base Projection	Turn Down	Main Reinforcement
H_S*	H_N*	B_W	T	P	S	"W" bars
2	4	2'-0"	8"	0'-11"	6"	sim s11~21-5
4	6	3'-6"	8"	2'-5"	6"	#4 @ 18"
6	8	5'-0"	8"	3'-11"	12"	#4 @ 12"
8	10	6'-6"	8"	5'-5"	20"	#5 @ 12"
10	12	8'-0"	10"	6'-9"	28"	#6 @ 12"
12	14	9'-6"	12"	8'-1"	36"	#6 @ 8"

* H_S or H_N = Actual grade difference plus 1'-4".

NOTES:
1. Concrete f'c = 3000 psi @ 28 days.
2. Reinforcement fy = 60,000 psi.
3. Re-bar can be substituted as follows:
   a. #4 @ 8" may replace #5 @ 12"
   b. #4 @ 4" or #5 @ 6" may replace #6 @ 8".
4. Distribution bars shall be one size less and 1½ times the spacing of main reinforcing (i.e., distribution to #5 @ 12" shall be #4 @ 18") except that minimum distribution bars shall not be less than #3 @ 18".
5. For relevant wall section, see Figure B.13.
6. For expansion and crack control joints see Figures B. and B.??
7. H_S use for 33° (max) surcharge or car parking. Not suitable for full highway loading. H_N = level backfill with pedestrian load only.
8. No footing or wall shall be poured without prior approval of the engineer.
9. "Toe out" cantilevered retaining walls cost more for concrete than "Toe in" walls, however, this may be offset by reduced excavation costs, particularly in rock. "Toe out" walls may also be required where it is necessary to keep clear of an adjacent property line.

Gabions

1. Prepare foundations by excavating to the lines and grades shown on the engineering drawings.
2. Compact and level subgrade to receive first layer of gabions. The first row will be keyed into the existing grade at the toe to a minimum of 1.5 feet.
3. Place gabions according to the manufacturers recommendations.
4. Fill gabions with stone or crushed rock that is 4 to 8 inches in diameter. Make sure that voids and bulges are minimized in the gabions so that proper alignment can be maintained
5. Coat gabion wire with PVC in corrosive environments (eg., where gabions will be in contact with salt spray).
6. Where walls are higher than 12 to 15 feet, it is better to use 1.5 foot deep gabions rather than 3 foot deep gabions in the lower levels and foundation where the compression and shear stresses are highest.
7. Increase the number of panels aligned perpendicular to the face of the wall (parallel to the soil thrust) to reduce deformation caused by shear.
8. Stepped front-face walls are advisable for walls 15 to 18 feet high. A stepped rear-face is acceptable for lower wall providing that the wall is built to a batter greater than 6°.
9. Even though gabion walls are permeable and self-draining, areas where heavy rainfalls occur may require addition of a concrete apron shaped to drain off collected water and installation of land drains (see Figure B.19).

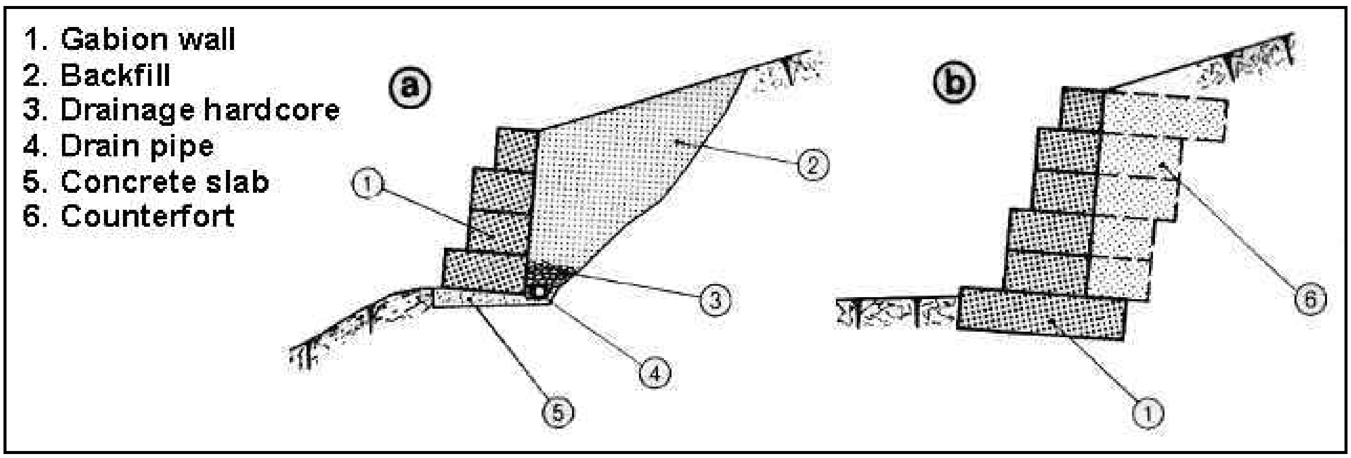


Figure B.19. Two possible methods of draining a gabion box wall (*Maccaferri Gabions, Inc., 1994*).

Structural Calculations

Check for sliding

This check is made with reference to a horizontal plane (figs. a-c). Specifically, for gabion walls, the stabilizing forces (Fs) resisting sliding are friction (fN) and cohesion (cB) at the sliding surface, passive pressure (Sp) at the toe of the wall and anchorage forces (Ss) at the heel of the wall:

$$F_s = fN + cB + S_p \cos\delta + S_s$$

Some of these componenets may not be present depending on the type of wall and existing conditions. The normal force N is the sum of the vertical forces perpendicular to the sliding surface, i.e. soil weight, wall weight, vertical component of the soil thrust, surcharge and eventually seismic action.

The coefficient of friction is:

$$f = \tan\varphi$$

(f = 0.64 for concrete base).
The force causing sliding is:

$$F_i = [S_a \cos(90 + \delta - \beta)] \cos\alpha$$

for gravity walls

$$F_i = (S_a \cos\delta) \cos\alpha$$

for walls with extended foundation.

The factor of safety against sliding is:

$$\eta_s = \frac{F_s}{F_i} \geqslant 1.3$$

In favor of stability the passive downstream thrust Sp can be ignored.

Check for overturning

For a retaining wall that is resisting active earth pressure and where its own mass is a resisting force, the overturning moment (fig. b) is:

$$M_i = S_{ah} \cdot d$$

and the restoring moment Ms is:

$$M_s = W \cdot s' + W_t \cdot b + S_{av} \cdot s$$

where:
W = weight of the structure
Wt = soil (boxed) weight plus any possible surcharge
Sah/Sav = horizontal and vertical components of the pressure including the seismic one if necessary

$$d = H/3 - B\sin\alpha$$

(in absence of surcharge)

$$d = \frac{H}{3}\left(\frac{H + 3\,p_0/\gamma_s}{H + 2\,p_0/\gamma_s}\right) - B\sin\alpha$$

(in presence of surcharge p_0 cos γ_s the soil unit weight)

$$s' = x_a \cos\alpha + y_a \sin\alpha$$

(x_a e y_a coordinates of the center of gravity of the structure weight, referred to a system of cartesian axis, with origin at the point F).

$$s = B\cos\alpha - \frac{H}{3}\left(\frac{H + 3\,p_0/\gamma_s}{H + 2\,p_0/\gamma_s}\right)\frac{1}{\tan\beta}$$

b = distance from the center of gravity of the (boxed) soil weight from the point F.

The safety factor against overturning is given by:

$$\eta_r = \frac{M_s}{M_i} \geqslant 1.5$$

Check on overall stability

A retaining wall may fail on a semi-circular slip surface located within the soil below and behind the wall. To check whether this condition exists, a conventional slip circle analysis must be made to find the minimum factor of safety which must not be less than 1.2 - 1.3.

Stresses in the wall

In the analysis of the stresses acting on a horizontal section through a retaining wall, it is the bending moment, M, the horizontal resultant T and the vertical resultant N which are taken into consideration. The eccentricity (e) of N from the center of the section of unit width and height B is given by M/N.

The stress developed in the section is:

$$\sigma_{max} = \frac{N}{B - 2e}$$

which must not exceed the allowable stress

$\sigma_{am} = 1.14\,\gamma_g - 42.77$ (where σ_{am} is in lb/in² and γ_g in lb/ft³)

The average shear stress is:

$$\tau = T/B$$

and it must not exceed

$$\tau_{am} = N \tan\varphi^*/B + c_g$$

where $\varphi^* = 0.398\,\gamma_g - 9.80°$ (γ_g in lb/ft³) and c_g,
the coefficient of cohesion, is
$c_g = 6.837\,P_u - 0.717$ where c_g is in lb/in² and P_u (weight of the steel mesh per cubic yard of gabion) is in lb/ft³
The value of c_g is normally from 2 to 6 lb/in².

Check on foundation bearing pressures

The bearing pressure on the soil beneath the foundation is computed using the relevant values of M and N, and eccentricity e = M/N.
For e < B/6 the maximum pressure is:

$$\sigma_{max} = \frac{N}{B}\left(1 + \frac{6e}{B}\right)$$

where e > B/6 part of the section adjacent to the backfill will be in tension and $\sigma_{max} = 2N/3u$, where u = B/2 - e.

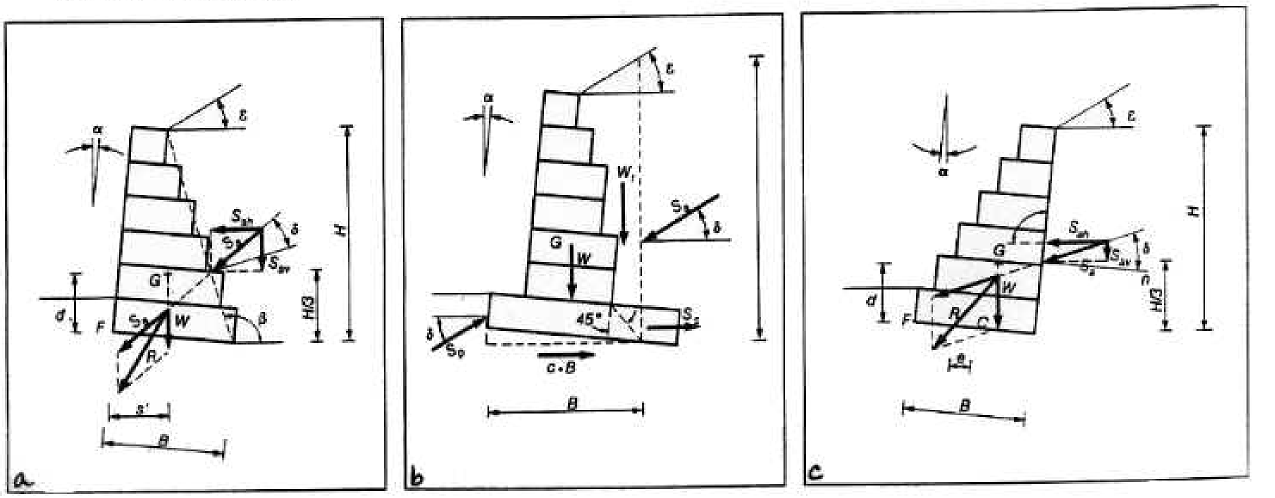


Figure B.20. Forces to be considered when checking a gabion structure (*Maccaferri Gabions, Inc., 1994*).

Soil Bioengineering

There are a number of different soil bioengineering practices that can be applied on a construction site. They are used for different purposes and different site constraints, such as slope, vegetation available, and microclimate. The soil bioengineering practices detailed here are those most applicable to conditions and materials available in the Virgin Islands.

Brushlayer

Description

Brushlayering is the placing of live branch cuttings (preferably native vegetation, see Chapter 3) in small benches excavated into the slope perpendicular to the slope contour. These benches can range from 2 to 3 feet wide. Brushlayering is recommended on slopes up to 2:1 and that do not exceed 15 feet in vertical height. Brushlayer branches serve as reinforcing units. The portions of the brush that protrude from the slope face help to slow runoff and reduce surface erosion.

Applications and Effectiveness

Construction Guidelines

Brushlayers control erosion, provide earth reinforcement, and stabilize slopes by:

1. Breaking up the slope length into a series of shorter slopes separated by rows of brushlayer.
2. Reinforcing the soil with the unrooted branch stems.
3. Reinforcing the soil as roots develop, adding resistance to sliding or shear displacement.
4. Providing slope stability and allowing vegetative cover to become established.
5. Trapping debris on the slope.
6. Aiding infiltration on arid sites.
7. Drying excessively wet sites.
8. Adjusting the site's microclimate, thus aiding seed germination and natural regeneration.
9. Redirecting and mitigating adverse slope seepage by acting as horizontal drains.

Branch cuttings shall be ½ to 2 inches in diameter and long enough to reach the back of the bench. Side branches shall remain intact for installation. Follow these installation guidelines:

1. Starting at the toe of the slope, excavate benches horizontally, on the contour, or at an angle slightly down the slope to aid drainage. The bench shall be built 2 to 3 feet wide.
2. Slope the surface of the bench so that the outside edge is higher than the inside.
3. Place live branch cuttings on the bench in a criss-cross or overlapping configuration.
4. Align branch growing tips toward the outside of the bench.
5. Backfill soil on top of branches and compact to eliminate air spaces. Extend brush tips slightly beyond the fill to filter sediment.
6. Backfill each lower bench with the soil obtained from excavating the bench above.
7. Place long straw or similar mulching material with seeding between rows on 3:1 or flatter slopes, while slopes steeper than 3:1 require jute mesh or a similar matting placed in addition to the mulch.

8. Space brushlayers 3 to 5 feet apart, depending upon slope angle and stability (see Table B.9).

Table B.9. Brushlayer installation guidelines (*USDA-SCS, 1992*).

Slope	Slope distance between benches: Wet slopes (feet)	Slope distance between benches: Dry slopes (feet)	Maximum slope length (feet)
2:1 to 2.5:1	3	3	15
2.5:1 to 3:1	3	4	15
3:1 to 4:1	4	5	20

Live Gully Repair

Description

Live gully repair uses alternating layers of live branch cuttings and compacted soil to repair small gullies.

Applications and Effectiveness

Installed branches provide immediate reinforcement to the compacted soil and reduce the velocity of concentrated stormwater flows. They also provide a filter barrier to reduce rill and gully erosion. Live gully repair is limited to gullies that are a maximum of 2 feet wide, 1 foot deep, and 15 feet long.

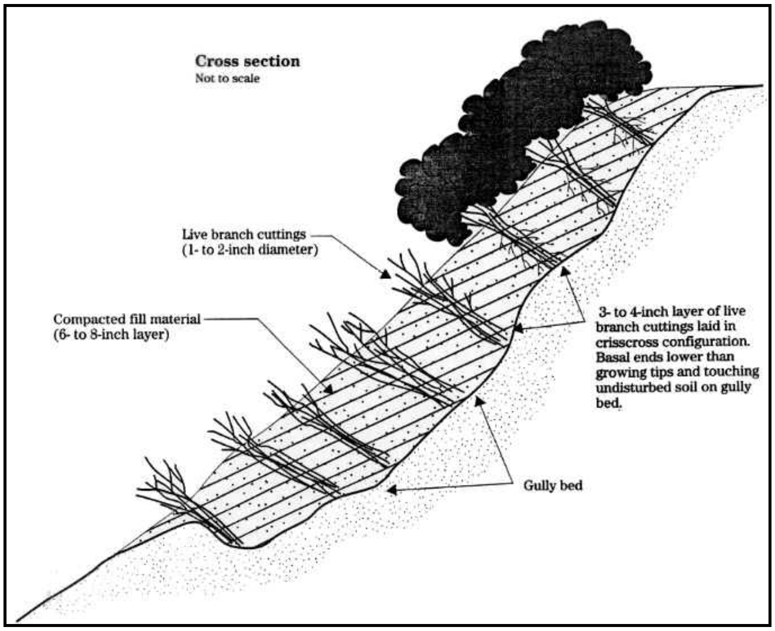


Figure B.21. Live gully repair details; Note: rooted/leafed condition of the living plant material is not representative of the time of installation *(USDA-SCS, 1992)*.

Construction Guidelines

Live branch cuttings shall range from ½ to 2 inches in diameter. They shall be long enough to touch the undisturbed soil at the back of the gully and extend slightly from the rebuilt slope face. Follow these installation guidelines:

1. Starting at the lowest point of the slope, place a 3- to 4- inch layer of branches at the lowest end of the gully perpendicular to the slope.
2. Cover branches with a 6- to 8- inch layer of fill soil.
3. Install the live branches in a criss-cross fashion. Orient the growing tips toward the slope face with basal ends lower than the growing tips.
4. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings (see Figure B.21).

Vegetated Rock Gabions

Description

Vegetated gabions are rectangular containers made of heavily galvanized steel wire that is triple-twisted into a hexagonal mesh. Empty gabions are placed in position, wired to adjoining gabions, filled with stones, and then folded shut and wired at the ends and sides. Live branches are placed on each consecutive layer between the rock-filled baskets. These branches will root inside the gabion baskets and in the soil behind the structures. The roots consolidate the structure and bind it to the slope.

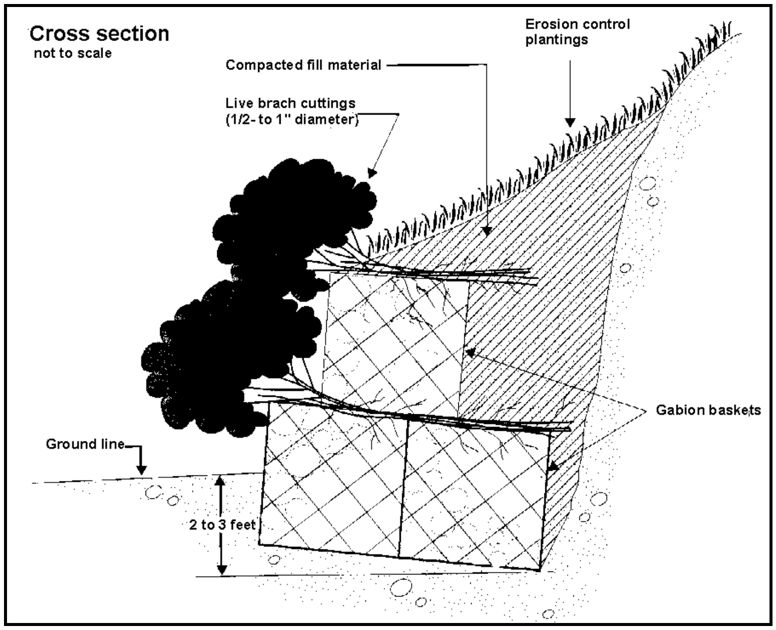


Figure B.22. Vegetated rock gabion details (Note: rooted/leafed condition of the living plant material is not representative of the time of installation; *USDA-SCS, 1992*).

Applications and Effectiveness

Vegetated rock gabions are appropriate to use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness. They are not designed for or intended to resist large, lateral earth stresses. They shall be built to a maximum 5 foot overall height, including the excavation required for a stable foundation. Vegetated rock gabions are useful where space is limited and a more vertical structure is required.

Construction Guidelines

Branches shall range in size from ½ to 1 inch in diameter and must be long enough to reach beyond the back of the rock basket structure into the backfill. Install rock gabions following these guidelines:

1. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached.
2. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure. This will provide additional stability and ensure that the branches root well.
3. Place the wire baskets in the bottom of the excavation and fill with rock.
4. Place backfill between and behind the wire baskets.
5. Place live branch cuttings on the wire baskets perpendicular to the slope with the growing tips oriented away from the slope and extending slightly beyond the gabions. The live cuttings must extend beyond the backs of the wire baskets into the fill material. Place soil over the cuttings and compact it.
6. Repeat the construction sequence until the structure reaches the required height (see Figure B.22).

Vegetated Rock Wall

Description

A vegetated rock wall is a combination of rock and live branch cuttings that is used to stabilize and protect the toe of steep slopes. Vegetated rock walls differ from conventional retaining walls in that they are placed against relatively undisturbed earth and are not intended to resist large lateral earth pressures.

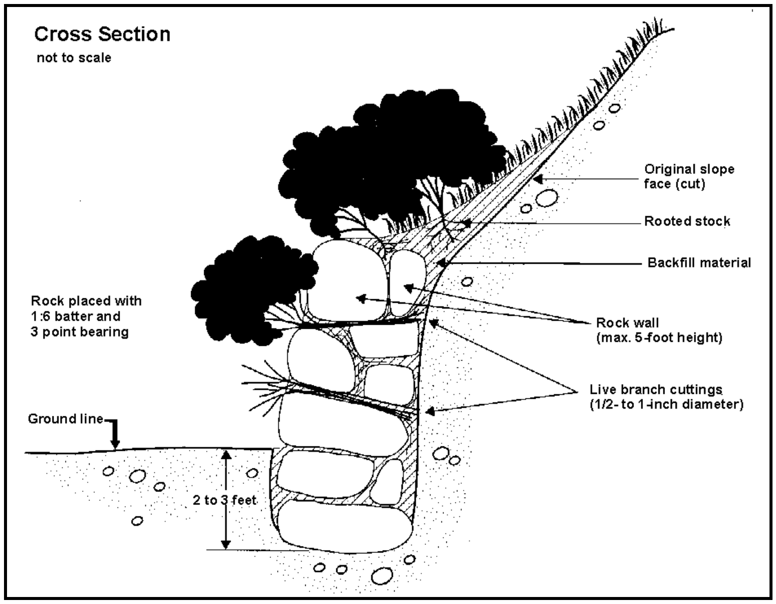


Figure B.23. Vegetated rock wall details (*USDA-SCS, 1992*).

Applications and Effectiveness

These systems are appropriate for use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness. Vegetated rock walls are useful where space is limited and natural rock is available.

Construction Guidelines

Live cuttings shall have a diameter of ½ to 1 inch and be long enough to reach beyond the rock structure into the fill or undisturbed soil behind. Rock used for the wall shall range from 8 to 24 inches in diameter. Large boulders shall be used for the base. Use the following guidelines for installation:

1. Starting at the lowest point of the slope, remove loose soil until a stable base (such as bedrock) is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.
2. Excavate the minimum amount from the existing slope to provide a suitable recess for the wall.
3. Place rocks with at least a three-point bearing on the foundation material or underlying rock course. They shall also be placed so that their center of gravity is as low as possible, with their long axis slanting inward toward the slope, if possible.
4. When a rock wall is constructed adjacent to an impervious surface, place a drainage system at the back of the foundation and outside the toe of the wall to provide an appropriate drainage outlet.
5. Overall height of the rock wall, including the footing, shall not exceed 5 feet.
6. A wall can be constructed with a sloping bench behind it to provide a base on which live branch cuttings shall also be tamped or placed into the openings of the rock wall during or after construction. The butt ends of the branches shall extend into the backfill or undisturbed soil behind the wall.
7. The live branch cuttings shall be oriented perpendicular to the slope contour with growing tips protruding slightly from the finished rock wall face (see Figure B.23).

Vegetated Structures

Vegetated structures are low walls or revetments at the foot of a slope that have plantings on the interposed benches. A structure at the foot of a slope protects the slope against undermining or scouring and provides slight buttressing. Low walls also allow regrading of the slope face to a more stable angle without excessive retreat at the crest. Vegetation planted on the crest of the wall and the slope face protects against erosion and shallow sloughing. For tiered structures, the roots of woody plants grow into the soil and backfill within the structure to bind them together. These systems are **NOT** soil bioengineering structures because the plant materials represent little or no reinforcement value to the structure.

Low Wall/Slope Face Plantings

Description – A low retaining structure at the foot of a slope makes it possible to flatten the slope and establish vegetation. Vegetation on the face of the slope protects it against surface erosion and shallow face sliding.

Materials and Installation – Several basic types of retaining structures can be used as low walls. The simplest type is a gravity wall that resists lateral earth pressures with its weight or mass. The following types of retaining structures can be classified as gravity walls:

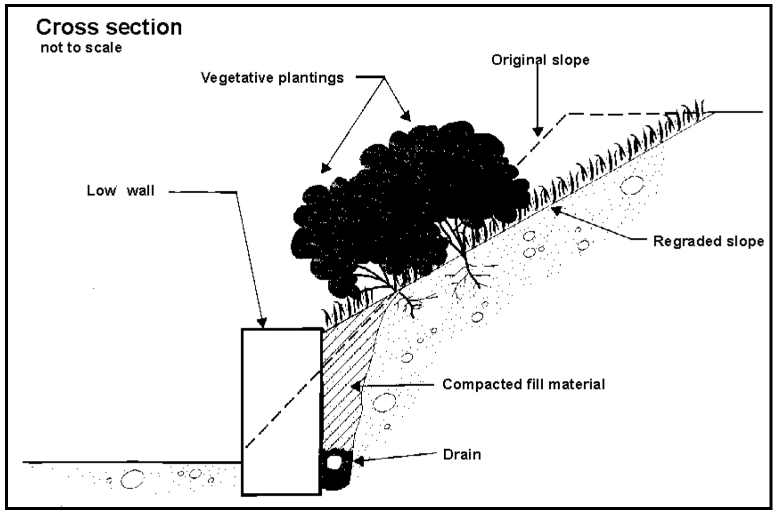


Figure B.24. A low wall with plantings above (*USDA-SCS, 1992*).

- Masonry and concrete walls
- Crib and bin walls
- Cantilever and counterfort walls
- Reinforced earth and geogrid walls

Each of these can be modified a number of ways to fit almost any condition or requirement. Figure B.24 depicts a low wall with vegetated slope.

Tiered Wall/Bench Plantings

Description – An alternative to a low wall with face planting is a tiered retaining wall system. This alternative effectively allows vegetation to be planted on slopes that would otherwise be too steep. Shrubs and trees planted on the benches screen the structure behind and lend a more natural appearance while tier roots permeate and protect the benches.

Almost any type of retaining structure can be used in a tiered wall system. A tiered wall system provides numerous opportunities to add vegetative values on steep slopes and embankments.

Perimeter Dike/Swale

Perimeter dike/swales are used to divert flows from entering a disturbed area, along tops of slopes to prevent flows from eroding the slope, or along the base of slopes to direct sediment-laden runoff to a trapping device. The perimeter dike/swale shall remain in place until the disturbed areas are permanently stabilized.

Design Criteria

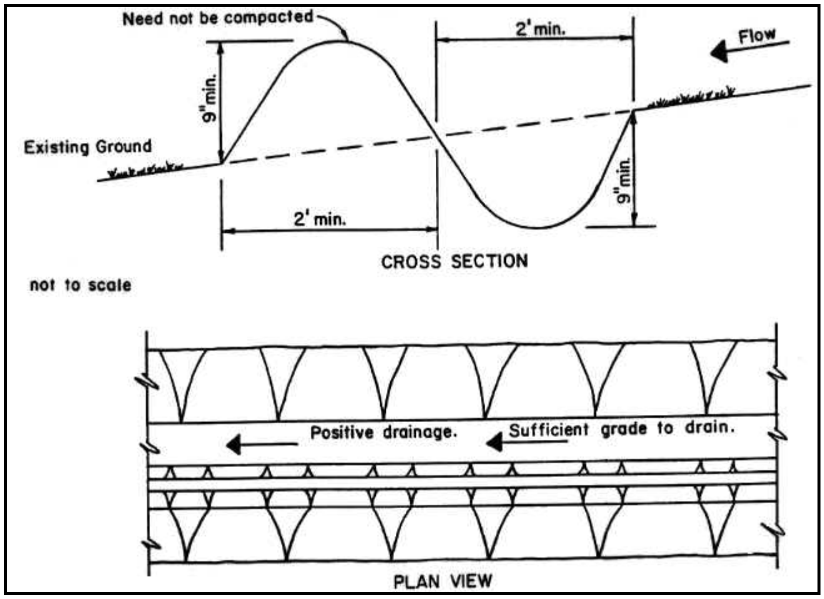


Figure B.25. Perimeter dike/swale details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

1. Use a perimeter dike/swale to convey runoff from contributing drainage areas of 2 acres or less. For drainage areas larger than 2 acres, see ***Diversions***' specifications.
2. The minimum height from the bottom of the swale to the top of the dike is 18 inches, and must be evenly divided between dike height and swale depth.
3. The width of the swale and the bottom width of the dike must both be a minimum of 2 feet (Figure B.25).
4. The maximum dike/swale grade shall not exceed 20%. The grade of the swale depends on topography, but shall be sufficient to drain to an adequate outlet.
5. Stabilize the disturbed area of the dike/swale within 10 days of installation, in accordance with specifications for ***Temporary Seeding*** and/or ***Mulch, Mats & Geotextiles***.
6. Do **NOT** build the perimeter dike/swale outside the property lines without obtaining legal easements from effected adjacent property owners.

Outlet

1. The perimeter dike/swale outlet shall function with a minimum of erosion.
2. Outlet diverted runoff from a protected or stabilized upland area directly onto an undisturbed, stabilized area.
3. Convey diverted runoff from a disturbed or exposed upland area to a sediment-trapping device such as a sediment trap, sediment basin, or to an area protected by one of these practices.

Construction Specifications

1. All perimeter dikes/swales shall have an uninterrupted positive grade to an outlet.
2. Convey diverted runoff from a disturbed area to a sediment-trapping device.
3. Outlet diverted runoff from an undisturbed area into an undisturbed, stabilized area at non-erosive velocity.
4. Excavate or shape the swale to line, grade and cross section as required to meet design criteria.
5. Stabilize the area disturbed by the dike/swale in accordance with ***Temporary Seeding*** and ***Mulch, Mat & Geotextiles*** specifications within 10 days of completion of dike/swale.
6. Periodic inspection and required maintenance must be provided after each heavy rain event.

Drainage Swales

Design Criteria

Table B.10. Design criteria for two swales serving different-sized drainage areas (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Parameter	Swale A	Swale B
Drainage Area	< 5 acres	5 - 10 acres
Bottom Width of Flow Channel	4 feet	6 feet
Depth of Flow Channel	1 foot	1 foot
Side Slopes	2:1 or flatter	2:1 or flatter
Grade	0.5% minimum 20% maximum	0.5% minimum 20% maximum

Table B.10 provides design criteria for drainage swales of two different sizes: Swale A is designed to transport runoff from a contributing drainage area less than 5 acres and Swale B is designed to transport runoff from a contributing drainage area 5 to 10 acres in size (Figure B.26). For drainage areas larger than 10 acres, refer to specifications for ***Diversions***.

Stabilization

Complete stabilization of the swale within 10 days of installation in accordance with the appropriate specifications for ***Temporary Seeding*** and/or ***Mulches, Mats & Geotextiles***. Stabilize the flow channel according to the criteria in Table B.11.

Table B.11. Flow channel stabilization criteria (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Channel Grade[1]	Swale A Flow Channel	Swale B Flow Channel
0.5 - 3.0%	seed and straw mulch/mats	seed and straw mulch/mats
3.1 - 5.0%	seed and straw mulch/mats	seed and cover with jute, excelsior, sod, or line with 2 inch stone
5.1 - 8.0%	seed and cover with jute, excelsior, or sod	line with high velocity erosion control mat, 4 - 8" rip-rap or recycled concrete equivalent[2]
8.1 - 20%	line with high velocity erosion control mat, 4 - 8" rip-rap or recycled concrete equivalent[2]	engineering design

[1] In highly erodible soils, as defined by the Virgin Islands Soil Survey, refer to the next higher slope grade for type of stabilization.
[2] Recycled concrete equivalent shall be concrete broken into the required size, containing no steel reinforcement.

Outlet

Swale outlets shall function with a minimum of erosion and dissipate runoff velocity before discharging off the site. The runoff shall be conveyed to a sediment-trapping device, such as a sediment trap or sediment basin, until the drainage area above the swale is adequately stabilized. However, if the swale is used to divert runoff around a disturbed area, a sediment-trapping device may not be needed. Figure B.27 provides another grassed swale design example for use along roadways.

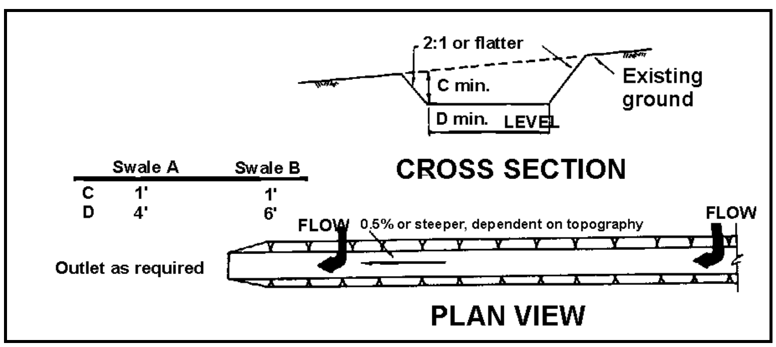


Figure B.26. Temporary drainage swale details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Construction Specifications

1. All temporary swales shall have uninterrupted positive grade to an outlet.
2. Convey diverted runoff from a disturbed area to a sediment-trapping device.
3. Outlet diverted runoff from an undisturbed area directly into an undisturbed, stabilized area at non-erosive velocity.
4. Remove and dispose of all trees, brush, stumps, obstructions, and other objectionable material so that they do not interfere with the functioning of the swale.

5. Excavate or shape the swale to line, grade, and cross section in accordance with the design criteria, and keep free of bank projections or any other irregularities that may impede normal water flow.
6. Compact fill with earth-moving equipment.
7. Place all soil removed and not needed for the project so that it will not interfere with the functioning of the swale.
8. Swale stabilization shall be according to that set forth in Table B.11.
9. Provide periodic inspection and required maintenance after each significant rain event.

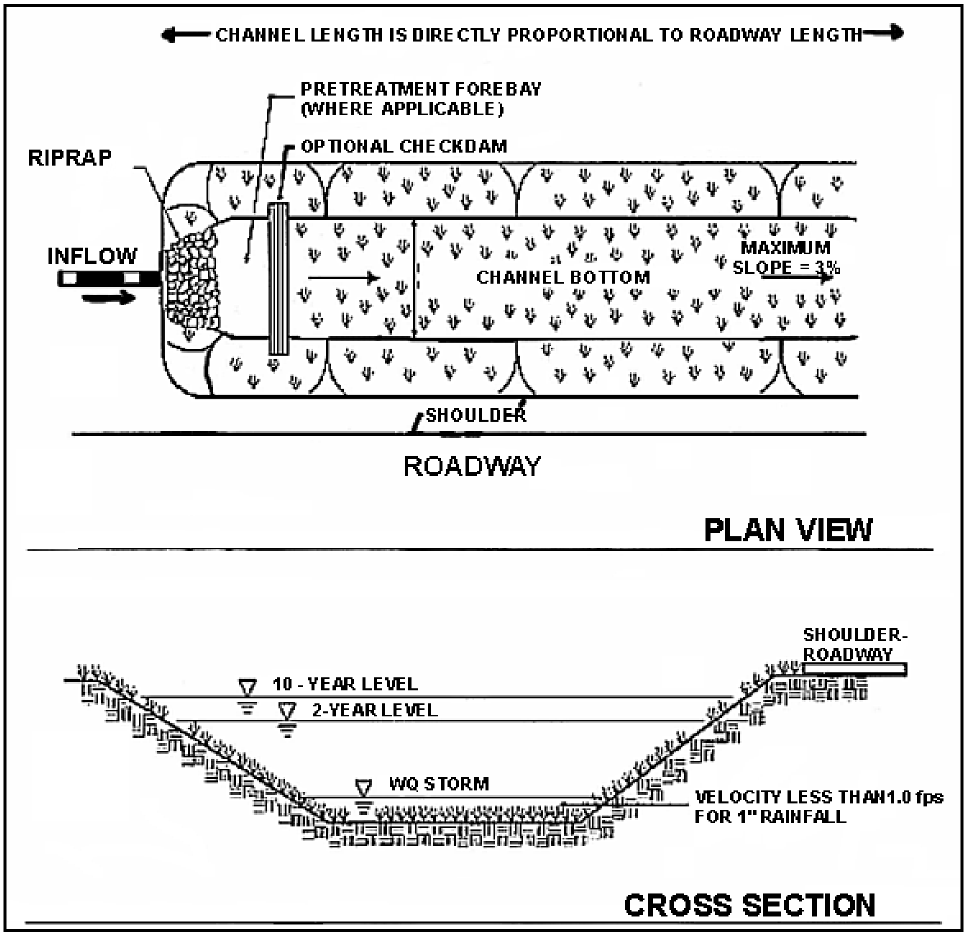


Figure B.27. Grassed drainage swale details (*Schueler, 1995*).

Temporary Storm Drain Diversion

Design Criteria

1. **Construction of a sediment trap or basin below a permanent storm drain outfall:** the storm drain system outfalls into a temporary basin or trap constructed below the permanent outfall channel.
2. **In-line diversion of storm drain at an inlet or manhole:** this diversion requires installing a pipe stub in the side of a manhole or inlet and temporarily blocking the permanent outfall pipe from that structure. A temporary outfall ditch or pipe may be used to convey stormwater runoff from the pipe stub to a sediment trap or basin. This method may be used just above a permanent outfall or prior to connecting into an existing storm drain system.
3. **Delay completion of the permanent storm drain outfall and temporarily divert storm flow into a sediment basin or trap:** and earth dike, swale or designed diversion, can be used depending on the drainage area to direct flow into a sediment basin or trap.
4. **Installation of a stormwater management basin early in the construction sequence:** install temporary measures to allow use as a sediment basin. Because these structures are designed to receive storm drain outfalls, diversion shall not be necessary.
5. Inlet protection is not required if storm drain diversions have been installed and are functioning properly.

Removal and Restoration

When areas contributing sediment to the storm drain system have been stabilized, restore the system to its planned use according to the following removal and restoration procedure:

1. Flush the storm drain system prior to removal of the trap or basin to remove any accumulated sediment.
2. Establish a permanent stabilized outfall channel as noted on engineering plans.
3. For sites where an inlet was modified, plug the temporary pipe stub and open the permanent outfall pipe.
4. Remove the temporary sediment control devices (traps, basins, dikes, swales, etc.).
5. Restore the area to grades shown on the engineering plan and stabilize with vegetative measures.
6. For basins that will be converted to stormwater management, remove the accumulated sediment, open the low flow orifice, and seed all disturbed areas in the basin to permanent vegetation.

Silt Fence

Conditions Where Practice Applies

Use of silt fences for sediment detention is subject to the following conditions: the maximum allowable slope lengths contributing runoff shall not exceed those listed in Table B.12. The slope shall be 25 percent or less – if the slope is greater than 25 percent, fences shall be located on 100-foot spacing; the maximum drainage area for overland flow to a silt fence shall not exceed ½-acre per 100 foot of fence; the fence shall counter-act erosion that occurs as sheet and rill erosion; and there is no concentration of water in a channel or other drainage way above the barrier.

Table B.12. Maximum allowable slope lengths contributing runoff to a silt fence (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Slope Steepness	Maximum Slope Length (feet)
2:1	50
3:1	75
4:1	125
5:1	175
Less than 5:1	200

Design Criteria

All silt fences shall be placed as close to the disturbed area as possible and the area below the fence must be undisturbed or stabilized. Details of the silt fence shall be shown on the plan, and shall contain the following requirements:

1. The type, size and spacing of fence posts.
2. The size of woven wire support fences.
3. The type of filter cloth used.
4. The method of anchoring the filter cloth.
5. The method of fastening the filter cloth to the fence support.
6. Where ends of the filter cloth come together, they shall be overlapped, folded and stapled to prevent sediment by-pass.

Fence Material Criteria

Silt Fence Cloth: Use filter fabric that is a pervious sheet of woven geotextile fabric consisting of long chain polymeric filaments or yarns such as polypropylene, polyethylene, polyester, polyamide, or polyvinylidene-chloride. Set the fabric so that the filaments or yarns retain their relative positions to each other. The filter fabric shall have a minimum filtering efficiency of 75 – 85 percent with a minimum standard tensile strength of 30 pounds/linear inch and minimum extra tensile strength of 50 pounds/linear inch at a maximum elongation of 20 percent. The fabric shall be resistant to commonly encountered chemicals, mildew, rot, insects, and rodents.

Fence Posts: The length shall be a minimum of 48 inches long. Wood posts will be of quality hardwood with a minimum diameter of 2 inches. Steel posts will be standard T- or U-section weighing not less than 1.33 pounds per linear foot.

Wire Fence: Woven wire fencing shall be a minimum 14½-gage with maximum 6-inch mesh opening.

Pre-fabricated Silt Fence: Pre-fabricated silt fences with posts attached are available. This fence is installed as described above. While this type of fence is cheaper and easier to install, it requires more maintenance in order to perform satisfactorily.

Construction Specifications

1. Space fence posts a maximum distance of 10' center-to-center.
2. Fasten woven wire fence securely to the upstream side of the fence posts by staples or wire ties spaced every 24" at top- and mid-sections.
3. Staple or securely fasten the filter cloth (geotextile) to the upstream side of the woven wire. Allow 6" to 12" of filter cloth to anchor into the soil at the bottom.
4. Overlap adjoining sections of filter cloth by 6" and fold.
5. Embed the filter cloth a minimum of 4" into the soil and compact the fill.
6. Frequently inspect the fence and replace promptly as needed. Sediment may also need to be removed from behind the cloth to maintain filtering capacity (see Figures B.28 and B.29).

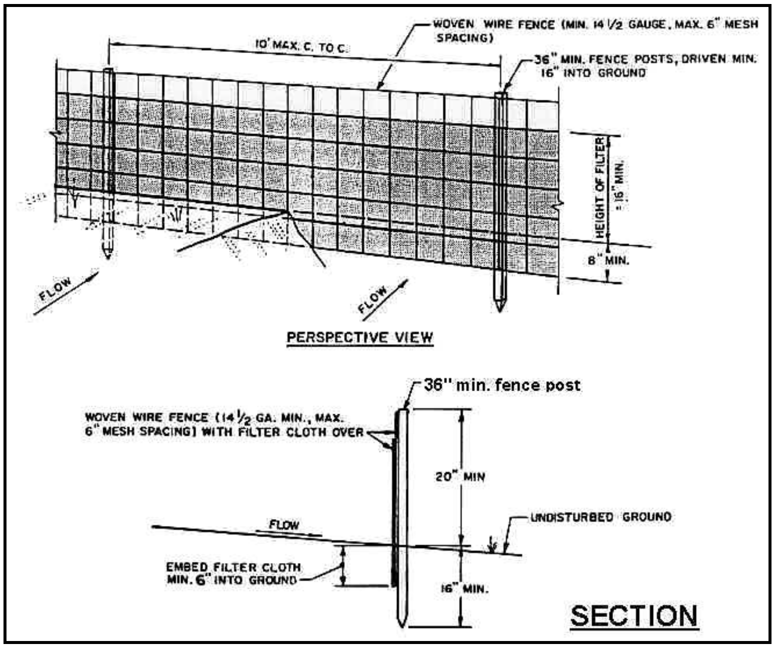


Figure B.28. Silt fence details (perspective and section views; *Empire State Chapter Soil & Water Conservation Society, 1997*).

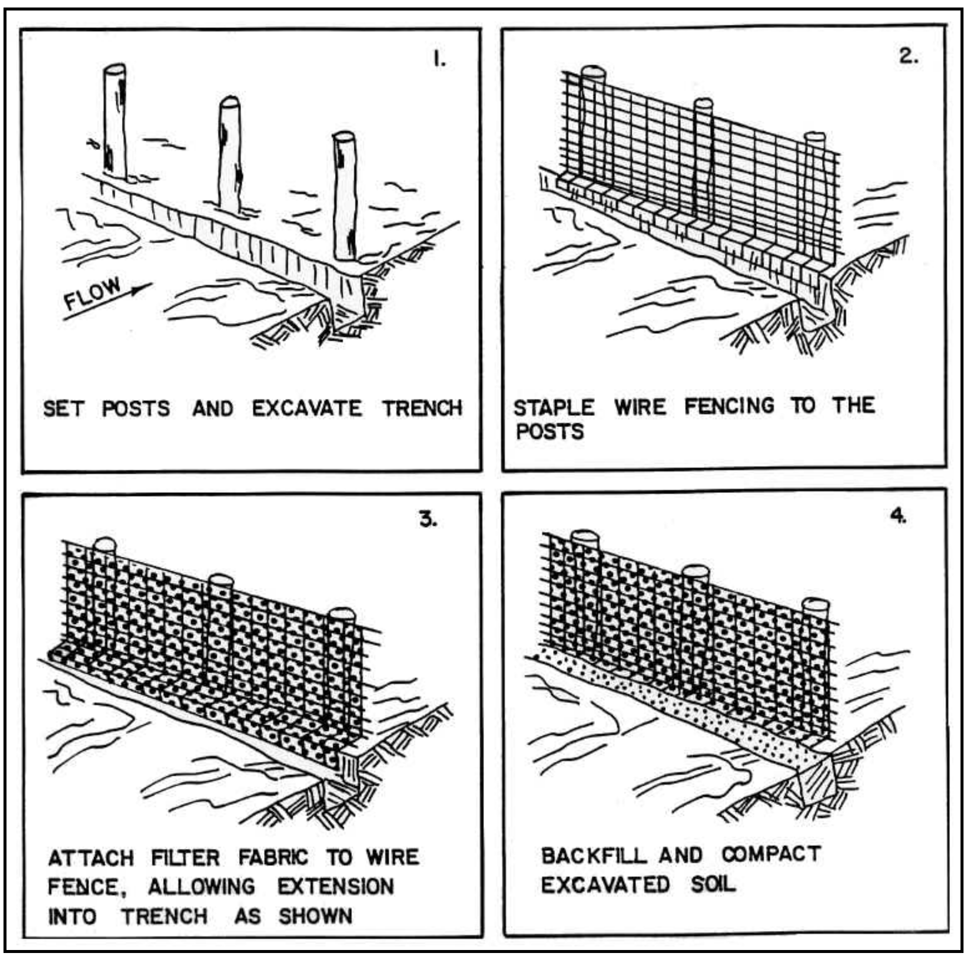


Figure B.29. A step-by-step procedure for building a silt fence (*USDA-SCS, 1993b*).

Stabilized Construction Entrance

Design Criteria and Construction Specifications

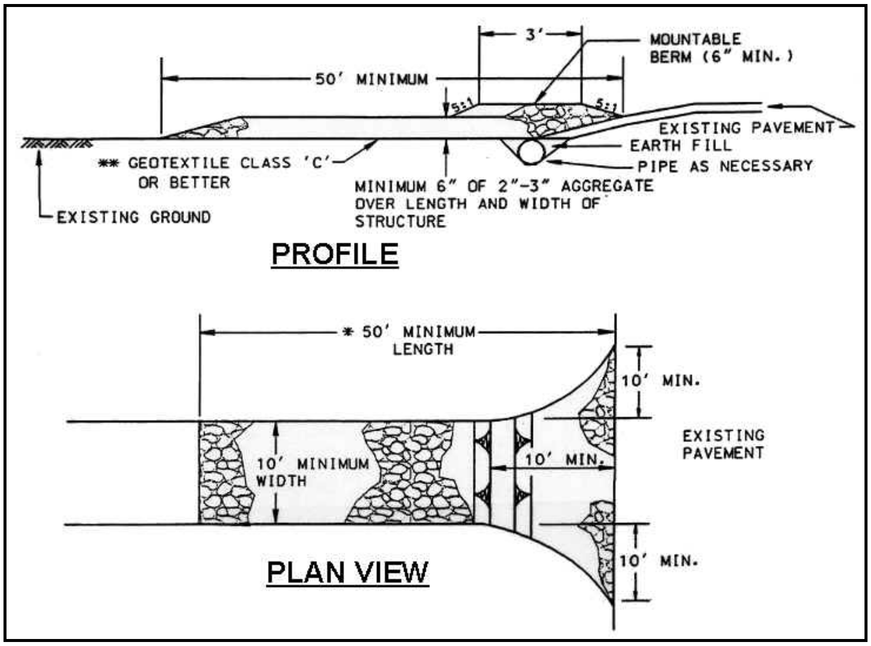


Figure B.30. Stabilized construction entrance details *(Maryland Department of the Environment, 1994)*.

1. **Length:** Minimum of 50 feet (30 feet for single residence lot), Figure B.30.
2. **Width:** 10- to 12-foot minimum, flared at the existing road to provide a turning radius.
3. Place geotextile over the existing ground prior to placing stone. Geotextile is not necessary for single-family residences.
4. **Stone:** Place crushed aggregate (2 to 3 inches) or recycled concrete equivalent (RCE) at least 6 inches deep over the length and width of the entrance.
5. **Surface Water:** Pipe all surface water flowing to or diverted toward construction entrances underneath the entrance. Protect the pipe installed under the construction entrance with a mountable berm. Size the pipe according to the drainage, with a minimum diameter of 6 inches. If piping is impractical, a mountable berm with 5:1 slopes may be used.
6. **Location:** Locate a stabilized construction entrance at every point where construction traffic enters or leaves a construction site. Vehicles leaving the site should travel over the entire length of the stabilized construction entrance.
7. The filter fabric used shall be resistant to commonly encountered chemicals, hydrocarbons, mildew, rot and rodents, and conform to the properties listed in Table B.13.
8. The construction entrance shall be maintained in a condition that will prevent tracking or flowing of sediment onto public rights-of-way. All sediment spilled, dropped, washed or tracked onto public rights-of-way must be removed immediately.

Table B.13. Geotextile fabric properties for stabilized constriction entrance (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Fabric Properties[1]	Light Duty[2] Roads Grade Subgrade	Heavy Duty[2] Haul Roads Rough Graded	Test Method
Grab Tensile Strength (pounds)	200	220	ASTM D1682
Elongation at Failure (%)	50	60	ASTM D1682
Mullen Burst Strength (pounds)	190	430	ASTM D3786
Puncture Strength (pounds)	40	125	ASTM D751 (modified)
Equivalent	40 - 80	40 - 80	US Std. Sieve
Opening Size	--	--	CW-02215
Aggregate Depth (inches)	6	10	--

[1] Fabrics not meeting these specifications may be used only when design procedure and supporting documentation are supplied to determine aggregate depth and fabric strength.
[2] Light Duty Road: Area sites that have been graded to subgrade and where most travel would be single axle vehicles and an occasional multi-axle truck.
[3] Heavy Duty Road: Area Sites with only rough grading, and where most travel would be multi-axle vehicles.

Check Dams

Design Criteria

1. Locate check dams so as to provide maximum velocity reduction. Place check dams in reasonably straight ditch sections to minimize erosion potential in channel bends.
2. All stone check dams should be keyed into the sides and bottom of the channel.
3. Maximum drainage area above the check dam shall not exceed 2 acres.
4. Height shall not exceed one-half the depth of the ditch or swale, and shall not be greater than 2 feet. Center shall be 9 inches lower than sides at natural ground elevation.
5. Side Slopes shall be 2:1 or less.
6. Space check dams so that the crest of the downstream dam is at the elevation of the toe of the upstream dam (see Table B.14). Spacing is determined by:

$$x = \frac{y}{S} \quad \text{[EQ. B-1]}$$

where: x = check dam spacing (feet)
y = check dam height (feet)
S = natural channel slope (feet/feet)

7. Use graded stone 2 to 15 inches in size.
8. Stabilize the overflow of the check dams to resist erosion that might be caused by the check dam.

Table B.14. Standard stone check dam design (*Maryland Department of the Environment, 1994*).

Slope	Spacing (feet)
2% or less	80
2.1% to 4%	40
4.1% to 7%	25
7.1% to 10%	15
over 10%	use lined waterway design

Construction Specifications

1. Construct swales and ditches in accordance with ***Drainage Swale*** specifications as provided in this Handbook.
2. Construct check dam of 4- to 7-inch stone. Place stone so that it completely covers the width of the channel and is keyed into the channel banks (Figure B.31).
3. Construct the top of the check dam so that the center is approximately 9 inches lower than the outer edges, forming a weir that water can flow across.
4. The maximum height of the check dam at the center shall not exceed 2 feet.
5. Line the upstream side of the check dam with around one foot of ¾" to 1½-inch aggregate.
6. Extend stone a minimum of 1 ½ feet beyond ditch banks to prevent cutting around the dam.

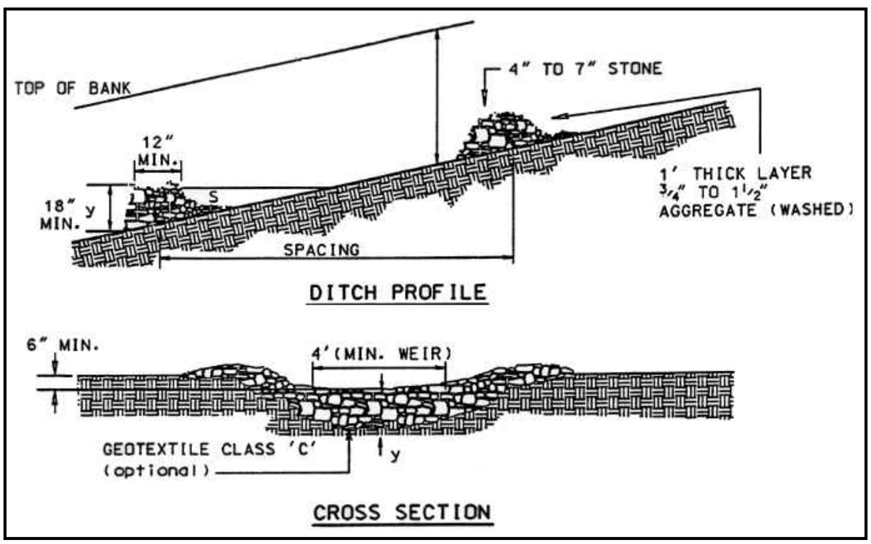


Figure B.31. Check dam details (*Maryland Department of the Environment, 1994*).

7. Protect the channel downstream of the lowest check dam from scour and erosion with stone or liner as appropriate.
8. Ensure that channel openings, such as culvert entrances, below check dams are not subject to damage or blockage from displaced stones.
9. Remove accumulated sediment when it has built up to one-half of the original height of the weir crest.

Triangular Dikes/Berms can be used in place of stone to form check dams. Materials such as Triangular Silt Dike™ (www.tri-siltdike.com) or EnviroBerm® (www.cascade.ab.ca) are barrier systems that can be used as check dams or perimeter barriers (in place of silt fences or perimeter dikes). Specifications vary by product, so check manufacturer guidelines for specifics for each material. An example check dam installation for triangular dikes is provided in Figure B.32.

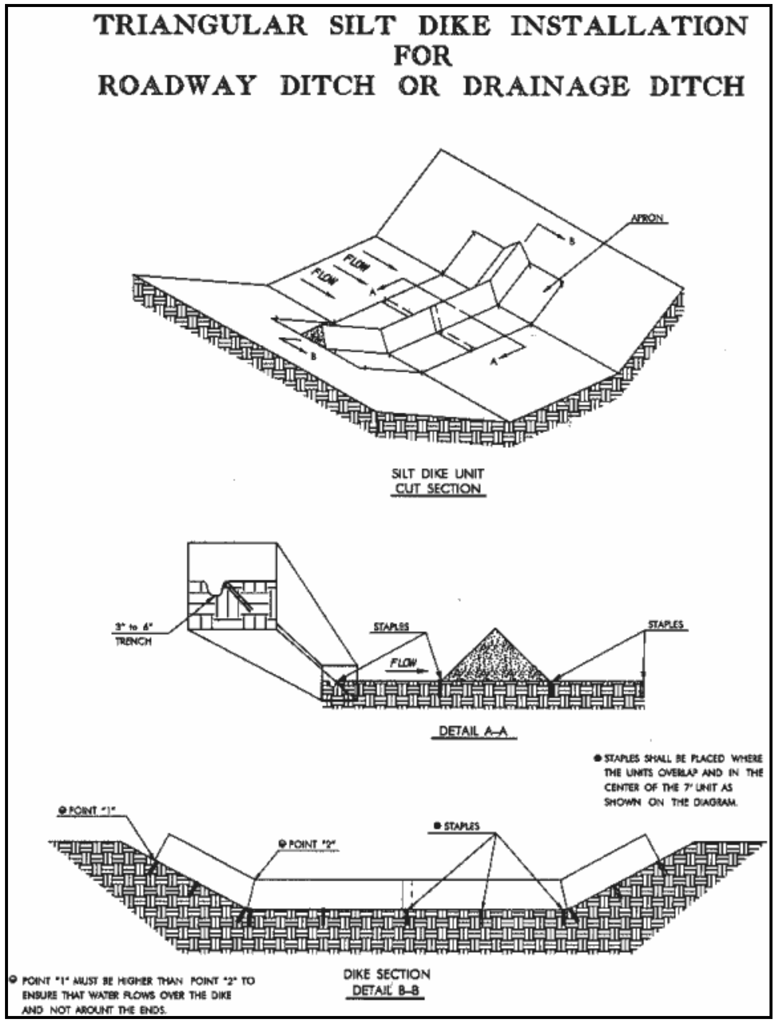


Figure B.32. Specifications for a triangular silt dike™ used as a check dam (*Triangular Silt Dike™, 2001*).

Sediment Traps

Temporary sediment traps are appropriate at the outlet of perimeter controls installed during the first stage of construction; at the outlet of any structure that concentrates sediment-laden runoff (discharge point of diversions, channels, slope drains, or other runoff conveyances); or above a storm water inlet that is in line to receive sediment-laden runoff.

Design Criteria

1. Temporary sediment traps may be built by excavation alone or by excavation in combination with an embankment.
2. Sediment traps are temporary measures and shall not be planned to remain in place longer than between 18 and 24 months.
3. The contributing drainage area for sediment traps varies between 2 and 5 acres, depending upon the type of sediment trap used.
4. Locate sediment traps so that they can be installed prior to grading or filling in the drainage area they are to protect. Traps must not be located any closer than 20 feet from a proposed building foundation if the trap is to function during building construction. Locate traps so as to obtain maximum storage benefit from the terrain, for ease of clean-out, and disposal of the trapped sediment.
5. The volume of a sediment trap, as measured at the elevation of the crest of the outlet, should be at least 3600 cubic feet per acre of drainage area. The volume of a constructed trap shall be calculated using the following approximation:

$$volume\ (ft^3) = 0.4 \times surface\ area\ (ft^2) \times maximum\ depth\ (ft) \qquad [EQ.\ B\text{-}2]$$

6. Sediment trap embankments shall not exceed 5 feet in height, as measured at the low point of the original ground along the centerline of the embankment. (See Table B.15 for an illustration of the typical relationship between embankment height, the height of the outlet, and the width at the top of the embankment.) The recommended minimum embankment top width is between 2 feet and 5 feet with side slopes of 2:1 or flatter. Compact the embankment with heavy equipment during construction. The elevation of the top of any dike carrying stormwater to a sediment trap will be equal to or exceed the maximum height of the outlet structure along the entire length of the trap.
7. Carry out all excavation operations so as to minimize resultant erosion and water pollution. Excavated portions of sediment traps shall have 1:1 or flatter slopes.
8. Design, construct and maintain the outlet so that sediment does not leave the trap and so that erosion at or below the outlet does not occur. Sediment traps must outlet onto stabilized (preferably undisturbed) ground, into a watercourse, stabilized channel, or into a storm drain system.
9. Recommended weir length is between a minimum of 4 feet and a maximum of 12 feet.

Table B.15. Embankment height vs. outlet height and embankment width (*U.S. EPA, 1992*).

Embankment Height (feet)	Outlet Height (feet)	Top Width of Embankment (feet)
1.5	0.5	2.0
2.0	1.0	2.0
2.5	1.5	2.5
3.0	2.0	2.5
3.5	2.5	3.0
4.0	3.0	3.0
4.5	3.5	4.0
5.0	4.0	4.5

Construction Specifications

Sediment traps can be built as either single or double chamber systems (Figures B.33 and B.34 , Fifield, 1996). There are six different types of sediment traps (primarily based on outlet design) that can be installed depending upon the function needed, the location, and drainage area. These types are: pipe outlet, rip-rap outlet, stone outlet, swale outlet, grass outlet, and storm inlet sediment traps.

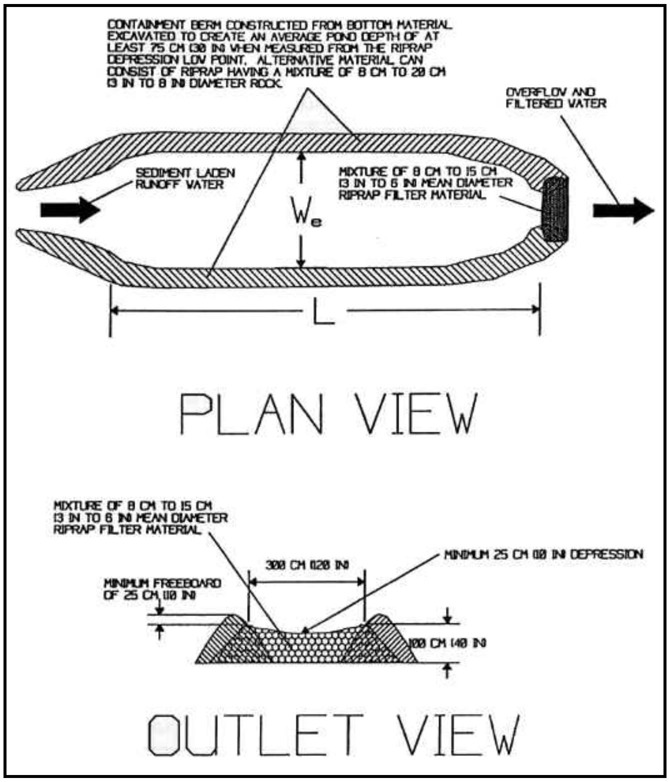


Figure B.33. Single chamber sediment trap (*Fifield, 1996*).

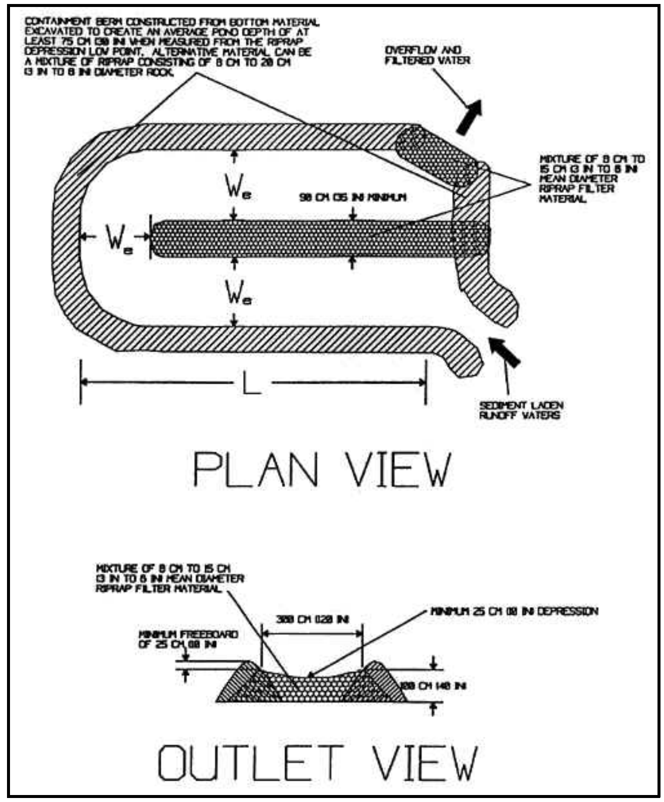


Figure B.34. Double chamber sediment trap (*Fifield, 1996*).

Pipe Outlet Sediment Trap

A pipe outlet sediment trap is formed by embankment or excavation. The outlet for the trap is through a perforated riser and a pipe through the embankment (Figure B.35).

1. Clear, grub and strip the area under the embankment of any vegetation and root mat. Also clear the pool area.
2. The fill material for the embankment shall be free of roots or other woody vegetation as well as large stones, rocks, organic material, or other objectionable material. Compact the embankment by traversing with equipment while it is being built.
3. The volume of sediment storage should be 3600 cubic feet per acre of contributory drainage.
4. Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Deposit removed sediment in a suitable area so that it will not erode.
5. Inspect the trap after each heavy rainfall and repair as needed.
6. Carry out construction operations so that erosion and water pollution are minimized.
7. Remove the trap and stabilize the area when the drainage area has been properly stabilized.
8. All fill slopes shall be 2:1 or flatter; cut slopes 1:1 or flatter.
9. Make all pipe connections water tight.

10. The outlet pipe and riser shall be made of corrugated metal. The top of the embankment shall be at least 1½ feet above the crest of the riser.
11. The top two-thirds of the riser shall be perforated with 1-inch nominal diameter holes or slits spaced 6 inches apart vertically and horizontally placed in the concave portion of the corrugated pipe. No holes will be allowed within 6 inches of the horizontal barrel.
12. Wrap the riser with ¼- to ½-inch hardware cloth wire and then wrap with filter cloth (having an equivalent sieve size of #40-80). Extend the filter cloth 6 inches above the higher hole and 6 inches below the lowest hole. Overlap, fold and staple ends of filter cloth where they come together, to prevent bypass.
13. Use straps or connecting bands to hold the filter cloth and wire fabric in place. Place these at the top and bottom of the cloth.
14. Hand-compact fill material around the pipe spillway in 4-inch layers. Place a minimum 2 feet of hand-compacted backfill over pipe spillway before crossing it with construction equipment.
15. Anchor the riser with either a concrete base or steel plate base to prevent flotation. For concrete base, the thickness shall be 12 inches with the riser embedded 9 inches. Attach a ¼-inch minimum thickness steel plate to the riser by a continuous weld around the bottom to form a water-tight connection. Then place 2.5 feet of stone, gravel, or tamped earth on the plate. Square base measurement shall be the riser diameter plus 24 inches.
16. Limit pipe outlet sediment traps to a 5-acre maximum drainage area. Pipe outlet traps may be interchanged with stoned outlet or rip-rap outlet traps, provided that these are constructed in accordance with their respective specifications as outlined in this Handbook.
17. Select pipe diameter using Table B.16.

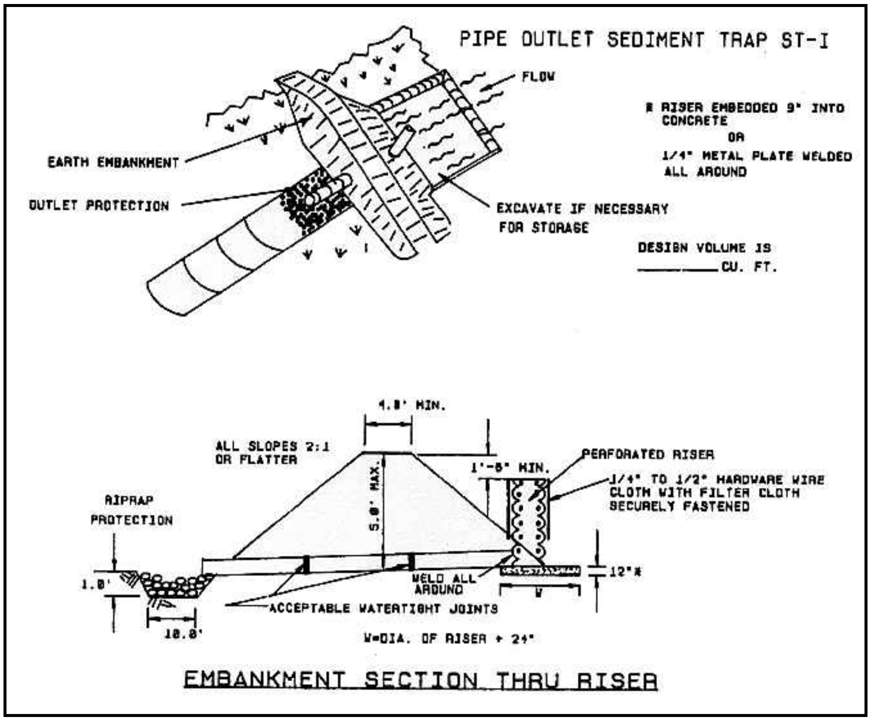


Figure B.35. Pipe outlet sediment trap details (construction specification should be attached to this detail to complete design; *Empire State Chapter Soil & Water Conservation Society, 1997*).

Table B.16. Pipe diameter based upon maximum contributing drainage area (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Minimum Barrel Diameter (inches)[1]	Minimum Riser Diameter (inches)[1]	Maximum Drainage Area (acres)
12	15	1
15	18	2
18	21	3
21	24	4
21	27	5

[1] Barrel diameter may be the same size as riser diameter.

Rip-rap Outlet Sediment Trap

A rip-rap outlet sediment trap is formed by excavation and embankment. The trap outlets through a partially-excavated channel lined with rip-rap (Figure B.36). The outlet discharges onto a stabilized area or to a stable watercourse. See Table B.17 for necessary channel depth and weir length for a given contributing drainage area.

1. Clear and grub area under embankment and strip area of any vegetation and root mat. Clear the pool area.

2. The fill material for the embankment shall be free of roots or other woody vegetation as well as large stones, rocks, organic material, or other objectionable material. Compact the embankment by traversing with equipment while it is being built. The maximum height of the embankment shall be 5 feet, measured at centerline of embankment.
3. All fill slopes shall be 2:1 or flatter; cut slopes 1:1 or flatter.
4. Elevation of the top of any dike directing water into trap must equal or exceed the height of embankment.
5. Compute storage area provided by calculating the volume available behind the outlet channel up to an elevation of 1 foot below the level weir crest.
6. Place the filter cloth over the bottom and sides of the outlet channel prior to placement of stone. Sections of fabric must overlap at least 1 foot with section nearest the entrance placed on top. Embed fabric at least 6 inches into existing ground at the entrance of the outlet channel.
7. Use 4- to 8-inch stone (rip-rap) in the outlet channel. To provide a filtering effect, embed a layer of filter cloth 1 foot with the section nearest the entrance placed on top. Embed the fabric at least 6 inches into existing ground at the entrance of the outlet channel.

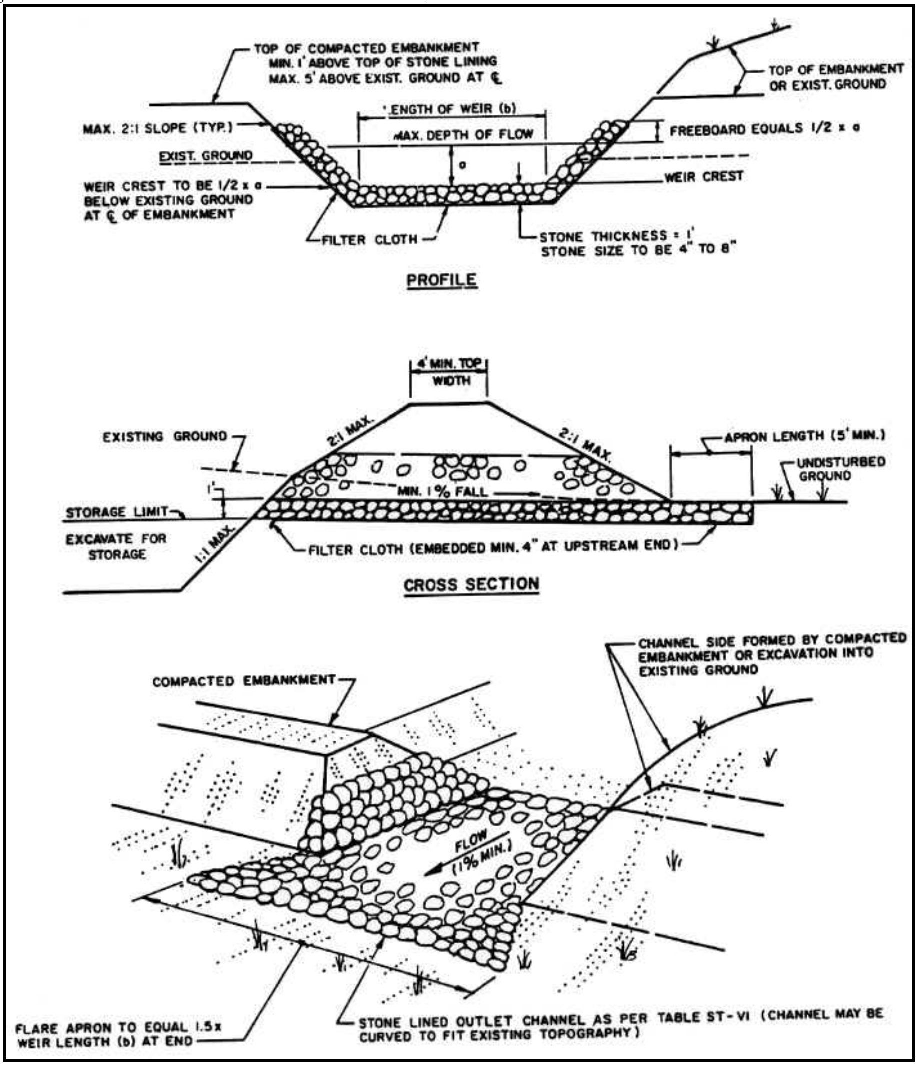


Figure B.36. Rip-rap outlet sediment trap details *(Empire State Chapter Soil & Water Conservation Society, 1997*).

8. Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to ½ the design depth of the trap. Deposit removed sediment in a suitable area so that it will not erode.
9. Inspect the structure after each rain and make repairs as needed.
10. Carry out construction operations so that resulting erosion and water pollution are minimized.
11. Maximum contributing drainage area to sediment trap shall be 15 acres.
12. Remove the sediment trap and stabilize the area when the remaining drainage area has been properly stabilized.

Table B.17. Channel depth and weir length for given contributing drainage areas (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Contributing Drainage Area (acres)	Channel Depth (a) (feet)	Weir Length (b) (feet)
1	1.5	4.0
2	1.5	5.0
3	1.5	6.0
4	1.5	10.0
5	1.5	12.0
6	1.5	14.0
7	1.5	16.0
8	2.0	10.0
9	2.0	10.0
10	2.0	12.0
11	2.0	14.0
12	2.0	14.0
13	2.0	16.0
14	2.0	16.0
15	2.0	18.0

Stone Outlet Sediment Trap

A stone outlet sediment trap is formed by an embankment or excavation. The trap outlets over a stone section placed on level ground (Figure B.37). Stone outlet traps may be interchanged with pipe or rip-rap outlet traps, provided they are constructed in accordance with their respective specifications in this Handbook.

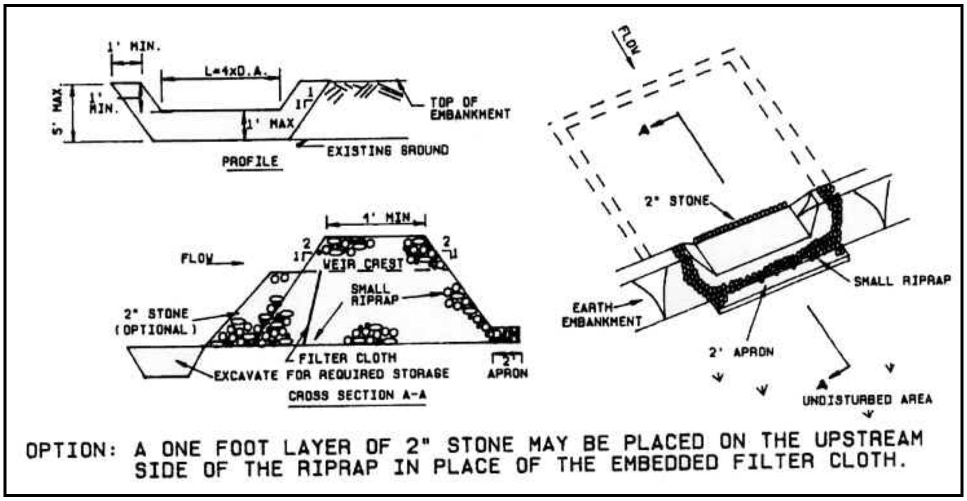


Figure B.37. Stone outlet sediment trap details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

1. Clear and grub the area under the embankment and strip area of any vegetation and root mat. Clear the pool area.
2. The fill material for the embankment shall be free of roots or other woody vegetation as well as large stones, rocks, organic material, or other objectionable material. Compact the embankment by traversing with equipment while it is being constructed.
3. Volume of sediment storage shall be 3600 cubic feet per acre of contributory drainage.
4. All cut and fill slopes shall be 2:1 or flatter.
5. The outlet crest (top of stone in weir section) shall be level, at least 1 foot below the top of the embankment or no more than 1 foot above the ground beneath the outlet.
6. To provide more efficient trapping, embed a layer of filter cloth 1 foot back into the upstream face of the outlet or place a 1-foot thick layer of 2-inch or finer aggregate on the upstream face of the outlet.
7. Use small (4- to 8-inch) rip-rap in the outlet along with a 1-foot thickness of 2-inch aggregate placed on the up-grade side of the small rip-rap or embed filter cloth in the rip-rap.
8. The minimum length of the outlet shall be 4 times the contributing drainage area.
9. Remove sediment and restore trap to its original dimensions when the sediment has accumulated to ½ the design depth of the trap. Deposit removed sediment in a suitable area so that it will not erode.
10. Inspect the structure after each rain and make repairs as needed.
11. Carry out construction operations so that resulting erosion and water pollution are minimized.
12. Maximum contributing drainage area to sediment trap shall be 5 acres.
13. Remove the sediment trap and stabilize the area when the remaining drainage area has been properly stabilized.

Swale Outlet Sediment Trap

A swale outlet sediment trap is built by over-excavating a swale or drainage ditch. The outlet is controlled by the invert of the downstream swale (Figure B.38). These traps are placed in surface drain ditches at the edge of the property, before a waterway at the end

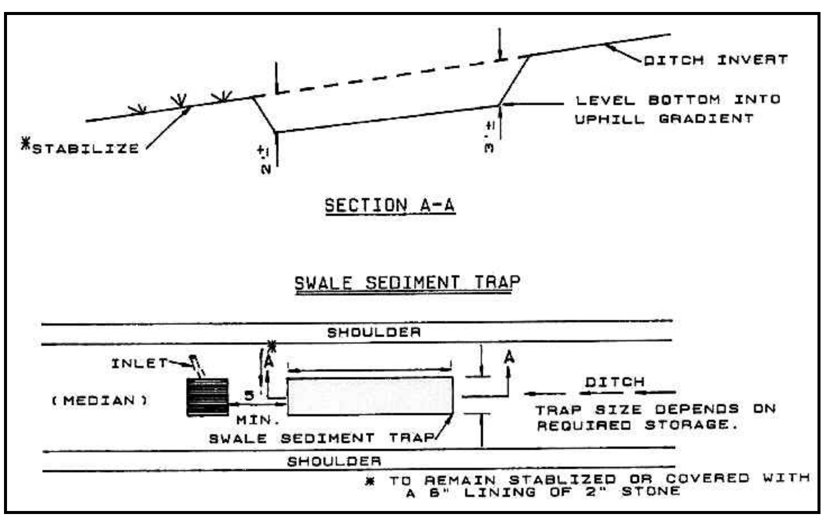


Figure B.38. Swale outlet sediment trap details *(Empire State Chapter Soil & Water Conservation Society, 1991*).

of cut sections, or immediately before ditch inlets or stabilized outlets. Use a swale trap only where no other device is feasible.

1. Construct the swale trap in accordance with the dimensions provided on the design drawings or size to provide the minimum sediment storage necessary – 3600 cubic feet per acre of contributing drainage area.
2. Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Deposit removed sediment in a suitable area so that it will not erode.
3. Inspect the structure after each rain and make repairs as needed.
4. Carry out construction operations so that resulting erosion and water pollution are minimized.
5. Remove the sediment trap and stabilize the area when the remaining drainage area has been properly stabilized. Properly backfill the trap and reconstruct the swale or ditch.
6. Maximum contributing drainage area to sediment trap shall be 2 acres.

Grass Outlet Sediment Trap

A grass outlet sediment trap is constructed by excavating soil to create a holding area. The trap has a discharge point over natural existing grass (Figure B.39).

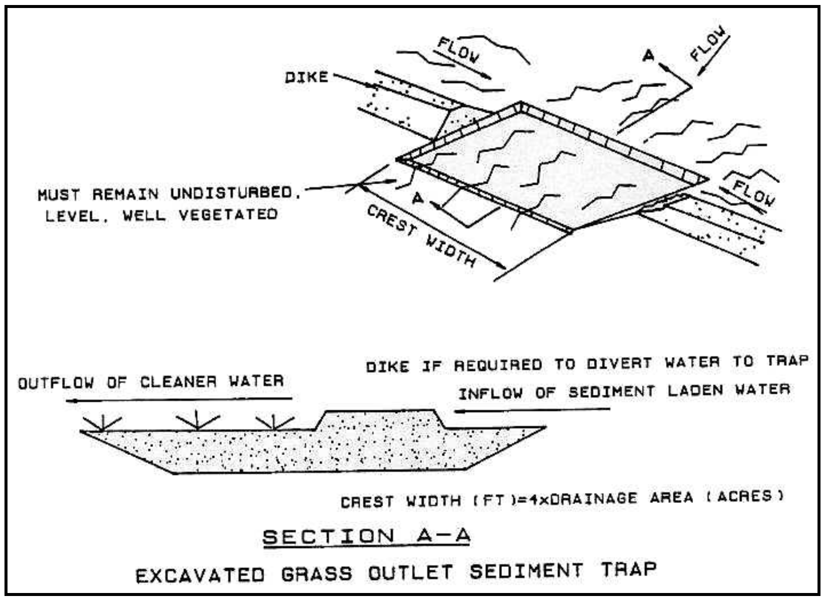


Figure B.39. Grass outlet sediment trap details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

1. Volume of sediment storage shall be 3600 cubic feet per acre of contributing drainage area.
2. Minimum crest width (or outlet length) shall be 4 times drainage area and a minimum length of 4 feet.
3. Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Deposit removed sediment in a suitable area so that it will not erode.
4. Inspect the structure after each rain and make repairs as needed.
5. Keep the outlet free of any restrictions to flow.
6. The outlet lip shall remain undisturbed and level.
7. Carry out construction operations so that erosion and water pollution are minimized.
8. Remove the sediment trap and stabilize the area when the remaining drainage area has been properly stabilized.
9. All cut slopes shall be 1:1 or flatter.
10. Maximum contributing drainage area to sediment trap shall be 5 acres.

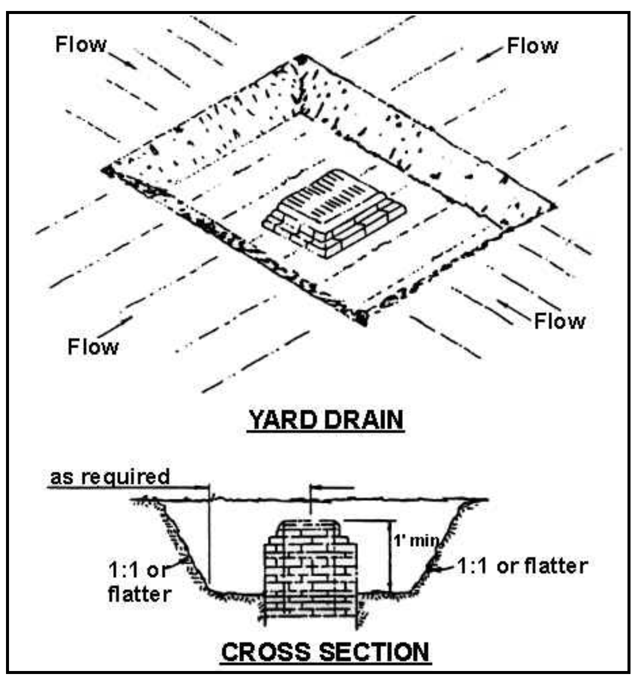


Figure B.40. Storm inlet sediment trap details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Storm Inlet Sediment Trap

A storm inlet sediment trap is formed by excavation on natural ground that discharges through an opening in a storm drain inlet structure (Figure B.40). This opening can either be the inlet opening or a temporary opening made by omitting bricks or blocks in the inlet.

1. Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to one-half the design depth of the trap. Deposit removed sediment in a suitable area so that it will not erode.
2. Volume of sediment storage shall be 3600 cubic feet per acre of contributing drainage area, measured at the elevation of the crest of the outlet.
3. Inspect the structure after each rain and make repairs as needed.
4. Carry out construction operations so that erosion and water pollution are minimized.
5. Remove the sediment trap and stabilize the area when the remaining drainage area has been properly stabilized.
6. All cut slopes shall be 1:1 or flatter.
7. Maximum contributing drainage area to sediment trap shall be 3 acres.

Maintenance

Remove sediment and restore the trap to its original dimensions when the sediment has accumulated to ½ of the design depth of the trap. Deposit sediment removed from the trap in a protected area and so that it will not erode. Repair embankment and rock filters, as necessary.

Temporary Sediment Basin

Scope of Practice

These criteria and specifications apply to the installation of temporary sediment basins on sites where: (a) failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities; (b) the drainage area does not exceed 100 acres; and (c) the basin is to be removed within 36 months after the beginning of construction of the basin.

Table B.18. Classification of temporary sediment basins (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Class	1	2
Maximum drainage area (acres)	100	100
Maximum height[1] of dam (feet)	10	15
Minimum embankment top width (feet)	8	10
Embankment side slopes	2:1 or less	2 ½ :1 or less
Anti-seep collar required	yes	yes

[1] Height is measured from the low point of original ground along the centerline of dam to the top of the dam.

Permanent sediment basins (lasting longer than 36 months) or temporary sediment basins exceeding the requirements provided in Table B.18 shall be designed and constructed to conform to USDA Natural Resources Conservation Service (NRCS) Standard and Specification No. 378 for Ponds in the *National Handbook of Conservation Practices* (USDA-SCS, 1988). Standard sediment basin designs can be used for drainage areas of 10 or 20 acres. (See Figures B.41 and B.42 for details.)

Design Criteria

Location

Locate the sediment basin to obtain the maximum storage benefit from the terrain and for ease of maintenance. It should be located to minimize interference with construction activities and utilities. Sediment basins should be located so that storm drains may outfall or be diverted into the basin. Do **NOT** locate sediment basins in natural drainage channels (guts).

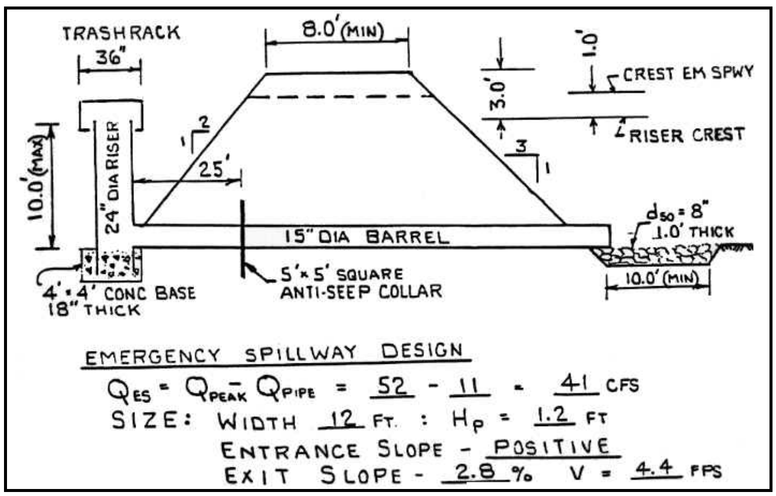


Figure B.41. Standard sediment basin I details (*Empire State Chapter Soil & Water Conservation Society, 1991*).

Basin Size

The sediment storage volume of the basin, as measured from the bottom of the basin to the elevation of the crest of the principal spillway shall be at least 3,600 cubic feet per acre of disturbed area draining to the basin. 3,600 cubic feet is equivalent to 1 inch of sediment per acre of drainage area. The entire drainage area should be used for this computation, rather than the disturbed area above, in order to maximize trapping efficiency.

Conditions Where Sediment Basin I Applies

1. Drainage area to the basin is 10 acres or less.
2. An emergency spillway **is** required.
3. One anti-seep collar shall be used and placed 25 feet from the riser.
4. Watertight bands shall be used.

5. All pipe material shall be of good quality with no holes.
6. Volume of storage computed is 3,600 ft³/acre of drainage area.

Conditions Where Sediment Basin II Applies

1. Drainage area to the basin is 20 acres or less.
2. An emergency spillway **is** required.
3. One anti-seep collar shall be used and placed 25 feet from the riser.
4. Watertight bands shall be used.
5. All pipe material shall be of good quality with no holes.
6. Volume of storage computed is 3,600 ft³/acre of drainage area.

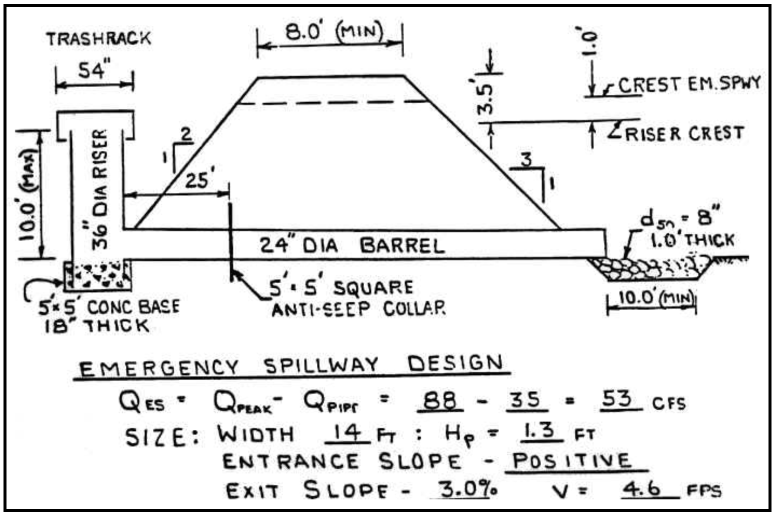


Figure B.42. Standard sediment basin II details (*Empire State Chapter Soil & Water Conservation Society, 1991*).

Sediment basins shall be cleaned out when they are 50 percent full, by volume. In no case shall the sediment be allowed to build up higher than one foot below the principal spillway crest. The elevation corresponding to the maximum allowable sediment level shall be determined and indicated in the design data as a distance below the top of the riser and shall be clearly marked on the riser. The basin dimensions necessary to obtain the required basin volume shall be clearly shown on the plans.

Basin Shape

The designer of a sediment basin is encouraged to incorporate the following features:

1. Length to width ratio greater than 2:1, where length is the distance between the inlet and outlet.
2. A wedge shape with the inlet located at the narrow end.

Spillway Design

Runoff shall be computed by the method outlined in Chapter 6 of this Handbook or by TR-55, *Urban Hydrology for Small Watersheds* (USDA-SCS, 1986). Runoff calculations shall be based upon the worst soil cover conditions expected to prevail in the contributing drainage area during the anticipated effective life of the structure. The combined capacities of the principal and emergency spillway shall be sufficient to pass the peak rate of runoff from a 10-year frequency storm. (See Figure B.43 at the end of this section for Pipe Spillway Design details and instructions.)

1. **Principal Spillway:** A spillway consisting of a vertical pipe or box-type riser joined (with a watertight connection) to a pipe (barrel) that extends through the embankment and outlets beyond the downstream toe of the fill. The minimum capacity of the principal spillway shall be 0.3 cubic feet per second (cfs) per acre of drainage area when the water surface is at the emergency spillway crest elevation. For those basins with no emergency spillway, the principal spillway shall have the capacity to handle the peak flow from a 10-year frequency storm. The minimum size of the barrel shall be 8 inches in diameter. See Figures B.44, B.45, and B.46 for principal spillway sizes and capacities.
   a. <u>Crest elevation:</u> When used in combination with an emergency spillway, the crest elevation of the riser shall be a minimum one foot below the elevation of the control section of the emergency spillway.

b. **Watertight riser and barrel assembly:** The riser and all pipe connections shall be completely watertight, except for the inlet opening at the top or a de-watering opening, and shall not have any other holes, leaks, rips or perforations in it.

c. **De-watering the basin:** There are two stages of de-watering the basin: (i) de-watering the detention pool that is below the crest of the riser and above the surface of the trapped sediment; and (ii) de-watering the sediment itself that will have a high water content to the point of being "soupy."
   i. Individual de-watering methods may be dictated by the intended use of the basin, i.e., sediment, fly ash, or other special materials, that are to be trapped and retained within the basin. If a de-watering device is needed it shall be included in the sediment basin plans submitted for approval and shall be installed during construction of the basin.
   ii. De-watering shall be done in such a manner as to remove the relatively clean water without removing any appreciable quantities of floating debris or sediment. De-watering sediments trapped in a basin is often advantageous to the developer or contractor. Relatively dry material can be handled with on-site equipment rather than expensive draglines often needed to handle wet sediments. Usually, the detention pool may be de-watered by a siphon installed on the riser, mechanical pumping, and surface or subsurface drains. For details on methods of de-watering, see Figure B.47.
   iii. De-watering the sediment is not required, but facilitates handling of the material. One very successful means of doing this is by use of a de-watering device.

d. **Anti-vortex device and trash rack:** An anti-vortex device and trash rack shall be securely installed on top of the riser and shall be the concentric type as shown in Figure B.48 and Table B.19.

e. **Base:** The riser shall have a base attached with a watertight connection and shall have sufficient weight to prevent flotation of the riser. Two approved bases for risers 10 feet or less in height are: 1) a concrete base 18 in. thick with the riser embedded 9 inches in the base, or 2) a ¼-inch minimum thickness steel plate attached to the riser by a continuous weld around the circumference of the riser to form a watertight connection. The plate shall have 2.5 feet of stone, gravel, or compacted earth placed on it to prevent flotation. In either case, each side of the square base shall be twice the riser diameter. For risers greater than 10 feet high, calculations shall be made to design a base that will prevent flotation. The minimum safety factor shall be 1.20 (downward forces = 1.20 x upward forces). See Figure B.49 for details.

f. **Anti-seep collars:** Anti-seep collars shall be installed around all conduits through earth fills of impoundment structures according to the following criteria:
   i. Collars shall be placed to increase the seepage length along the conduit by a minimum of 15 percent of the pipe length located within the saturation zone.
   ii. Collar spacing shall be between 5 and 14 times the vertical projection of each collar.
   iii. All collars shall be placed within the saturation zone.
   iv. The assumed normal saturation zone (phreatic line) shall be determined by projecting a line at a slope of 4:1 from the point where the normal water (riser crest) elevation touches the upstream slope of the fill to a point where this line intersects the invert of the pipe conduit. All fill located within this line may be assumed as saturated.

When anti-seep collars are used, the equation for revised seepage length becomes:

$$2\,(N)\,(P) = 1.15\,(L_s)\;;\; N = \frac{(0.075)\,(L_s)}{P} \qquad \textit{[EQ. B-3]}$$

where: L_s = saturated length; length (in feet) of pipe between riser and intersection of phreatic line and pipe invert.
N = number of anti-seep collars.
P = vertical projection of collar from pipe (feet).

v. All anti-seep collars and their connections shall be watertight. See Figures B.50 and B.51 for anti-seep collar design, and Figure B.52 for construction details.

g. **Outlet:** An outlet shall be provided, including a means of conveying the discharge in an erosion-free manner to an existing stable channel. Where discharge occurs at the property line, drainage easements will be obtained in accordance with DPNR requirements. Adequate notes and references will be shown on the erosion and sediment control plan. Protection against scour at the discharge end of the pipe spillway shall be provided. Measures may include impact basin, rip-rap, revetment, excavated plunge pools, or other approved methods. See specifications for ***Rock Outlet Protection***.

h. **Emergency Spillways:** The entire flow of the emergency spillway shall be constructed in undisturbed ground (not fill). The emergency spillway cross-section shall be trapezoidal with a minimum bottom width of 8 feet. This spillway channel shall have a straight control section of at least 20 feet in length; and a straight outlet section for a minimum distance equal to 25 feet.

   i. ***Capacity:*** The minimum capacity of the emergency spillway shall be that required to pass the peak rate of runoff from the 10-year, 24-hour frequency storm, less any reduction due to flow in the pipe spillway. Emergency spillway dimensions may be determined by using the method described in Figure B.53 and Table B.20.

   ii. ***Velocity:*** The velocity of flow in the exit channel shall not exceed 5 feet per second for vegetated channels. For channels with erosion protection other than vegetation, velocities shall be within the non-erosive range for the type of protection used.

   iii. ***Erosion Protection:*** Erosion protection shall be provided for by vegetation as prescribed in this Handbook or by other suitable means such as rip-rap, concrete or asphalt.

   iv. ***Freeboard:*** Freeboard is the difference between the design high water elevation in the emergency spillway and the top of the settled embankment. If there is no emergency spillway, it is the difference between the water surface elevation required to pass the design flow through the pipe and the top of the settled embankment. Freeboard shall be a minimum of one foot.

Embankment Cross-Section

Class 1 Basins: The minimum top width shall be 8 feet. The side slopes shall not be steeper than 2:1.
Class 2 Basins: The minimum top width shall be 10 feet. The side slopes shall not be steeper than 2½:1.

Entrance of Runoff Into Basin

Protect points of entrance of surface runoff into excavated sediment basins to prevent erosion. Care should be given to the major points of inflow into basins. In many instances, the difference in elevation between the inflow and the bottom of the basin is considerable, creating a potential for severe gullying and sediment generation. A rip-rap drop at major points of inflow can eliminate gullying and sediment generation.

Install diversions, grade stabilization structures, or other water control devices as necessary to insure direction of runoff and to protect point of entry into the basin. Locate points of entry so as to insure that runoff travels the maximum distance between the entrance to the point of exit (riser) from the basin.

Disposal

Indicate disposal method(s) for sediment removed from the basin in sediment basin plans. Place sediment in such a manner that it will not erode from the site. Do **NOT** deposit sediment downstream from the basin, adjacent to a stream or in a floodplain.

Sediment basin plans shall also show the method of removing the sediment basin after the drainage area is stabilized, and shall include the stabilization method for the sediment basin site. Remove water contained within the storage area by pumping, cutting the top of the riser, or other appropriate method prior to removing or breaching the embankment. Allow sediment to flush into any drainage way.

Figure B.54 provides a data sheet for use in Temporary Sediment Basin Design.

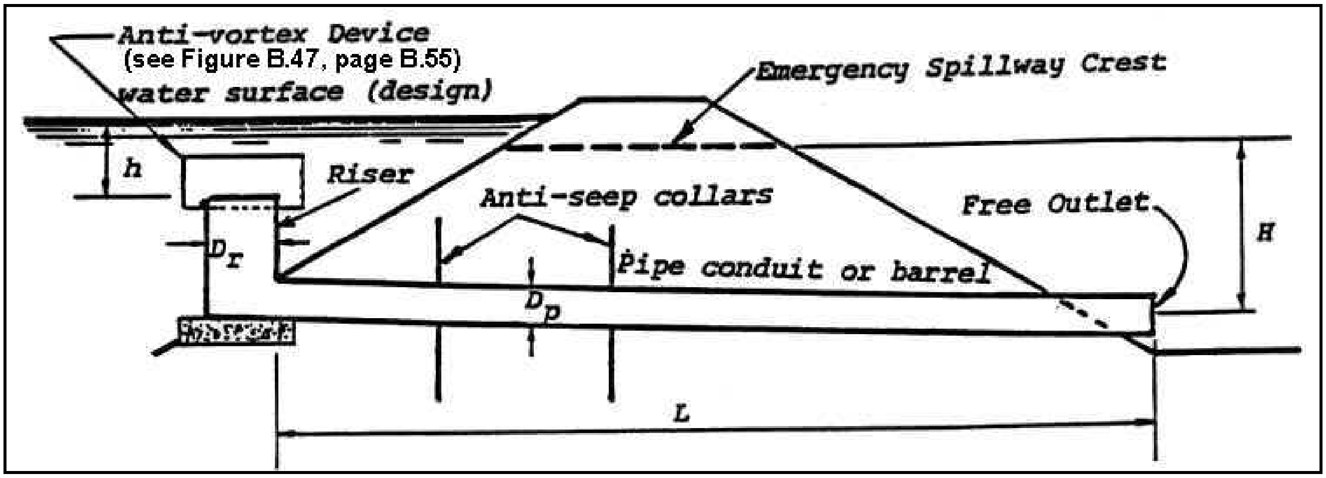


Figure B.43. Pipe spillway design (*Empire State Chapter Soil & Water Conservation Society, 1991*).

H = Head on pipe spillway (pipe flow), feet (centerline of outlet to emergency crest or to design high water if no emergency spillway).
h = Head over riser crest, feet.
L = Length of pipe, in feet.
D_p = Diameter of pipe conduit (barrel).
D_r = Diameter of riser.

To use charts for pipe spillway design:

- Enter chart, Figures B.45 and B.46 with H and required discharge.
- Find diameter of pipe conduit that provides equal or greater discharge.
- Enter chart, Figure B.44, with actual pipe discharge. Read across to select smallest riser that provides discharge within weir flow portion of rating curve. Read down to find corresponding h required.

Example:
Given: Q (required) = 5.8 cfs, L = 60 feet, H = 9 feet to centerline of pipe = Free outlet
Find: Pipe size, actual Q and size of riser
Q of 12 inch pipe = 6.0 cfs x 1.07 (correction factor) = 6.4 cfs from the Pipe Flow Chart
From Riser Inflow Curves (Figure B.35), smallest riser = 18 inches (@h = 0.6)

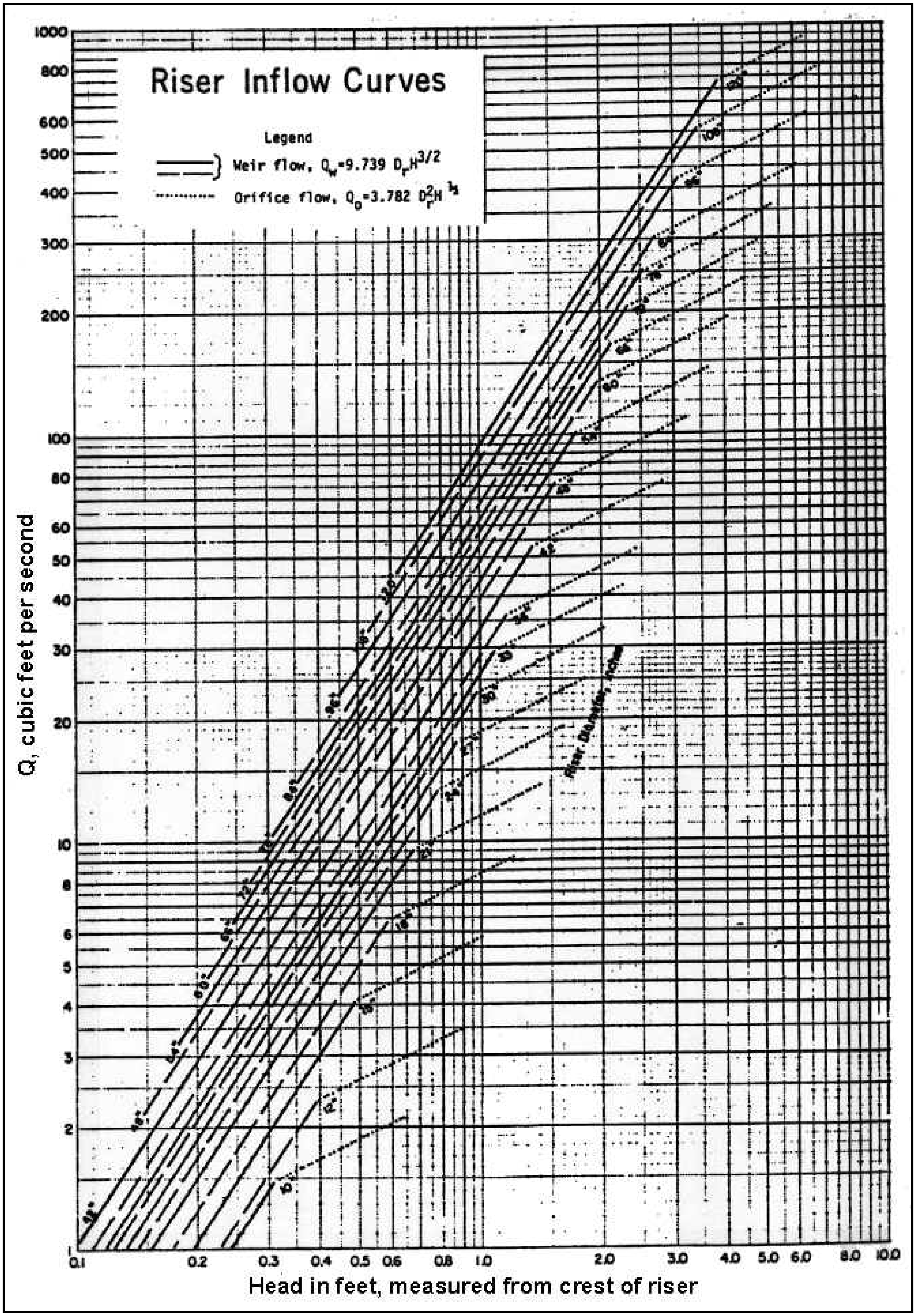


Figure B.43. Riser inflow chart (*Empire State Chapter Soil & Water Conservation Society, 1997*).

PIPE FLOW CHART n = 0.025
FOR CORRUGATED METAL PIPE INLET $K_m = K_e + K_b = 1.0$ AND 70 FEET OF CORRUGATED METAL PIPE CONDUIT (full flow assumed)
Note correction factors for pipe lengths other than 70 feet

diameter of pipe in inches

H, in feet	6"	8"	10"	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
1	0.33	0.70	1.25	1.98	3.48	5.47	7.99	11.0	18.8	28.8	41.1	55.7	72.6	91.8	113	137	163	191	222	255	290
2	0.47	0.99	1.76	2.80	4.92	7.74	11.3	15.6	26.6	40.8	58.2	78.8	103	130	160	194	231	271	314	360	410
3	0.58	1.22	2.16	3.43	6.02	9.48	13.8	19.1	32.6	49.9	71.2	96.5	126	159	196	237	282	331	384	441	502
4	0.67	1.40	2.49	3.97	6.96	10.9	16.0	22.1	37.6	57.7	82.3	111	145	184	226	274	326	383	444	510	580
5	0.74	1.57	2.79	4.43	7.78	12.2	17.9	24.7	42.1	64.5	92.0	125	162	205	253	306	365	428	496	570	648
6	0.82	1.72	3.05	4.86	8.52	13.4	19.6	27.0	46.1	70.6	101	136	178	225	277	336	399	469	544	624	710
7	0.88	1.86	3.30	5.25	9.20	14.5	21.1	29.2	49.8	76.3	109	147	192	243	300	362	431	506	587	674	767
8	0.94	1.99	3.53	5.61	9.84	15.5	22.6	31.2	53.2	81.5	116	158	205	260	320	388	461	541	628	721	820
9	1.00	2.11	3.74	5.95	10.4	16.4	24.0	33.1	56.4	86.5	123	167	218	275	340	411	489	574	666	764	870
10	1.05	2.22	3.94	6.27	11.0	17.3	25.3	34.9	59.5	91.2	130	176	230	290	358	433	516	605	702	806	917
11	1.10	2.33	4.13	6.58	11.5	18.2	26.5	36.6	62.4	95.6	136	185	241	304	376	454	541	635	736	845	962
12	1.15	2.43	4.32	6.87	12.1	19.0	27.7	38.2	65.2	99.9	142	193	252	318	392	475	565	663	769	883	1004
13	1.20	2.53	4.49	7.15	12.6	19.7	28.8	39.8	67.8	104	148	201	262	331	408	494	588	690	800	919	1045
14	1.25	2.63	4.66	7.42	13.0	20.5	29.9	41.3	70.4	108	154	208	272	343	424	513	610	716	830	953	1085
15	1.29	2.72	4.83	7.68	13.5	21.2	30.9	42.8	72.8	112	159	216	281	355	439	531	631	741	860	987	1123
16	1.33	2.81	4.99	7.93	13.9	21.9	32.0	44.2	75.2	115	165	223	290	367	453	548	652	765	888	1019	1160
17	1.37	2.90	5.14	8.18	14.3	22.6	32.9	45.5	77.5	119	170	230	229	378	467	565	672	789	915	1051	1195
18	1.41	2.98	5.29	8.41	14.8	23.2	33.9	46.8	79.8	120	174	236	308	389	480	581	692	812	942	1081	1230
19	1.45	3.06	5.43	8.64	15.2	23.9	34.8	48.1	82.0	126	179	243	316	400	494	597	711	834	967	1111	1264
20	1.49	3.14	5.57	8.87	15.6	24.5	35.7	49.4	84.1	129	184	249	325	410	506	613	729	856	993	1139	1297
21	1.53	3.22	5.71	9.09	15.9	25.1	36.6	50.6	86.2	132	188	255	333	421	519	628	747	877	1017	1168	1329
22	1.56	3.29	5.85	9.30	16.3	25.7	37.5	51.8	88.2	135	193	261	341	430	531	643	765	898	1041	1195	1360
23	1.60	3.37	5.98	9.51	16.7	26.2	38.3	53.0	90.2	138	197	267	348	440	543	657	782	918	1064	1222	1390
24	1.63	3.44	6.11	9.72	17.0	26.8	39.1	54.1	92.1	141	201	273	356	450	555	671	799	937	1087	1248	1420
25	1.66	3.51	6.23	9.92	17.4	27.4	39.9	55.2	94.0	144	206	279	363	459	566	685	815	957	1110	1274	1450
26	1.70	3.58	6.36	10.1	17.7	27.9	40.7	56.3	95.9	147	210	284	370	468	577	699	831	976	1132	1299	1478
27	1.73	3.65	6.48	10.3	18.1	28.4	41.5	57.4	97.7	150	214	290	377	477	588	712	847	994	1153	1324	1507
28	1.76	3.72	6.60	10.5	18.4	29.0	42.3	58.4	99.5	153	218	295	384	486	599	725	863	1013	1174	1348	1534
29	1.79	3.78	6.71	10.7	18.7	29.5	43.0	59.5	101	155	221	300	391	494	610	738	878	1030	1195	1372	1561
30	1.82	3.85	6.83	10.9	19.1	30.0	43.7	60.5	103	158	225	305	398	503	620	750	893	1048	1216	1396	1588
L, in feet	**Correction Factors For Other Pipe Lengths**																				
20	1.69	1.63	1.58	1.53	1.47	1.42	1.37	1.34	1.28	1.24	1.20	1.18	1.16	1.14	1.13	1.11	1.10	1.10	1.09	1.08	1.08
30	1.44	1.41	1.39	1.36	1.32	1.29	1.27	1.24	1.21	1.18	1.15	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.07	1.06	1.06
40	1.26	1.27	1.25	1.23	1.21	1.20	1.18	1.17	1.14	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.05	1.04
50	1.16	1.16	1.15	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.03
60	1.07	1.07	1.07	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	.94	.94	.95	.95	.95	.95	.96	.96	.96	.97	.97	.97	.98	.98	.98	.98	.98	.98	.99	.99	.99
90	.89	.89	.90	.90	.91	.91	.92	.92	.93	.94	.94	.95	.95	.96	.96	.96	.97	.97	.97	.97	.94
100	.85	.85	.86	.86	.87	.88	.89	.89	.90	.91	.92	.93	.93	.94	.94	.95	.95	.95	.96	.96	.94
120	.78	.79	.79	.90	.81	.82	.83	.83	.85	.86	.87	.89	.89	.90	.91	.89	.92	.93	.93	.94	.92
140	.72	.73	.74	.75	.76	.77	.78	.79	.81	.82	.84	.85	.86	.87	.88	.86	.89	.90	.91	.91	.90
160	.68	.69	.69	.70	.71	.73	.74	.75	.77	.79	.80	.82	.83	.84	.85	.92	.87	.88	.89	.89	

Figure B.44. Pipe flow chart, "n" = 0.025 (*Empire State Chapter Soil & Water Conservation Society, 1997*).

PIPE FLOW CHART n = 0.013

FOR REINFORCED CONCRETE PIPE INLET $K_m = K_e + K_b = 1.00$ AND 70 FEET OF REINFORCED CONCRETE PIPE CONDUIT (full flow assumed)

Note correction factors for pipe lengths other than 70 feet

diameter of pipe in inches

H, in feet	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
1	3.22	5.44	8.29	11.8	15.9	26.0	38.6	53.8	71.4	91.5	114	139	167	197	229	264	302	342
2	4.55	7.69	11.7	16.7	22.5	36.8	54.6	76.0	101	129	161	197	236	278	324	374	427	483
3	5.57	9.42	14.4	20.4	27.5	45.0	66.9	93.1	124	159	198	241	289	341	397	458	523	592
4	6.43	10.9	16.6	23.5	31.8	52.0	77.3	108	143	183	228	278	334	394	459	529	604	683
5	7.19	12.2	18.5	26.3	35.5	58.1	86.4	120	160	205	255	311	373	440	513	591	675	764
6	7.88	13.3	20.3	28.8	38.9	63.7	94.6	132	175	224	280	341	409	482	562	647	739	837
7	8.51	14.4	21.9	31.1	42.0	68.8	102	142	189	242	302	368	441	521	607	699	798	904
8	9.10	15.4	23.5	33.3	44.9	73.5	109	152	202	259	323	394	472	557	685	748	854	966
9	9.65	16.3	24.9	35.3	47.7	78.0	116	161	214	275	342	418	500	590	688	793	905	1025
10	10.2	17.2	26.2	37.2	50.2	82.2	122	170	226	289	361	440	527	622	725	836	954	1080
11	10.7	18.0	27.5	39.0	52.7	86.2	128	178	237	304	379	462	553	653	761	877	1001	1133
12	11.1	18.9	28.7	40.8	55.0	90.1	134	186	247	317	395	482	578	682	794	916	1045	1184
13	11.6	19.6	29.9	42.4	57.3	93.7	139	194	257	330	411	502	601	710	827	953	1088	1232
14	12.0	20.4	31.0	44.1	59.4	97.3	145	201	267	342	427	521	624	736	858	989	1129	1278
15	12.5	21.1	32.1	45.6	61.5	101	150	208	277	354	442	539	646	762	888	1024	1169	1323
16	12.9	21.8	33.2	47.1	63.5	104	155	215	286	366	457	557	667	787	917	1057	1207	1367
17	13.3	22.4	34.2	48.5	65.5	107	159	222	294	377	471	574	688	812	946	1090	1244	1409
18	13.7	23.1	35.2	49.9	67.4	110	164	228	303	388	484	591	708	835	973	1121	1280	1450
19	14.0	23.7	36.1	51.3	69.2	113	168	234	311	399	497	607	727	858	1000	1152	1315	1489
20	14.4	24.3	37.1	52.6	71.0	116	173	240	319	409	510	623	746	880	1026	1182	1350	1528
21	14.7	24.9	38.0	53.9	72.8	119	177	246	327	419	523	638	764	902	1051	1211	1383	1566
22	15.1	25.5	38.9	55.2	74.5	122	181	252	335	429	535	653	782	923	1076	1240	1415	1603
23	15.4	26.1	39.8	56.5	76.2	125	186	258	342	439	547	668	800	944	1100	1268	1447	1639
24	15.8	26.7	40.6	57.7	77.8	127	189	263	350	448	559	682	817	964	1123	1295	1478	1674
25	16.1	27.2	41.5	58.9	79.4	130	193	269	357	458	571	696	834	984	1147	1322	1509	1708
26	16.4	27.7	42.3	60.0	81.0	133	197	274	364	467	582	710	850	1004	1169	1348	1539	1742
27	16.7	28.3	43.1	61.2	82.5	135	201	279	371	476	593	723	867	1023	1192	1373	1568	1775
28	17.0	28.8	43.9	62.3	84.1	138	204	285	378	484	604	737	883	1041	1214	1399	1597	1808
29	17.3	29.3	44.7	63.4	85.5	140	208	290	384	493	615	750	898	1060	1235	1423	1625	1840
30	17.6	29.8	45.4	64.5	87.0	142	212	294	391	501	625	763	913	1078	1256	1448	1653	1871
L, in feet	**Correction Factors For Other Pipe Lengths**																	
20	1.30	1.24	1.21	1.18	1.15	1.12	1.10	1.08	1.07	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.03
30	1.22	1.18	1.15	1.13	1.12	1.09	1.08	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02
40	1.15	1.13	1.11	1.10	1.08	1.07	1.05	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02
50	1.09	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01
60	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	.96	.97	.97	.97	.98	.98	.98	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99
90	.93	.94	.94	.95	.95	.96	.97	.97	.98	.98	.98	.98	.98	.99	.99	.99	.99	.99
100	.90	.91	.92	.93	.93	.95	.95	.96	.97	.97	.97	.98	.98	.98	.98	.98	.98	.99
120	.84	.86	.87	.89	.90	.91	.93	.94	.94	.95	.96	.96	.96	.97	.97	.97	.97	.98
140	.80	.82	.83	.85	.86	.88	.90	.91	.92	.93	.94	.94	.95	.95	.96	.96	.96	.97
160	.76	.78	.80	.82	.83	.86	.88	.89	.90	.91	.92	.93	.94	.94	.95	.95	.95	.96

Figure B.45. Pipe flow chart, "n" = 0.013 (*Empire State Chapter Soil & Water Conservation Society, 1997*).

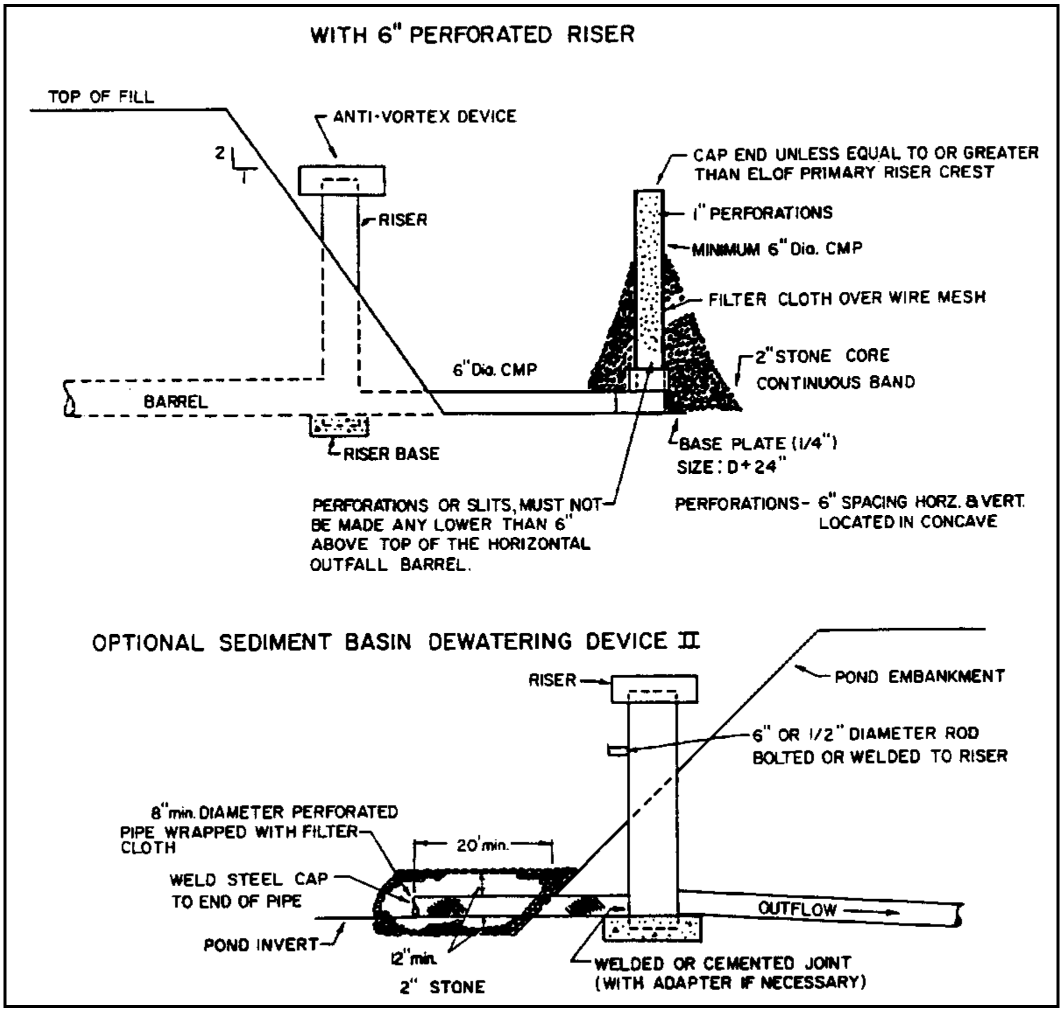


Figure B.46. Optional sediment basin de-watering methods (*Empire State Chapter Soil & Water Conservation Society, 1991*).

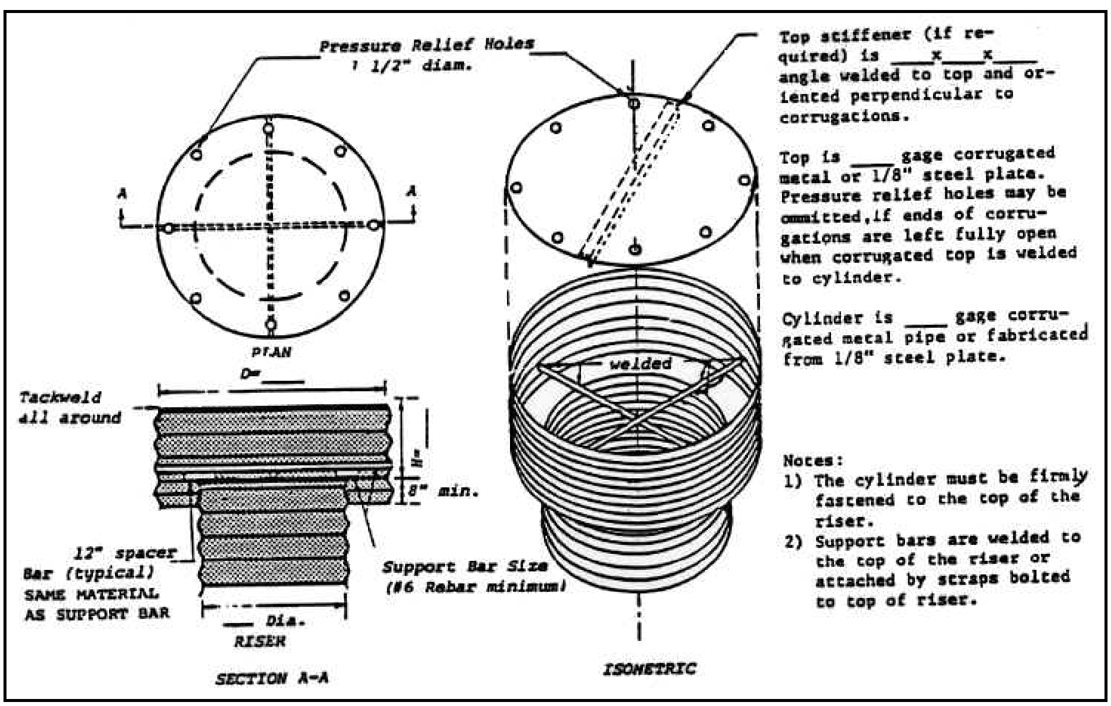
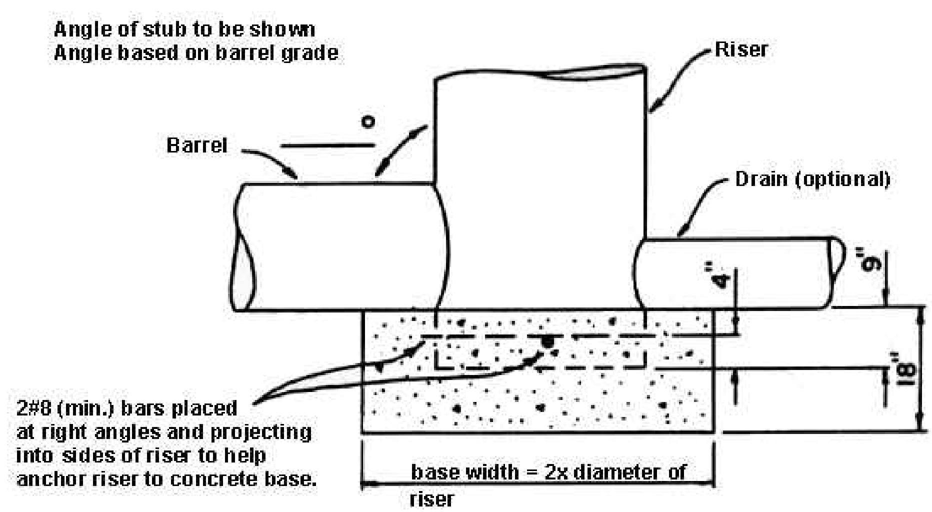


Figure B.47. Concentric trash rack and anti-vortex device *(Empire State Chapter Soil & Water Conservation Society, 1997*).

Table B.19. Concentric trash rack and anti-vortex device design table (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Riser Diameter (in.)	Cylinder Diameter (in.)	Thickness Gage	H (in.)	Minimum Size Support Bar	Minimum Top	
					Thickness	Stiffener
12	18	16	6	#6 Rebar	16 ga.	--
15	21	16	7	#6 Rebar	16 ga.	--
18	27	16	8	#6 Rebar	16 ga.	--
21	30	16	11	#6 Rebar	16 ga.	--
24	36	16	13	#6 Rebar	14 ga.	--
27	42	16	15	#6 Rebar	14 ga.	--
36	54	14	17	#8 Rebar	12 ga.	--
42	60	14	19	#8 Rebar	12 ga.	--
48	72	12	21	1¼" pipe or 1½x1, ½x½ angle	10 ga.	--
54	78	12	25	See 48" Riser	10 ga.	--
60	90	12	29	1½" pipe or 1½x1½x½ angle	8 ga.	--
66	96	10	33	2" pipe or 2x2x3/16 angle	8 ga. w/ stiffener	2x2x¼ angle
72	102	10	36	---See 66" Riser---		2½x2½x¼ angle
78	114	10	39	2½" pipe or 2x2x¼ angle	---See 72" Riser---	
84	120	10	42	2½" pipe or 2½x2½x¼ angle	See 72" Riser	2½x2½x5/16 angle

Note: The criteria for sizing the cylinder is that the area between the inside of the cylinder and the outside of the riser is equal to or greater than the area inside the riser. Therefore, the above table is invalid for use with concrete pipe risers.



NOTES:

1. The concrete base shall be poured in such a manner to insure that the concrete fills the bottom of the riser to the invert of the outlet pipe to prevent the riser from breaking away from the base.
2. With aluminum or aluminized pipe, the embedded section must be painted with zince chromate or equivalent.
3. Riser base may be sized as computed using floatation with a factor of safety of 1.2.

Figure B.48. Riser base details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

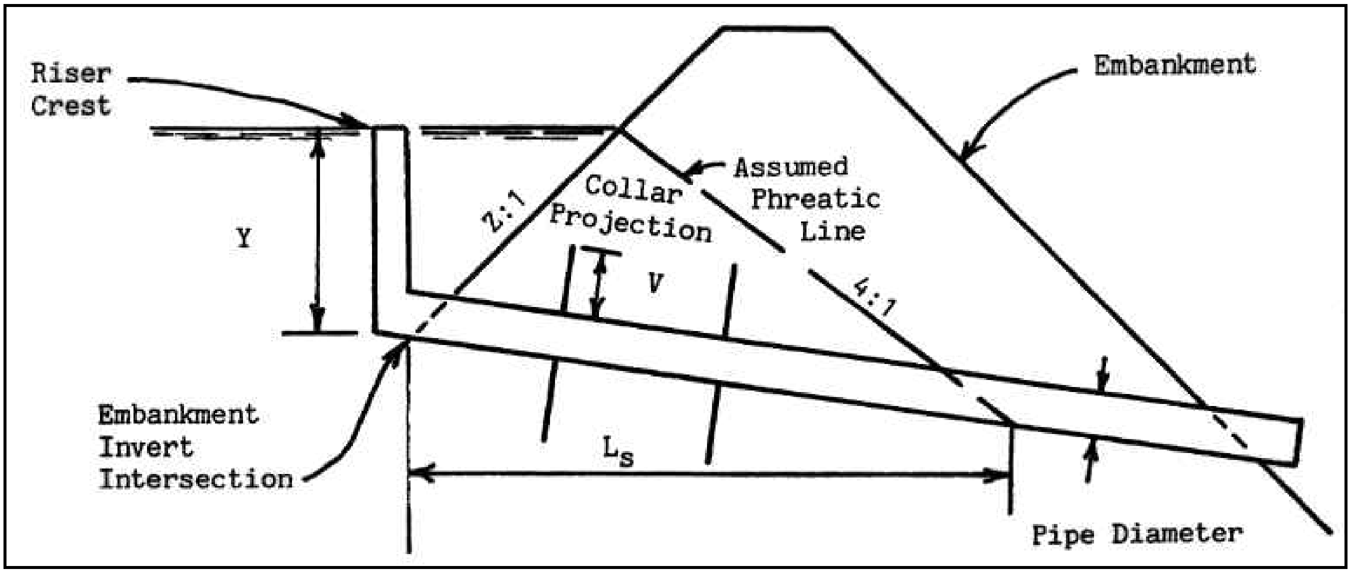


Figure B.49. Anti-seep collar design (see procedure detailed below; *Empire State Chapter Soil & Water Conservation Society, 1997*).

This procedure provides the anti-seep collar dimensions for only temporary sediment basins in order to increase the seepage length by 15 percent for various pipe slopes, embankment slopes, and riser heights.

The first step in designing anti-seep collars is to determine the length of pipe within the saturated zone of the embankment. This can be done graphically or by the following equation, assuming that the upstream slope of the embankment intersects the invert of the pipe at its upstream end. (See embankment-invert intersection on the drawing above).

$$L_s = y\,(z + 4)\left[1 + \frac{\textit{pipe slope}}{0.25 - \textit{pipe slope}}\right] \qquad \textit{[EQ. B-4]}$$

Where: L_s = length of pipe in the saturated zone (feet).
y = distance (feet) from upstream invert of pipe to highest normal water level expected to occur during the life of the structure (usually the top of the riser).
z = slope of upstream embankment as a ratio of z feet horizontal to one foot vertical.
pipe slope = slope of pipe in feet per foot.

This procedure is based on the approximation of the phreatic line as shown in the drawing above (Figure B.49).

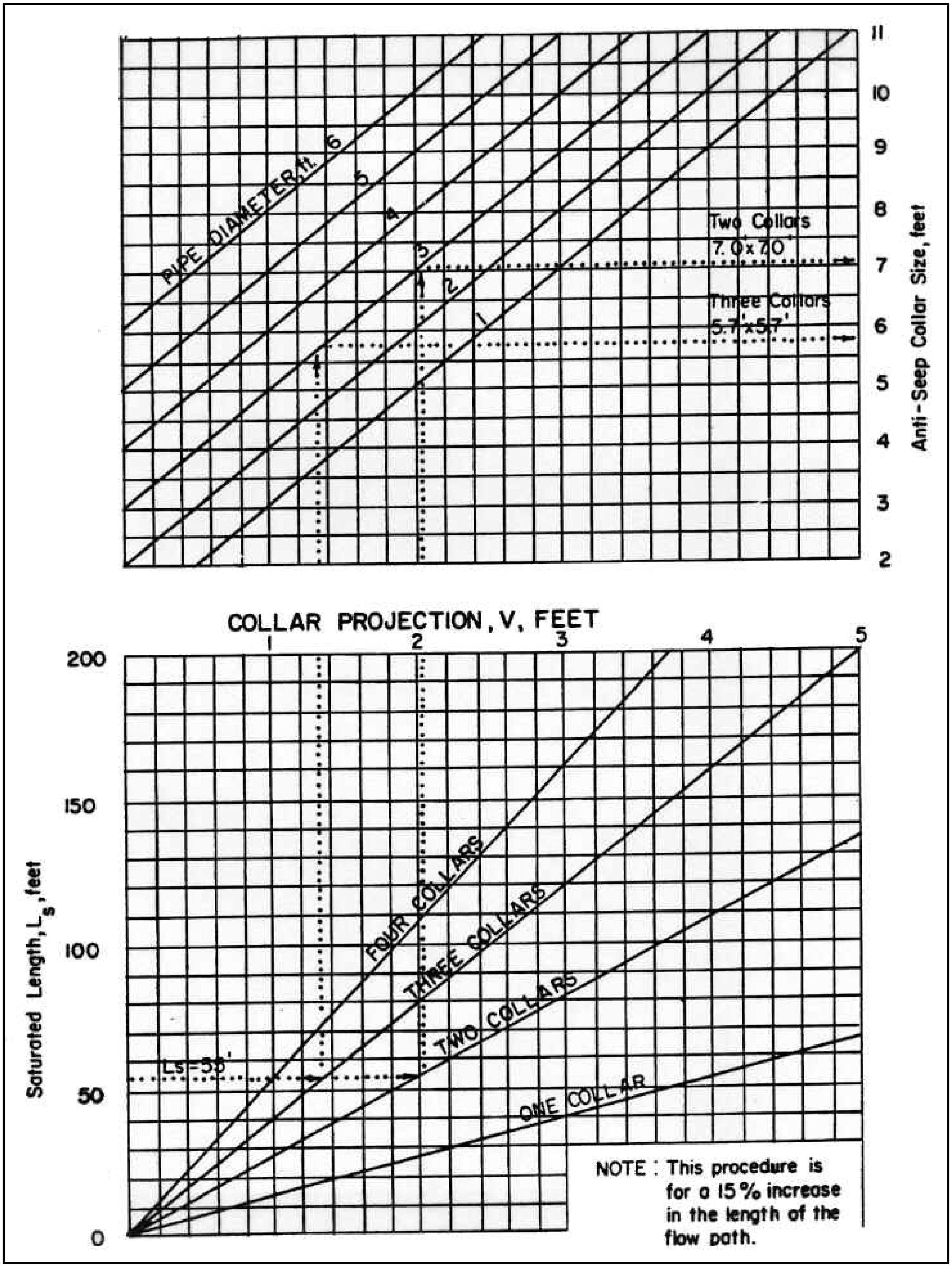


Figure B.50. Anti-seep collar design charts (*Empire State Chapter Soil & Water Conservation Society, 1997*).

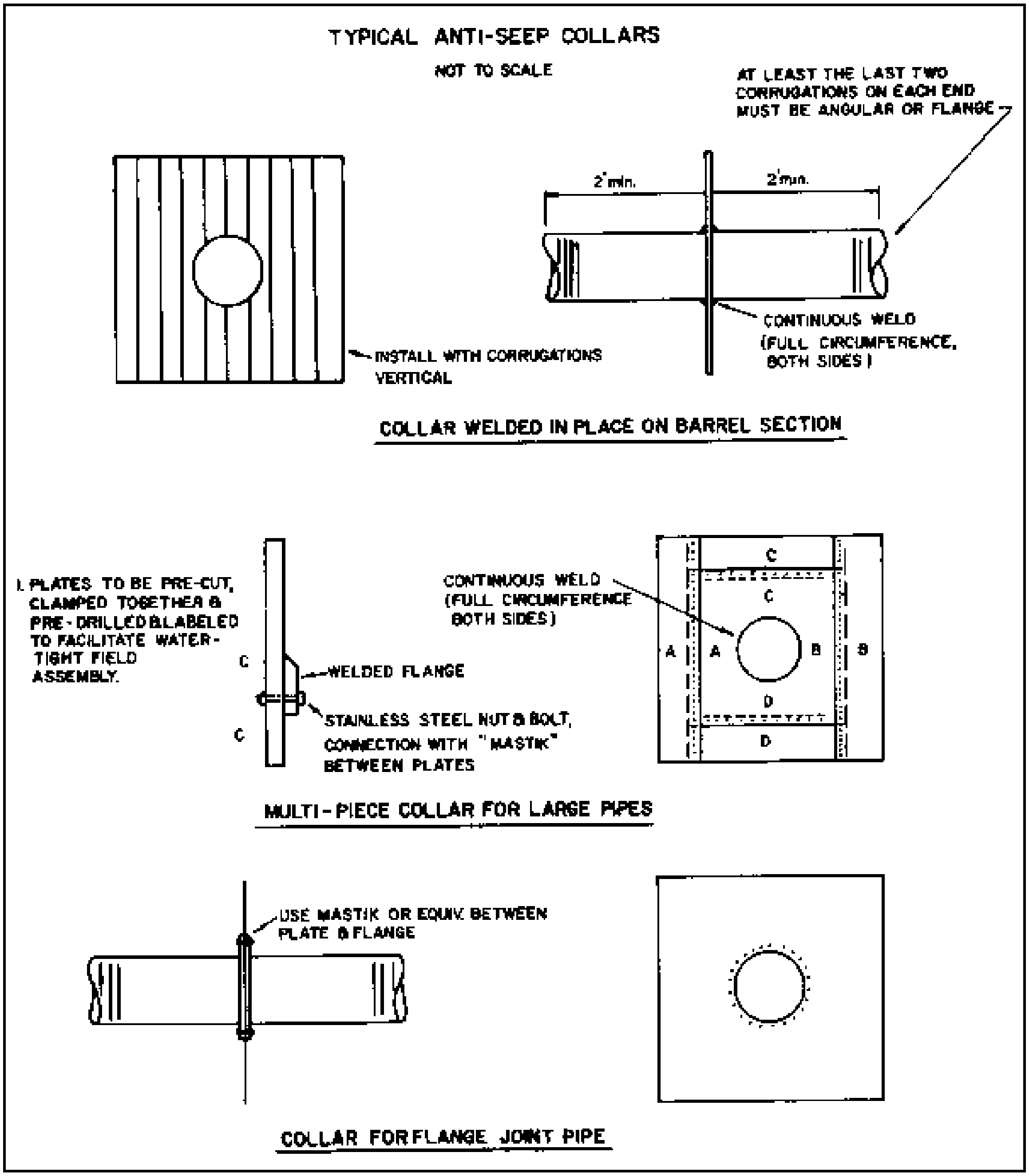


Figure B.51. Anti-seep collar construction details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

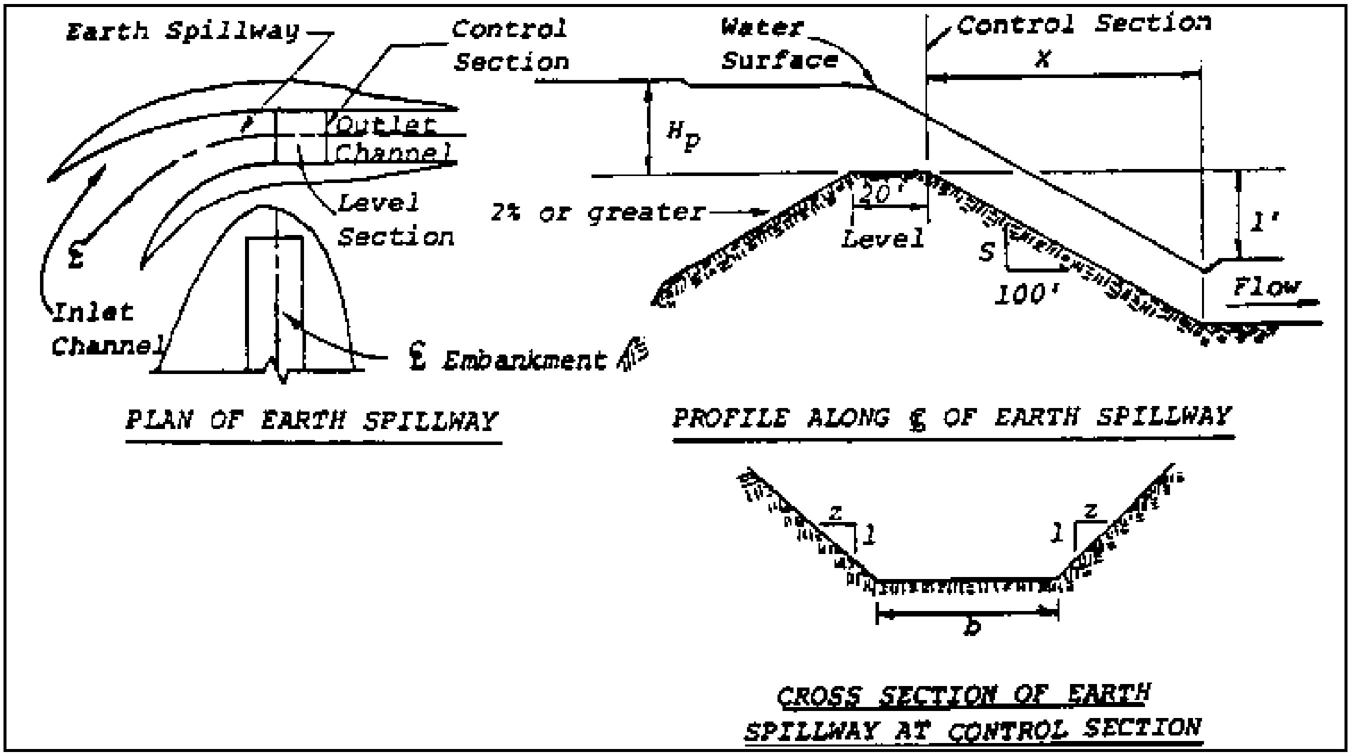


Figure B.52. Design data for earth spillways (*Empire State Chapter Soil & Water Conservation Society, 1991*).

Legend:

n = Manning's coefficient of roughness.
H_p = difference in elevation between crest of earth spillway at the control section and water surface in reservoir (feet).
b = bottom width of earth spillway at the control section (feet).
Q = total discharge (cfs).
V = velocity, (feet/second) that will exist in channel below control section, at design Q, if constructed to slope (S) that is shown.
S = flattest slope (%) allowable for channel below control section.
X = minimum length of channel below control section (feet).
z = side slope ratio.

Notes:

1. For a given H_p a decrease in the exit slope from S, as given in Table B.20, decreases spillway discharge, but increasing the exit slope from S does not increase discharge. If an exit slope (S_e) steeper than S is used, then velocity (V_e) in the exit channel will increase according to the following relationship:

$$V_e = V \left(\frac{S_e}{S}\right)^{0.3} \quad \text{[EQ. B-5]}$$

2. Data to right of heavy vertical lines on drawings should be used with caution, as the resulting sections will be either poorly proportioned or have velocities in excess of 6 feet/second.

Table B.20. Design data for earth spillways — side slope 2:1; vegetated, n = 0.04 (*Empire State Chapter Soil & Water Conservation Society, 1997*).

STAGE (Hp) IN FEET	SPILLWAY VARIABLES	BOTTOM WIDTH (b) IN FEET																
		8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
05	Q	6	7	8	10	11	13	14	15	17	18	20	21	22	24	25	27	28
	V	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	S	39	39	39	39	38	38	38	38	38	38	38	38	38	38	38	38	38
	X	32	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
06	Q	8	10	12	14	16	18	20	22	24	26	28	30	32	34	35	37	39
	V	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
	S	37	37	37	37	36	37	36	36	36	36	36	36	36	36	36	36	36
	X	36	36	36	36	36	36	37	37	37	37	37	37	37	37	37	37	37
07	Q	11	13	16	18	20	23	25	28	30	33	35	38	41	43	44	46	48
	V	32	32	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	S	35	35	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
	X	39	40	40	40	41	41	41	41	41	41	41	41	41	41	41	41	41
08	Q	13	16	19	22	26	29	32	35	38	42	45	46	48	51	54	57	60
	V	35	35	35	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	S	33	33	33	32	32	32	32	32	32	32	32	32	32	32	32	32	32
	X	44	44	44	44	45	45	45	45	45	45	45	45	45	45	45	45	45
09	Q	17	20	24	28	32	35	39	43	47	51	53	57	60	64	68	71	75
	V	37	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
	S	32	31	31	31	31	31	31	31	31	31	31	31	31	31	3.1	31	31
	X	47	47	48	48	48	48	48	48	48	48	49	49	49	49	49	49	49
10	Q	20	24	29	33	38	42	47	51	56	61	63	68	72	77	81	86	90
	V	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
	S	31	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
	X	51	51	51	51	52	52	52	52	52	52	52	52	52	52	52	52	52
11	Q	23	28	34	39	44	49	54	60	65	70	74	79	84	89	95	100	105
	V	42	42	42	43	43	43	43	43	43	43	43	43	43	43	43	43	43
	S	29	29	29	29	29	29	29	29	29	28	28	28	2.8	2.8	2.8	28	2.8
	X	55	55	55	55	55	55	55	56	56	56	56	56	56	56	56	56	56
12	Q	28	33	40	45	51	58	64	69	76	80	86	92	98	104	110	116	122
	V	44	44	44	44	44	45	45	45	45	45	45	45	45	45	45	45	45
	S	29	29	28	28	28	28	28	28	28	28	28	28	28	28	28	2.8	28
	X	58	58	59	59	59	59	59	59	60	60	60	60	60	60	60	60	60
13	Q	32	38	46	53	58	65	73	80	86	91	99	106	112	119	125	133	140
	V	45	46	46	46	46	46	47	47	47	47	47	47	47	47	47	47	47
	S	28	28	28	27	27	27	27	27	27	27	27	27	2.7	27	27	2.7	27
	X	62	62	62	63	63	63	63	63	63	63	63	64	64	64	64	64	64
14	Q	37	44	51	59	66	74	82	90	96	103	111	119	127	134	142	150	158
	V	47	48	48	48	48	46	48	48	48	49	49	49	49	49	49	49	49
	S	28	27	27	27	27	27	27	26	26	26	26	26	26	26	26	26	26
	X	65	66	66	66	66	67	67	67	67	67	67	68	68	68	68	68	69
15	Q	41	50	58	66	75	85	92	101	108	116	125	133	142	150	160	169	178
	V	48	49	49	50	50	50	50	50	50	50	50	50	50	50	51	51	51
	S	27	27	26	26	26	26	26	26	26	26	26	26	26	26	25	25	25
	X	69	69	70	70	71	71	71	71	71	71	7	72	72	72	72	72	72
16	Q	46	56	65	75	84	94	104	112	122	132	142	149	158	168	178	187	197
	V	50	51	51	51	51	52	52	52	52	52	52	52	52	52	52	52	52
	S	26	26	26	26	25	25	25	25	25	25	25	25	25	25	2.5	2.5	2.5
	X	72	74	74	75	75	76	76	76	76	76	76	76	76	76	76	76	76
17	Q	52	62	72	83	94	105	115	126	135	145	156	167	175	187	196	206	217
	V	52	52	52	53	53	53	53	54	54	54	54	54	5.4	5.4	5.4	5.4	54
	S	26	26	25	25	25	25	25	25	25	25	25	25	25	2.5	2.5	2.5	25
	X	76	78	79	80	80	80	80	80	80	80	80	80	80	80	80	80	80
18	Q	58	69	81	93	104	116	127	138	150	160	171	182	194	204	214	226	233
	V	53	54	5.4	5.5	5.5	55	5.5	5.5	5.5	5.5	5.5	56	56	56	5.6	5.6	56
	S	25	25	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24
	X	80	82	83	84	84	84	84	84	84	84	84	84	84	84	84	84	84
19	Q	64	76	88	102	114	127	140	152	164	175	188	201	213	225	235	248	260
	V	55	55	55	56	56	56	57	57	57	57	57	57	5.7	5.7	57	5.7	5.7
	S	25	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	X	84	85	86	87	88	88	88	88	88	88	88	88	88	88	88	88	88
20	Q	71	83	97	111	125	138	153	164	178	193	204	218	232	245	256	269	283
	V	56	57	57	57	58	58	58	58	58	58	58	59	59	59	59	59	59
	S	25	24	24	24	24	24	24	24	23	23	23	23	23	23	23	23	23
	X	88	90	91	91	91	9	92	92	92	92	92	92	92	92	92	92	92
21	Q	77	9	107	122	135	149	162	177	192	207	220	234	250	267	276	291	305
	V	57	58	59	59	59	59	59	60	60	60	60	60	6.0	6.0	60	60	60
	S	24	24	24	24	24	23	23	23	23	23	23	23	23	23	23	23	23
	X	92	93	95	95	95	95	95	95	95	96	96	96	96	96	96	96	96
22	Q	84	100	116	131	146	163	177	194	210	224	238	253	269	288	301	314	330
	V	59	59	60	60	60	61	61	61	61	61	61	61	61	62	62	62	6.2
	S	24	24	24	23	23	23	23	23	23	23	23	23	23	23	23	23	23
	X	96	98	99	99	99	99	99	100	100	100	100	100	100	100	100	100	100
23	Q	90	108	124	140	156	175	193	208	226	243	258	275	292	306	323	341	354
	V	60	61	61	61	62	62	62	62	63	63	63	63	63	63	63	63	63
	S	24	24	23	23	23	23	23	23	22	22	22	22	22	22	22	22	22
	X	100	102	102	103	103	103	104	104	104	105	105	105	105	105	105	105	105
24	Q	99	116	136	152	170	189	206	224	24	260	275	294	312	327	346	364	378
	V	61	62	62	63	63	63	64	64	64	64	64	64	64	64	64	64	64
	S	23	23	23	23	23	22	22	22	22	22	22	22	22	22	2.2	2.2	22
	X	105	105	106	107	107	108	108	108	108	109	109	109	109	109	109	109	109

Instructions for Temporary Sediment Basin Design Data Sheet

1. Minimum required detention volume is 67 cubic yards per acre from each acre of drainage area. Values larger than 67 cubic yards per acre may be used for greater protection. Compute volume using entire drainage area although only part may be disturbed.
2. The volume of a naturally-shaped (no excavation in basin) basin may be approximated by:

$$V = 0.4 \times A \times d \qquad \text{[EQ. B-6]}$$

Where: V = volume (cubic feet).
A = surface area of basin (square feet).
d = maximum depth of basin (feet).

3. If volume of basin is not adequate for required storage, excavate to obtain the required volume.
4. The methods described in Chapter 6 of this Handbook, or *Engineering Field Manual for Conservation Practices*, Chapter 2 (USDA-SCS, 1990), are the preferred methods for runoff calculation.
5. Required discharge from pipe spillway is equal to 0.2 cfs/acre times total drainage area. (This is equivalent to a uniform runoff of 5 inches per 24 hours.) The pipe shall be designed to carry Q_p if site conditions preclude installation of an emergency spillway to protect the structure.
6. Determine the value of "H" from field conditions – "H" is the interval between the centerline of the outlet pipe and the emergency spillway crest, or if there is no emergency spill way, to the design high water.
7. See Pipe Spillway Design Charts, Figures B.45 and B.46.
8. See Riser Inflow Curves, Figure B.44.
9. See Trash Rack and Anti-Vortex Device Design, Figure B.48 and Table B.19.
10. Compute Q_{es} by subtracting actual flow carried by the pipe spillway from the total inflow, Q_p.
11. Use appropriate tables to obtain values of H_p, bottom width, and actual Q_{es}. If no emergency spillway is to be used, state the reason(s).
12. See Anti-Seep Collar Design, Figures B.50, B.51, and B.52.
13. Fill in design elevations. The emergency spillway crest must be set no closer to the riser crest than the value of h which causes pipe spillway to carry the minimum required Q. Therefore, the elevation difference between spillways shall be equal to the value of h, or one foot, whichever is greater. Design high water is the elevation of the emergency spillway crest plus the value of H_p, or if there is no emergency spillway, it is the elevation of the riser crest plus h required to handle a 10-year storm. Minimum top of dam elevation requires one foot of freeboard above design high water.

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET

Computed by __________________ Date __________________ Checked by ___________________ Date __________ __________

Project ____ Basin # ____

Location ______________________________ Total Area draining to basin, _______________________________ Acres.

BASIN VOLUME DESIGN

1. Minimum required volume = 67 cubic yards x _____________ acres drainage = _______________ cubic yards.
2. Volume of basin = ____________________________________ = ____________________ cubic yards.
3. Excavate ______________________ cubic yards to obtain required capacity.
   a. Minimum volume before clean-out = 27 cubic yards x ________ acres drainage = _______ cubic yards.
   b. Elevation corresponding to scheduled time to clean out: ____________________.
   c. Distance below top of riser: ____________________.

DESIGN OF SPILLWAYS

Runoff

4. $Q_{p(io)}$ = _______________________ cfs

   (See Chapter 6 of this Handbook or USDA-SCS (1986)).

Pipe Spillway (Q_{ps})

5. Minimum pipe spillway capacity, Q_{ps} = 0.2 x ______________ acres drainage = _______________ cfs.

   (Note: if there is no emergency spillway, the required $Q_{ps} = Q_p$ = _____________ cfs.
6. H = ___________ feet. Barrel length = ___________________ feet.
7. Barrel: diameter _ inches; Q_{ps} = (Q) _______________ x (cor. fac.) ___________ = _____________ cfs.
8. Riser: diameter _________inches; Length __________ feet; h = ______________ feet.
9. Trash Rack: diameter ___________ inches; H = ____________ inches.

Emergency Spillway Design

10. Emergency Spillway Flow, $Q_{es} = Q_p - Q_{ps}$ = ________ - _____________ = _____________ cfs.
11. Width _________ feet; H_p _______________ feet.
    a. Entrance channel slope: __________ percent.
    b. Exit channel slope: ______________ percent.

ANTI-SEEP COLLAR DESIGN (if required)

12. y = ___________ feet; z = _______:1; pipe slope = _________%, L_s = ________ feet.

    Use ___________ collars, ________ - ______ inches square; projection = ______________ feet.

DESIGN ELEVATIONS

13. Riser Crest = __________________________ Design High Water = ___________________

    Embankment Spillway Crest = ____________ Top of Dam = _________________________

Figure B.53. Temporary sediment basin design data sheet (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Construction Specifications

Site Preparation

Clear, grub and strip areas under the embankment to remove trees, vegetation, roots or other objectionable material. Clear the pool area (measured at the top of the pipe spillway) of all brush, trees, and other objectionable materials in order to facilitate clean-out and restoration.

Cutoff Trench

Excavate a cutoff trench along the centerline of earth fill embankments. The minimum depth shall be 2 feet. The cutoff trench shall extend up both abutments to the riser crest elevation. The minimum bottom width shall be 4 feet, but wide enough to permit operation of excavation and compaction equipment. The side slopes shall be no steeper than 1:1. Compaction requirements are the same as those for the embankment. De-water the trench during backfilling/compaction operations.

Embankment

Take fill material from approved areas shown on the plans. Material shall be clean, mineral soil free of roots, woody vegetation, over-sized stones, rocks or other objectionable material. Do not place relatively pervious materials such as sand or gravel in the embankment. Scarify areas on which fill will be placed prior to placement. Fill material shall contain sufficient moisture so that it can be formed by hand into a ball without crumbling. However, if water can be squeezed out of it, it is too wet for proper compaction. Place fill material in 6- to 8-inch continuous layers over the length of the fill. Compact fill with construction equipment so that the entire surface of each layer is traversed by at least one wheel or tread track. Construct the embankment 10 percent higher than the design height to allow for settling.

Pipe Spillway

Securely attach the riser to the barrel or barrel stub by welding the full circumference, making a watertight structural connection. The barrel stub must be attached to the riser at the same grade angle as the outlet conduit. The connection between the riser and the riser base shall be watertight. All connections between barrel sections must be achieved by watertight bank assemblies (see Figure B.55 for details). Place barrel and riser on a firm, smooth foundation of impervious soil. Do **NOT** use pervious materials such as sand, gravel, or crushed stone as backfill around the pipe or anti-seep collars. Place the fill material around the pipe spillway in 4-inch layers and compact under and around the pipe to at least the same density as the adjacent embankment.

Place a minimum depth of 2 feet of hand-compacted backfill over the pipe spillway before crossing it with construction equipment. Place at least 2½ feet of compacted earth, stone or gravel over steel base plates on risers to prevent flotation.

Emergency Spillway

Install the emergency spillway in undisturbed ground. The achievement of planned elevations, grades, design width, entrance and exit channel slopes are critical to the successful operation of the emergency spillway and must be constructed within a tolerance of +/-0.2.

Vegetative Treatment

Stabilize the embankment and emergency spillway in accordance with the specifications for ***Temporary Seeding*** and/or ***Mulch, Mats and Geotextiles*** as presented in this Handbook. In no case shall the embankment remain unstabilized for more than 14 days.

Erosion and Pollution Control

Carry out construction operations so that resulting erosion and water pollution are minimized.

Maintenance

Repair all damages caused by soil erosion and construction equipment at or before the end of each working day. Remove sediment from the basin when it reaches the specified distance below the top of the riser. Dispose of this sediment in such a manner that it will not erode from the side. Do **NOT** deposit sediment downstream from the embankment, adjacent to a drainageway, or in a floodplain.

Final Disposal

At the end of the sediment basin's lifespan, and when the contributing drainage area has been properly stabilized, level and properly dispose of the embankment and resulting sediment deposits.

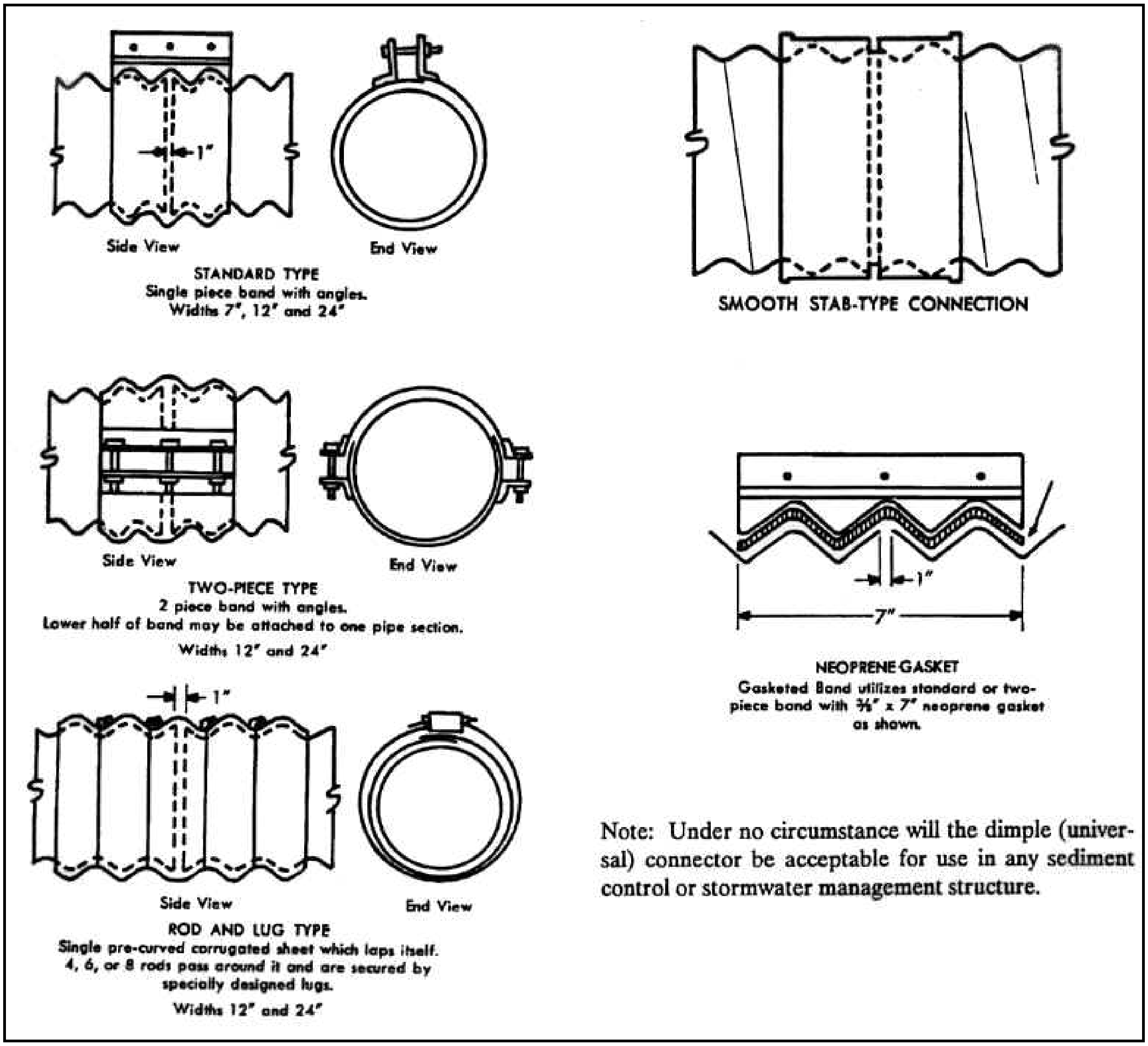


Figure B.54. Corrugated steel pipe couplers — all connector bands require neoprene gaskets *(Empire State Chapter Soil & Water Conservation Society, 1997*).

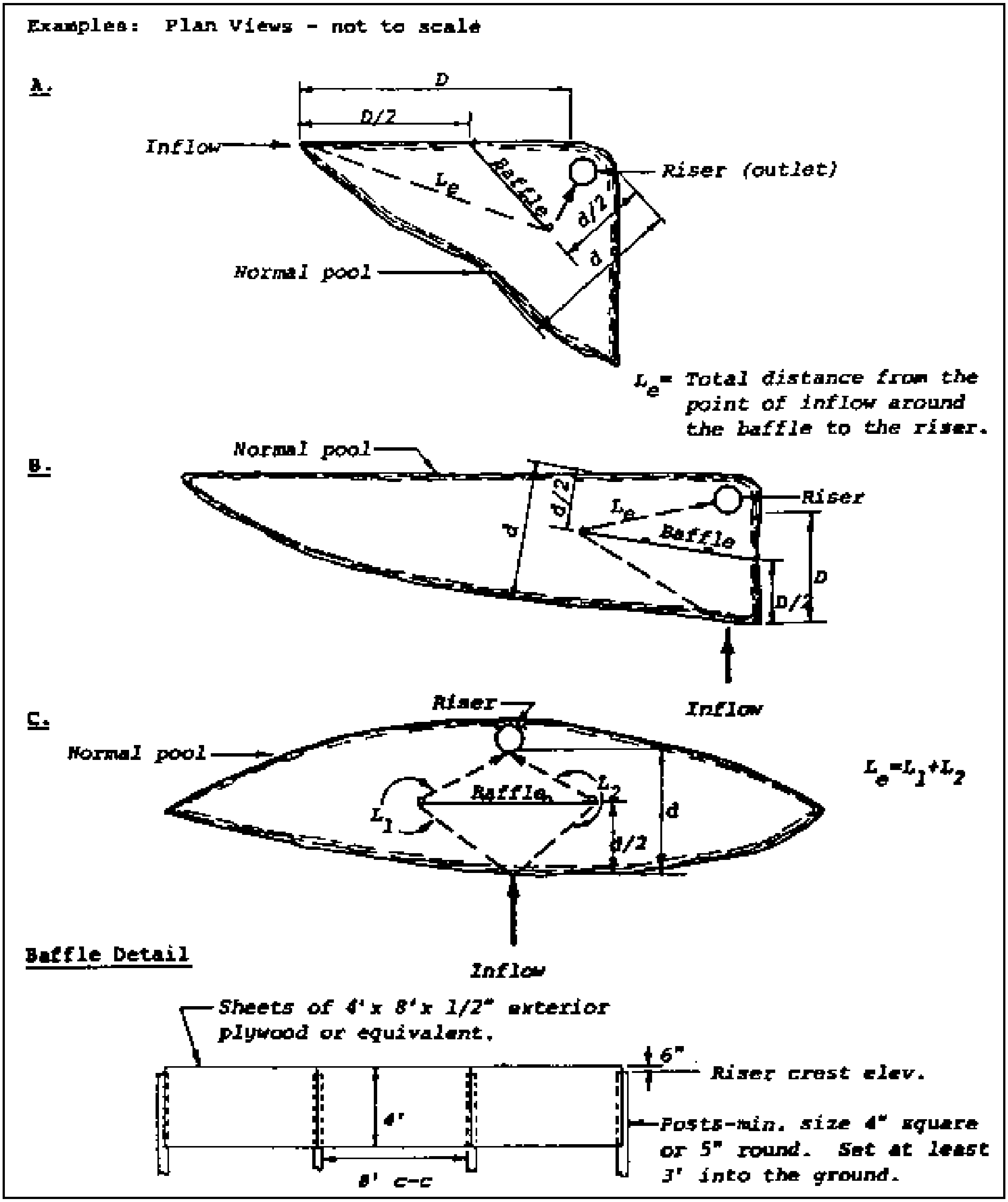


Figure B.55. Sediment basin baffle details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Storm Drain Inlet Protection

There are four basic types of storm drain inlet protection practices that vary according to their function, location, drainage area and availability of materials. Design criteria and construction specifications are presented for each. Commercially manufactured inlet inserts, such as Beaver Dam™, Silt Sack™, Silt Saver™ (Figure B.57), and others are also effective in reducing sediment loads to storm drains. Design and installation specifications for these practices vary and are provided by the manufacturer.

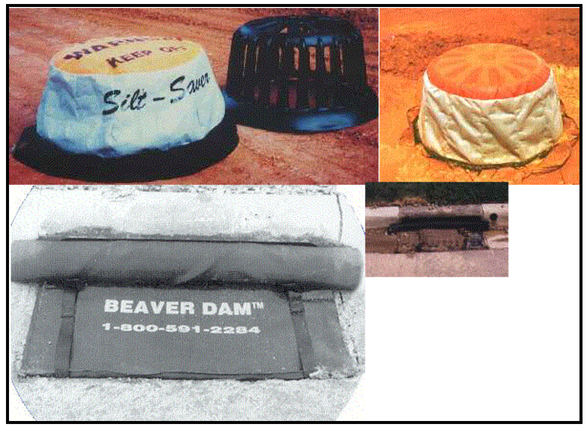


Figure B.56. Examples of manufactured inlet inserts (top: *SiltSaver Corp., 1999*, bottom: *Dandy Products, Inc., 2001*).

EXCAVATED DROP INLET PROTECTION (Figure B.57)

Design Criteria

1. Limit the drainage area contributing to the inlet device to 1 acre.
2. Excavated side slopes shall be no steeper than 2:1.
3. The minimum depth shall be 1 foot and the maximum depth 2 feet as measured from the crest of the inlet structure.
4. Shape the excavated basin to fit conditions with the longest dimension oriented toward the longest inflow area to provide maximum trap efficiency.
5. The capacity of the excavated basin should be able to contain 900 cubic feet of runoff per acre of disturbed area.
6. Weep holes, protected by filter fabric and stone, should be provided for draining the temporary pool.
7. Inspect and clean the excavated basin after every storm.
8. Sediment should be removed when 50 percent of the storage volume is achieved.

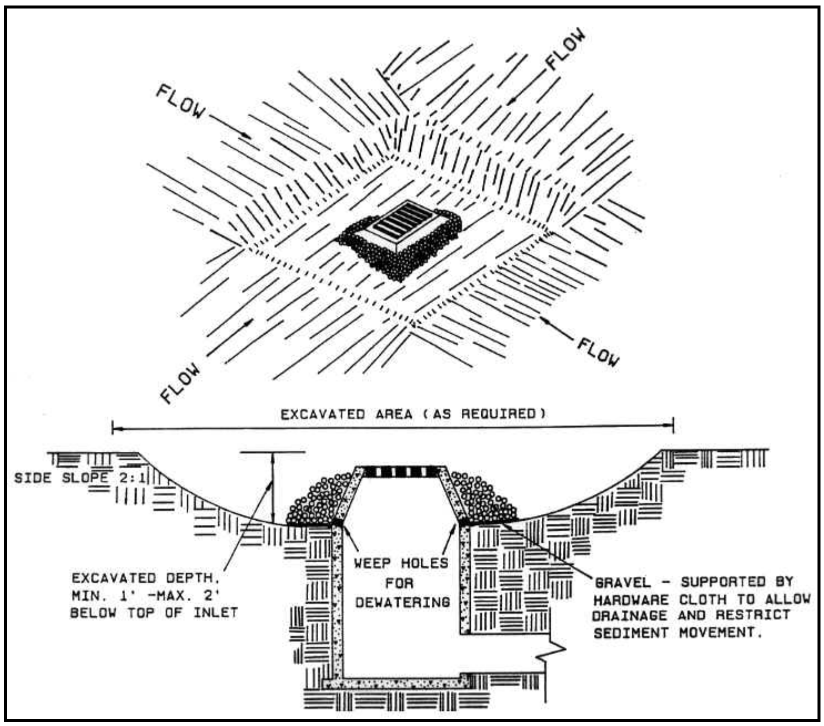


Figure B.57. Excavated drop inlet details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Construction Specifications

1. Clear the area of all debris that will hinder excavation.
2. Grade the approach to the inlet uniformly around the basin.
3. Protect weep holes with gravel.
4. Upon stabilization of contributing drainage area, seal weep holes, fill basin with stable soil to final grade, compact it properly, and stabilize with permanent seeding.
5. Maximum drainage area contributing runoff to practice is 1 acre.

FILTER FABRIC DROP INLET PROTECTION (Figure B.58)

Design Criteria

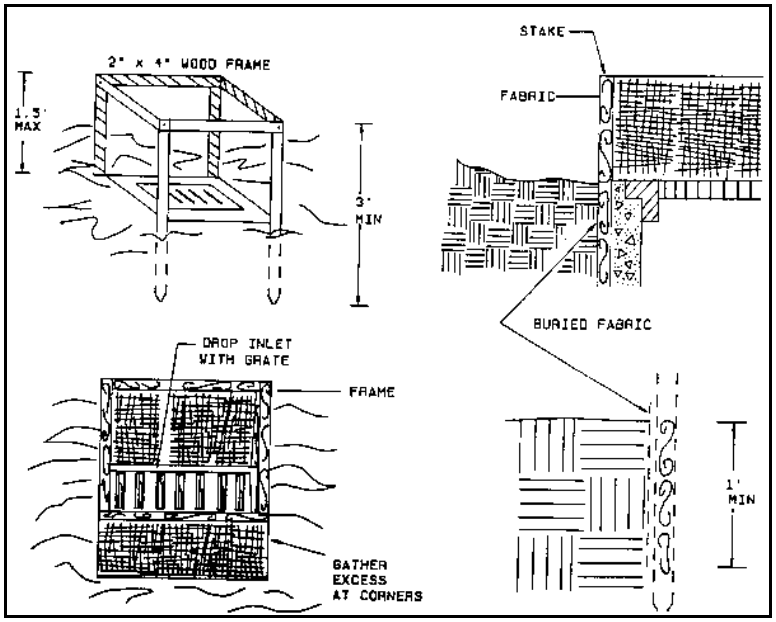


Figure B.58. Filter fabric drop inlet protection details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

1. Limit the contributing drainage area to 1 acre per inlet device.
2. Slope of land area immediately surrounding the device should not exceed 1 percent.
3. The maximum height of the fabric above the inlet crest shall not exceed 1.5 feet.
4. The top of the barrier should be maintained to allow overflow to drop into the drop inlet and not bypass the inlet to unprotected lower areas.
5. Support stakes ($^3/_8$" - ½" rebar or wood) for fabric shall be a minimum of 3 feet long, spaced a maximum of 3 feet apart. Stakes should be driven close to the inlet so any overflow drops into the inlet and not on unprotected soil.
6. Improved performance and sediment storage volume can be obtained by excavating the area.
7. Inspect the fabric barrier after each rain event and make repairs as needed.
8. Remove sediment from the pool area as necessary, taking care to not undercut or damage the fabric.
9. Upon stabilization of the drainage area, remove all materials and unstable sediment and dispose of properly.
10. Bring the area adjacent to the drop inlet to grade, smooth and compact the soil, and stabilize in a manner appropriate to the site.

Construction Specifications

1. Filter fabric shall have an equivalent opening size (EOS) of 40 - 85. Burlap may be used for emergency applications.
2. Cut fabric from a continuous roll to eliminate joints. If joints are necessary, they will be overlapped to the next stake.
3. Stake materials will be standard 2x4-inch wood or equivalent, or metal a minimum length of 3 feet.
4. Space stakes evenly around inlet, 3 feet apart, and drive a minimum of 18 inches deep. Spans greater than 3 feet may be bridged with the use of wire mesh behind the fabric for support.
5. Embed fabric 1 foot (minimum) below ground and backfill. Securely fasten fabric to the stakes and frame.
6. Complete a 2x4-inch wood frame shall be around the crest of the fabric for overflow stability.
7. Maximum drainage area contributing runoff to practice is 1 acre.

STONE AND BLOCK DROP INLET PROTECTION (Figure B.59)

Design Criteria

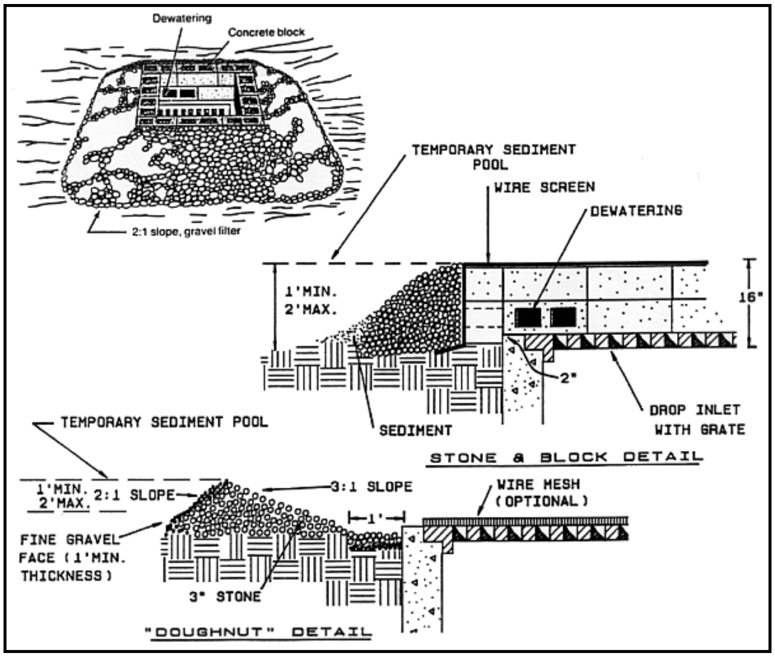


Figure B.59. Stone and block drop inlet protection details (*Empire State Chapter, 1997*).

1. Limit the drainage area to 1 acre at the drop inlet.
2. The stone barrier should have a minimum height of 1 foot and a maximum height of 2 feet. Height needs to be limited to prevent excess ponding and flow bypass.
3. Do not use mortar.
4. Recess the first course of blocks at least 2 inches below the crest opening of the storm drain for lateral support. Subsequent courses can be supported laterally, if needed, by placing a 2x4-inch wood stud through the block openings perpendicular to the course. The bottom row should have a few blocks oriented so that flow drains through the block to de-water the basin area.
5. Place stone just below the top of the blocks on slopes 2:1 or flatter. Place hardware cloth or wire mesh with ½-inch openings over all block openings to hold stone in place.
6. As an optional design, concrete blocks may be omitted and the entire structure constructed of stone ringing the outlet. The stone should be kept at a 3:1 slope toward the inlet to keep it from being washed into the inlet. A level area 1 foot wide and 4 inches below the crest will prevent further wash.
7. Stone on the slope toward the inlet should be at least 3 inches in size for stability and 1 inch or smaller away from the inlet to control flow rate.
8. The elevation of the top of the stone crest must be maintained 6 inches lower than the ground elevation downslope from the inlet to insure that all storm flows pass over the stone into the storm drain and not past the structure. Use temporary diking as necessary to prevent bypass flow.
9. Inspect the barrier after each rain event and make repairs where needed.
10. Remove sediment as necessary to provide for accurate storage volume for subsequent rains.
11. Upon stabilization of the contributing drainage area, remove all materials and any unstable soil and dispose of properly.
12. Bring the disturbed area to proper grade; smooth, compact, and stabilize in a manner appropriate to the site.

Construction Specifications

1. Lay one block on each side of the structure on its side for de-watering.
2. Build foundation 2 inches (minimum) below the crest of the inlet and place blocks against inlet for support.
3. Place hardware cloth or ½-inch wire mesh over block openings to support stone.
4. Use ½" - ¾" diameter clean stone or gravel placed 2 inches below the top of the block on a 2:1 slope or flatter.
5. For stone structures only, a 1-foot thick layer of the filter stone will be placed against the 3-inch stone as shown in Figure B.59.
6. Maximum drainage area contributing runoff to practice is 1 acre.

CURB DROP INLET PROTECTION (Figure B.60)

Design Criteria

1. Limit the contributing drainage area to 1 acre.
2. Wire mesh must be of sufficient strength to support the filter fabric and stone with runoff water fully impounded against it.
3. Stone shall be 2 inches in size and clean.
4. The filter fabric must be of a type designed for this purpose (see manufacturer's specifications) with an EOS of 40-85.
5. Construct the protective structure so that it extends 2 feet beyond the inlet in both directions.
6. Install temporary dikes directing flow to the inlet to prevent bypassing.
7. Inspect the structure after every storm event.
8. Remove any sediment and dispose of it on site.
9. Replace any missing stone.

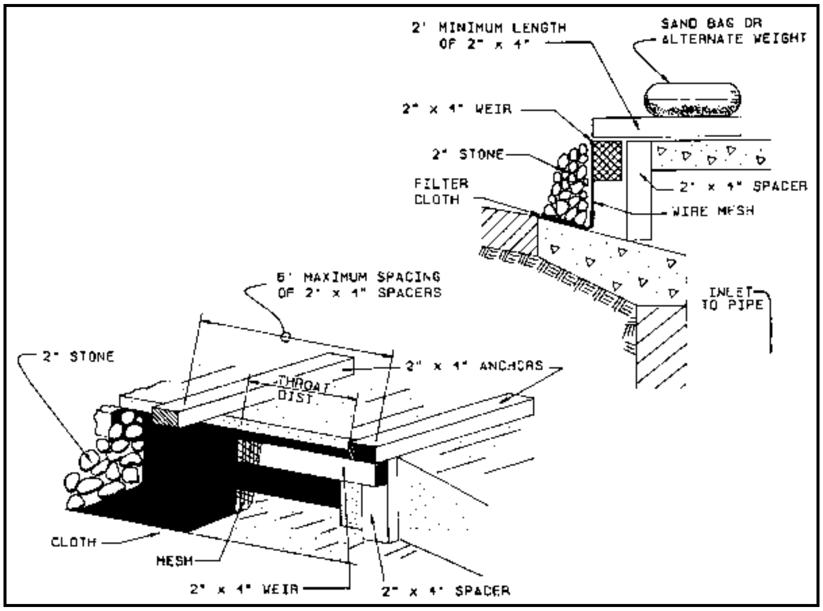


Figure B.60. Curb drop inlet protection details *(Empire State Chapter Soil & Water Conservation Society, 1997)*.

Construction Specifications

1. Filter fabric shall have an EOS of 40 - 85.
2. Construct wooden frame of 2x4-inch construction grade lumber.
3. Wire mesh across throat shall be a continuous piece, 30-inch minimum width and 4 feet longer than the throat. Shape mesh and nail securely to a 2x4-inch weir.
4. Securely nail the weir to 2x4-inch spacers 9 inches long and spaced no more than 6 feet apart.
5. Place the assembly against the inlet and secure it with 2x4-inch anchors 2 feet long, extending across the top of the inlet and held in place by sandbags or alternate weights.
6. Maximum drainage area contributing runoff to practice is 1 acre.

Outlet Protection

Design Criteria

The design of rock outlet protection depends entirely on the location. Pipe outlets at the top of cuts or on slopes steeper than 10 percent, cannot be protected by rock aprons or rip-rap sections due to reconcentration of flows and high velocities encountered after the flow leaves the apron.

Tailwater depth

The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. If the tailwater depth is less than half the diameter of the outlet pipe and the receiving stream is wide enough to accept divergence of the flow, it shall be classified as a **Minimum Tailwater Condition**. Figure B.61 depicts an example. If the tailwater depth is greater than half the pipe diameter and the receiving stream will continue to confine the flow, it shall be classified as a **Maximum Tailwater Condition** (Figures B.62 and B.63 provide an example). Pipes that outlet onto flat areas with no defined channel may be assumed to have a **Minimum Tailwater Condition**.

Apron Size

Determine the apron length and width from the curves according to the tailwater conditions:

Minimum Tailwater — Use Figure B.61.
Maximum Tailwater — Use Figure B.62.

If the pipe discharges directly into a well-defined channel, the apron shall extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank, whichever is less. The upstream end of the apron, adjacent to the pipe shall have a width 2 times the diameter of the outlet pipe, or conform to pipe end section, if used.

Bottom Grade

Construct the outlet protection apron with no slope along its length. There shall be no overfall at the end of the apron. The elevation of the downstream end of the apron shall be equal to the elevation of the receiving channel or adjacent ground.

Alignment

Locate the outlet protection apron so that there are no bends in the horizontal alignment.

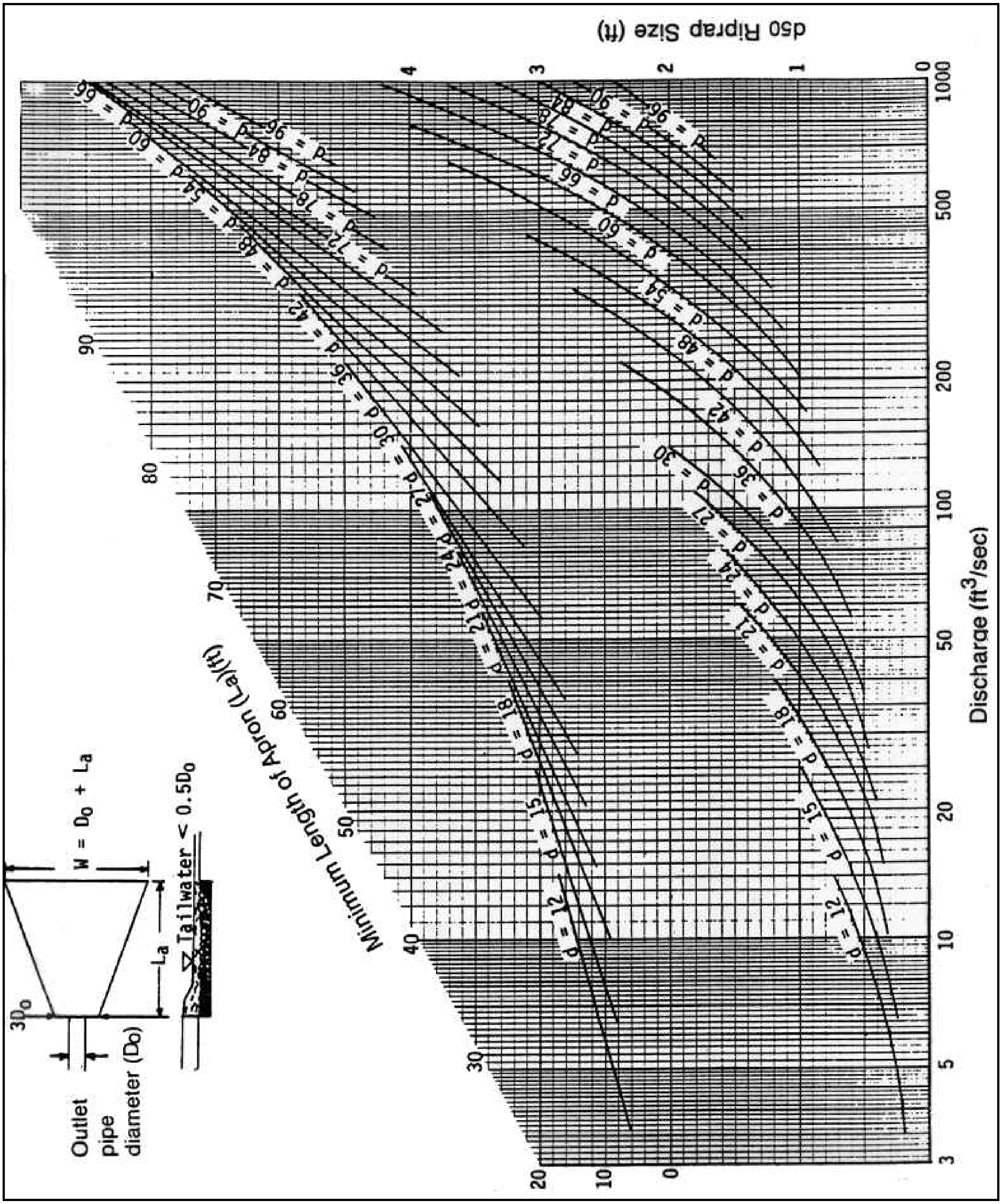


Figure B.61. Outlet protection design — Minimum Tailwater Condition (design of outlet protection from a round pipe flowing full, minimum tailwater condition: $T_w < 0.5D_o$; *Empire State Chapter Soil & Water Conservation Society, 1991*).

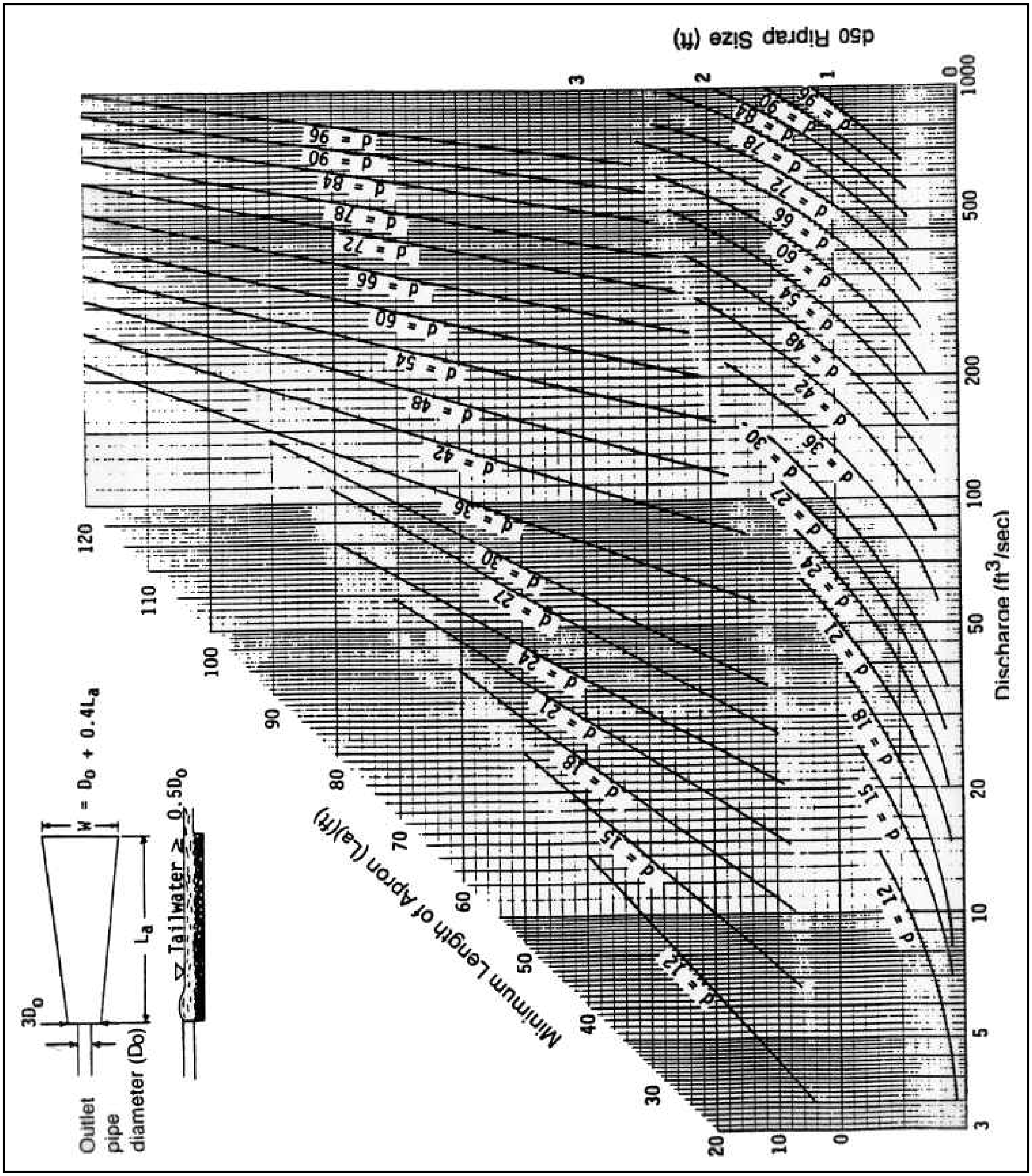


Figure B.62. Outlet protection design — Maximum Tailwater Condition (design of outlet protection from a round pipe flowing full, Maximum tailwater condition: $T_w > 0.5D_o$; *Empire State Chapter Soil & Water Conservation Society, 1991*).

Materials

The outlet protection may be done using rock rip-rap, grouted rip-rap, or gabions. Rip-rap shall be composed of a well-graded mixture of stone size so that 50 percent of the pieces, by weight, shall be larger than the d_{50} size determined by using the charts. (A well-graded mixture is defined as a mixture consisting mainly of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the stones.) The diameter of the largest stone size in the mixture shall be 1.5 times the d_{50} size.

Thickness

The minimum thickness of the rip-rap layer shall be 1.5 times the maximum stone diameter for d_{50} of 15 inches or less; and 1.2 times the maximum stone size for d_{50} greater than 15 inches. Refer to Table B.21 for some examples.

Table B.21. Minimum blanket thickness and stone sizes (*Empire State Chapter Soil & Water Conservation Society, 1991*).

D_{50} (inches)	d_{max} (inches)	Minimum Blanket Thickness (inches)
4	6	9
6	9	14
9	14	20
12	18	27
15	22	32
18	27	32
21	32	38
24	36	43

Stone Quality

Use field stone or rough un-hewn quarry stone for rip-rap. The stone shall be hard and angular and of a quality that will not disintegrate on exposure to water or weathering. The specific gravity of the individual stones shall be at least 2.5. Recycled concrete equivalent may be used provided it has a density of at least 150 pounds per cubic foot, and does not have any exposed steel or reinforcing bars.

Filter

Place a filter layer under rip-rap in all cases. A filter can be either a gravel layer or a plastic filter cloth. Use plastic filter cloth made of either woven or non-woven monofilament yarns with 20-60 mil thickness and 90-120 pound grab strength. If gravel filter blanket is used, design it by comparing particle sizes of the overlying material and the base material.

Gabions

Gabions shall be made of hexagonal, triple-twist mesh with heavily galvanized steel wire. The maximum linear dimension of the mesh opening shall not exceed 4½ inches and the area of the mesh opening shall not exceed 10 square inches. Construct gabions so that the sides, ends, and lid can be assembled at the construction site into a rectangular basket of the specified sizes. Grade the area on which the gabion is to be installed as shown on the drawings. Use the same foundation conditions as for placing rock rip-rap and place filter cloth under all gabions. A key may be needed to prevent undermining of the main gabion structure.

Design Procedure

1. Examine the downstream channel to assure that non-erosive velocities can be maintained.
2. Determine the tailwater condition at the outlet to establish which curve to use.
3. Enter the appropriate chart with the depth of flow and discharge velocity to determine the rip-rap size and apron length needed. (References to pipe diameter in the charts are based on full flow.) For other than full pipe flow, the parameters of depth of flow and velocity must be used.
4. Calculate apron width at the downstream end if a flared section is to be used.

Examples

1. Pipe flow (full) with discharge to unconfined section (Figure B.63).
   Given: A circular conduit flowing full.
   Q = 280 cfs
   Diameter = 66 inches
   Tailwater (surface) is 2 feet above pipe invert (minimum tailwater condition)
   Find: Read d_{50} = 1.2 and apron length (L_a) = 38 feet.
   Apron width = diameter + L_a = 5.5 + 38 = 43.5 feet.
   Use: d_{50} = 15 inches; d_{max} = 22 inches; blanket thickness = 32 inches.

2. Box flow (partial) with high tailwater (Figure B.64).
   Given: A box conduit discharging under partial flow conditions. A concrete box 5.5 feet x 10 feet flowing 5.0 feet deep.
   Q = 600 cfs and tailwater surface is 5 feet above invert (maximum tailwater condition).

   Since this is not full pipe flow and does not directly fit the nomograph assumptions, it is necessary to calculate the velocity in the conduit and then substitute the depth of flow as a diameter to find a discharge equal to full flow for that diameter (60 inches).

   Compute velocity: V = Q/A = 600/(5x10) = 12 feet/second (fps)
   Then substituting:

$$Q = \frac{\pi D^2}{4} \times V = \frac{3.14\ (5feet)^2}{4} \times 12fps = 236fps$$

   At the intersection of the curve d = 60 inches and Q = 236 cfs, read d_{50} = 0.4 feet. Then reading the d = 60 inches curve, read apron length (L_a) = 40 feet. Apron width, W = conduit width + 0.04 x L_a = 10 + 0.4 x 40 = 26 feet.

3. Open channel flow with discharge to unconfined section (Figure B.65).
   Given: A trapezoidal concrete channel 5 feet wide with 2:1 side slopes is flowing 2 feet deep; Q = 180 cfs (velocity = 10 fps); and the tailwater surface downstream is 0.8 feet (minimum tailwater condition).

   Find: Using similar principles as Example 1, compute equivalent discharge for a 2-foot circular pipe flowing full at 10 feet/second.

$$Q = \frac{\pi\ (2feet)^2}{4} \times 10fps = 31.4fps$$

At the intersection of the curves d = 24 inches and Q = 32 cfs, read d_{50} = 0.6 feet. Then reading the d = 24 inches curve, read apron length (L_a) = 20 feet. Apron width, w = bottom width of channel + L_a = 5 + 20 = 25 feet.

Construction Specifications

1. Prepare the subgrade for the filter, rip-rap, or gabion to the required lines and grades. Compact any fill required in the subgrade to a density of approximately equal to that of the surrounding undisturbed material.
2. The rock or gravel shall conform to the specified grading limits when installed in the rip-rap or filter.

3. Protect filter cloth from punching, cutting or tearing. Repair any damage other than occasional small holes by placing another piece of cloth over the damaged part or by completely replacing the cloth. All overlaps, whether for repairs or for joining two pieces of cloth, shall be a minimum of 1 foot.
4. Stone for the rip-rap or gabion outlets may be placed by equipment. Construct outlets to full thickness in one operation and so that displacement of underlying materials (such as filter fabric) is avoided. Deliver and place the stone for rip-rap or gabion outlets so that stone size distribution is relatively even, with the smaller stones filling the spaces between the larger stones. Place rip-rap in such a manner as to prevent damage to the filter blanket or filter cloth. Hand placement of some stone may be necessary to prevent damage to the permanent structure.

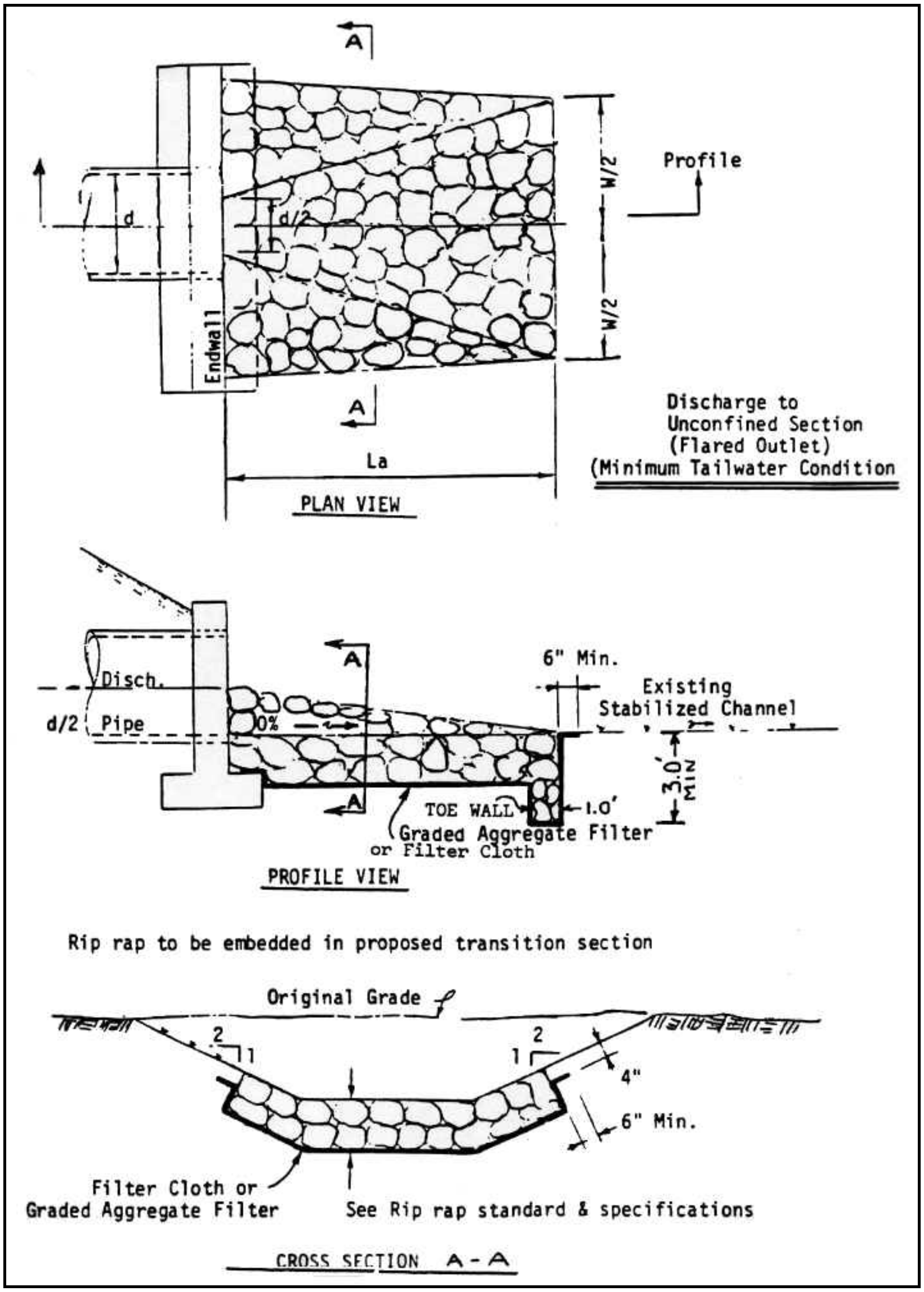


Figure B.63. Rip-rap outlet protection Example 1 *(Empire State Chapter Soil & Water Conservation Society, 1991)*.

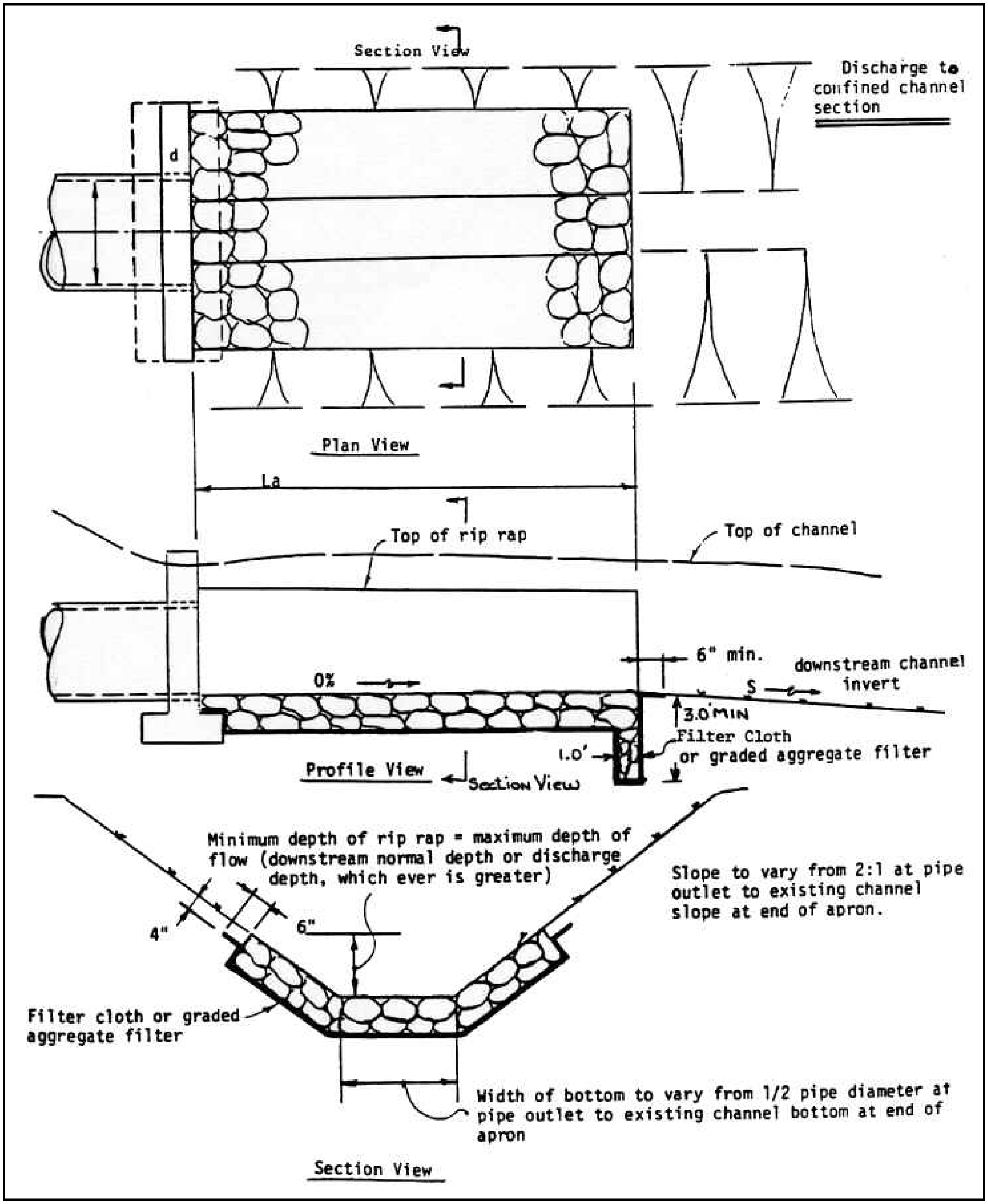


Figure B.64. Rip-rap outlet protection Example 2 (*Empire State Chapter Soil & Water Conservation Society, 1991*).

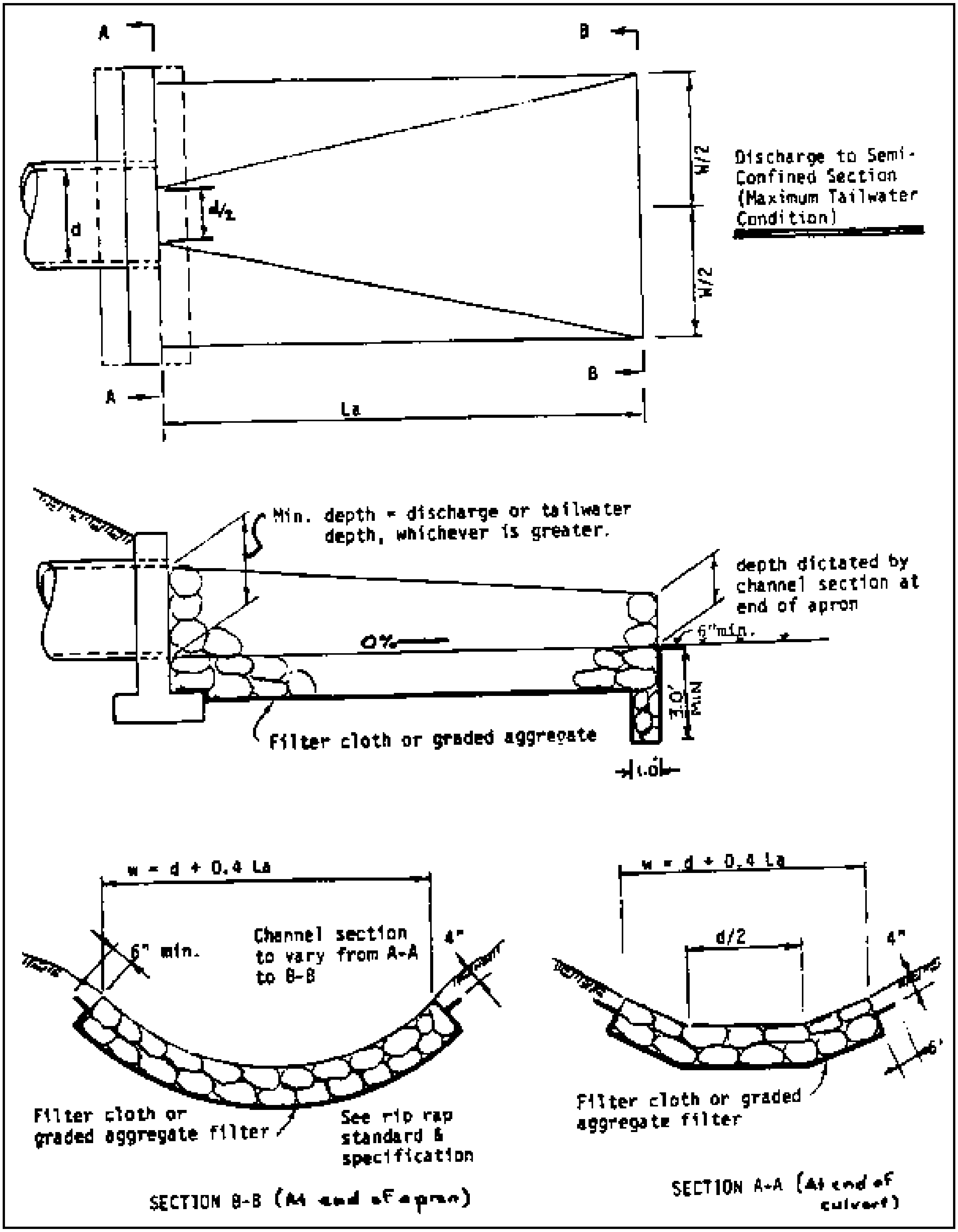


Figure B.65. Rip-rap outlet protection example (*Empire State Chapter Soil & Water Conservation Society, 1991*).

Gabion Inflow Protection

Gabion inflow protection is used to provide stable transport of concentrated runoff down steep slopes to prevent erosion of the flow channel. It is needed where the slope of a drainageway contributing to a sediment trap or basin exceeds 25 percent, or on other steep areas as applicable.

Design Criteria

1. Use 4- to 7-inch stone (minimum) for gabion inflow protection and place in wire baskets, underlain by geotextile. Place baskets from the ditch overfall elevation to the bottom of the trap or basin. Use this practice only when the inflow slope is between 2:1 and 4:1.
2. Stabilize slopes flatter than 10:1 in accordance with ***Temporary Swale*** criteria as described in this Handbook. Use rip-rap protection for slopes between 10:1 and 4:1.

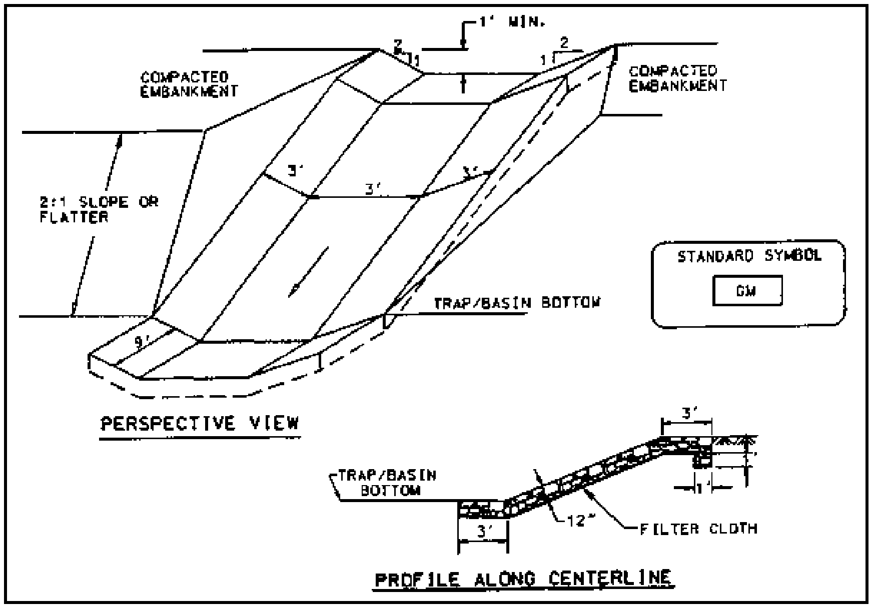


Figure B.66. Gabion inflow protection details *(Maryland Department of the Environment, 1994*).

Construction Specifications

1. Construct by arranging 9 foot x 3 foot x 9 inch gabion baskets forming a trapezoidal cross section 1 foot with 2:1 side slopes and 3 foot bottom width (Figure B.66).
2. Install Geotextile Class C under all gabion baskets.
3. Use 4- to 7-inch stone to fill the gabion baskets.
4. Install gabions in accordance with the manufacturer's specifications.
5. Use this practice where concentrated flow is present on slopes steeper than 4:1.

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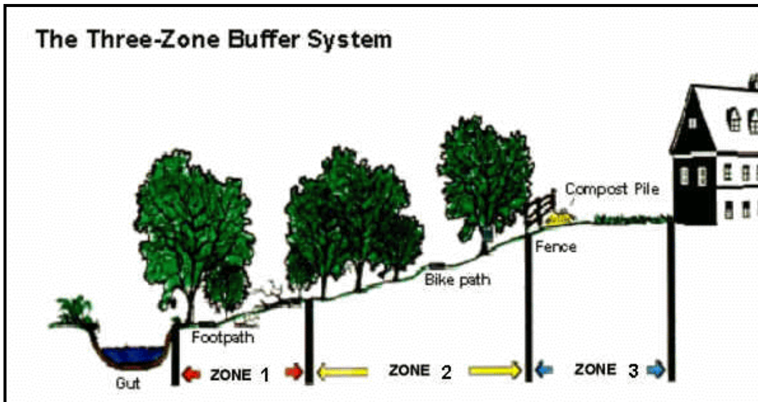
APPENDIX C: STORMWATER PRACTICE SPECIFICATIONS

Buffer Zones

Buffer zones are areas of vegetated land along a shoreline, wetland or gut where development is prohibited, or are vegetated areas located at the downstream (or hill) edge of disturbed, developed or impervious areas. There are three types of buffer zones: setbacks, vegetated buffers and engineered buffers (CWP, 2001b).

Setbacks are areas that separate waterways from potential pollution hazards (typically development sites). Vegetated buffers are natural areas that exist to divide land uses or provide landscaping. Engineered buffers are areas specifically designed to treat stormwater before it enters a gut, wetland or coastal area (CWP, 2001b). They may closely resemble natural ecosystems, such as grassy pastures or forests. Buffer zones are designed specifically to protect waterbodies, slow stormwater runoff and remove pollutants from stormwater, and in this way differ from ***Filter Strips*** (see Chapter 3), which are designed specifically to filter sediment from runoff.



CHARACTERISTICS	ZONE 1	ZONE 2	ZONE 3
FUNCTION	Protect physical integrity of aquatic ecosystem	Provide distance between upland development and aquatic zone	Prevent Encroachment and Filter Backyard Runoff
WIDTH	Minimum 25 feet plus wetlands and critical habitats	50 - 100 feet, depending on type of water body, slope and 100 year floodplain	25 foot minimum setback for structures
VEGETATIVE TARGET	Undisturbed mature forest, reforest if grass	Managed forest, some clearing allowable	Forest encouraged, but usually turfgrass
ALLOWABLE USES	*Very Restricted* e.g., flood control, utility right of ways, footpaths, etc.	*Restricted*, some recreational uses, some stormwater BMPs, bike paths, tree removal by permit	*Unrestricted*, e.g. residential uses, including lawn, garden, compost, yard wastes, most stormwater BMPs.

Figure C.1. Three-zone aquatic buffer system (modified from *CWP, 2001b* and *CH2M Hill, 1998*).

Siting and Design Criteria

Effective buffer zone design is based on criteria that determine how a buffer will be sized, delineated, managed and crossed, including: minimum total buffer width, three-zone buffer system, mature forest as target vegetation/habitat, conditions for buffer expansion or contraction, physical delineation requirements, conditions where buffer can be crossed, integrating stormwater and stormwater management within the buffer, buffer limit review, buffer education, inspection and enforcement, and buffer flexibility (CWP, 2001b).

Setbacks should have a minimum width of 100 feet to provide adequate protection of waterbodies from development activities (especially on steeper slopes i.e., > 15%). However, in urban and suburban areas where open space is limited, narrower buffers adjacent to guts and wetlands can still be beneficial. The three-zone buffer system is an effective way to establish a buffer (Figure C.1). This method consists of inner, middle and outer buffers zones that have different functions, width, target vegetation, and allowable uses.

The optimum width for a buffer depends on the function of the buffer (Figure C.2). For a three-zone buffer system (Figure C.1), the width of the zone depends on the size of the gut, pond, or bay and the topographic setting (slope, etc.). Zone 1 starts from the top of the gut bank, shoreline or cliff and is usually 15 to 25 feet or wider. It consist of woody trees and shrubs (preferably native) that provide

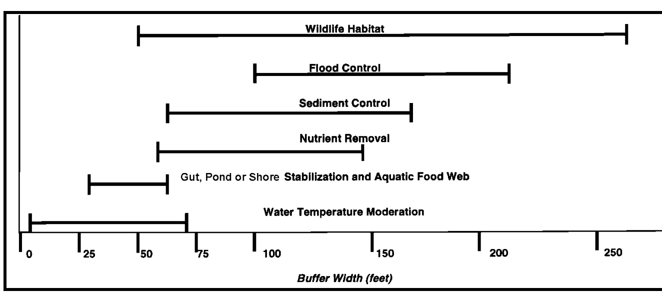


Figure C.2. Range of minimum width for meeting specific buffer objectives (*CH2M Hill, 1998*).

shade and nutrients to the water body and stabilize banks or shorelines. Minimal disturbance is recommended for this area, and vegetation must be maintained (CH2M Hill, 1998).

Zone 2 is usually 50 to 100 feet wide, depending on slopes and category of gut, pond or bay. Zone 2 provides stormwater filtering, buffering and infiltration. Only sheet or subsurface flow should reach this area, concentrated flows (from swales or channels) entering or crossing the area will cause erosion and decrease the effectiveness of the buffer. This zone also consists of trees and shrubs (preferably native, either set aside or planted).

Zone 3 is usually 20 to 25 feet or wider. This zone converts concentrated flows to sheet flow and also functions as a filter strip, removing sediment and nutrients from runoff (see ***Filter Strips*** in Chapter 3 and Appendix B).

In developed areas where wide buffers may not be available, a minimum buffer width of 35 feet can be used if following the following design principles:

- Encourage sheet flow into the edge of the buffer and use practices such as Filter Strips to create sheet flow before runoff enters the buffer.
- Width should be proportional to the watershed area and slope.
- Forest vegetation should include both understory (shrubs, forbs, grasses) and canopy species (trees). Tree species are particularly important to stabilize gut and pond banks and shorelines.
- Use native plants wherever possible. In suburban and urban areas, forested buffers do not have to resemble natural ecosystems to improve water quality and habitat. However, planting designs must be dense enough to filter sediment, provide stabilization and attenuate nutrients (CH2M Hill, 1998).

Buffers can be implemented on steep slopes along with soil bioengineering (see ***Soil Bioengineering***, Chapter 3 and Appendix B) practices to stabilize banks, shores and buffer zones. Areas susceptible to intense flooding may also need additional stabilization practices.

Maintenance

Corrective maintenance is needed around the edge of the buffer to prevent concentrated flows from forming. Accumulated sediments near the top of the buffer may need to be manually removed over time to keep the original grade and prevent channels from forming. Vegetation within the buffers should also be maintained, including selective pruning, weeding, and replanting. Fertilization is not recommended. Eradication of invasive, non-native (exotic) plants such as tan-tan, cashia and guinea grass may be necessary to ensure forest health and diversity. Some weeds can be suppressed by planting vigorous native species that can out-compete exotic species.

Inspect buffers annually and examine for damage by foot or vehicle traffic, livestock, encroachment, gully erosion and evidence of concentrated flows through or around strip.

GRASSED SWALES

Grassed swales can be used in most development situations with few restrictions, and are particularly well-suited to treat highway or residential road runoff because of their linear design. Grassed swales are commonly used to replace existing drainage ditches that are traditionally designed only to convey stormwater away from roads. It may also be possible to incorporate features to enhance swales' pollutant removal or infiltration by using check dams (small dams along the ditch that trap sediment, slow runoff, and reduce the swale slope) (CWP, 2001d).

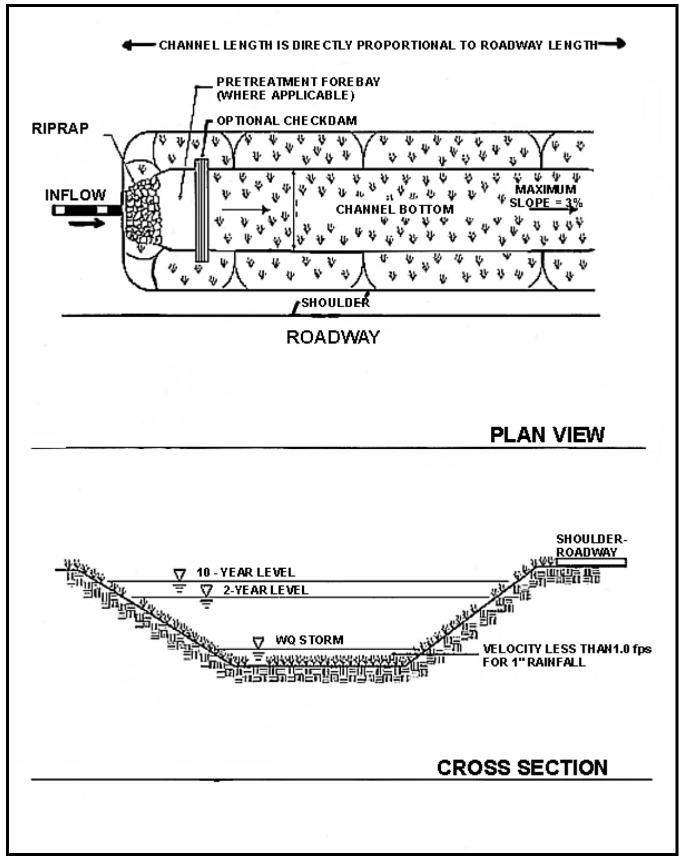


Figure C.3. Schematic design of a grassed swale (Schueler, 1987).

Siting and Design Criteria

1. Individual grassed swales or channels should only be used to treat small drainage areas (less than 5 acres). Otherwise, stormwater velocity is too great to treat runoff and prevent channel erosion.

2. Swales should only be used on sites with fairly flat slopes (< 5%). Swale side slopes should be no greater than 3:1 (horizontal:vertical).

3. A dense cover of water and drought-tolerant, erosion-resistant grass must be established. Swale grasses should never be cut closer than 2" from the ground surface; ideally, mower blades should be set to 3" - 4" above the ground surface.

3. Grassed swales can be used on most soils, except for highly impermeable soils. The swale may need to be tilled before grass cover can be established to restore infiltration capacity lost as a result of prior construction activities.

4. Check dams can be installed in swales to promote additional stormwater infiltration. The best method is to sink a log or large rip-rap halfway into the swale, and place large stone on the downstream site of the log (or rip-rap) to prevent a scour hole from forming. Earthen check dams are **NOT** recommended because they tend to erode on the downstream side of the dam. If a check dam is used, the maximum ponding time of runoff backed up behind the check dam is less than 24 hours.

Construction Specifications

See specifications for ***Drainage Swale*** in Appendix B.

Maintenance

Swale maintenance is aimed towards keeping the grass cover dense and vigorous. This involves periodic mowing, spot re-seeding, and weed control. Table C.1 provides an overview of typical maintenance activities for grassed swales.

Table C.1. Typical Maintenance Activities for Grassed Swales (adapted from: CWP, 1996).

Activity	Schedule
C Inspect pea gravel diaphragm for clogging and correct problem. C Inspect grass along side slopes for erosion and formation of rills or gullies and correct. C Remove accumulated trash and debris. C Inspect and correct erosion problems. C Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established.	Annual (Semi-annual the first year)
C Roto-till or cultivate the surface of the swale if it does not draw down (evaporate and/or infiltrate) within 48 hours. C Remove sediment build-up from bottom of swale once it has accumulated to 25% of original design volume.	As needed (Infrequent)
C Mow grass to maintain a height of 3 to 4 inches.	As needed (frequent seasonally)

Sand Filters

Design & Construction Criteria

Numerous design variations on the original sand filter have been developed. Those most applicable to Virgin Islands conditions are shown in Figure C.4. The required surface area of the filter is a direct function of the impervious acreage treated and varies according to local rainfall volumes. The Austin sand filter full sedimentation design (top left of Figure C.4) requires a basin liner, a 2:1 length to width ratio, and the sand must have a grain size smaller than sand used to make concrete. The Austin sand filter partial sedimentation design (top middle of Figure C.4) requires more frequent sand replacement than the full sedimentation design and requires a basin liner. The Delaware sand filter sand chamber design (bottom middle of Figure C.4) requires very little head. Grates cover each chamber for easy access, however, traffic load needs to be considered in designing the structure (Schueler, 1994).

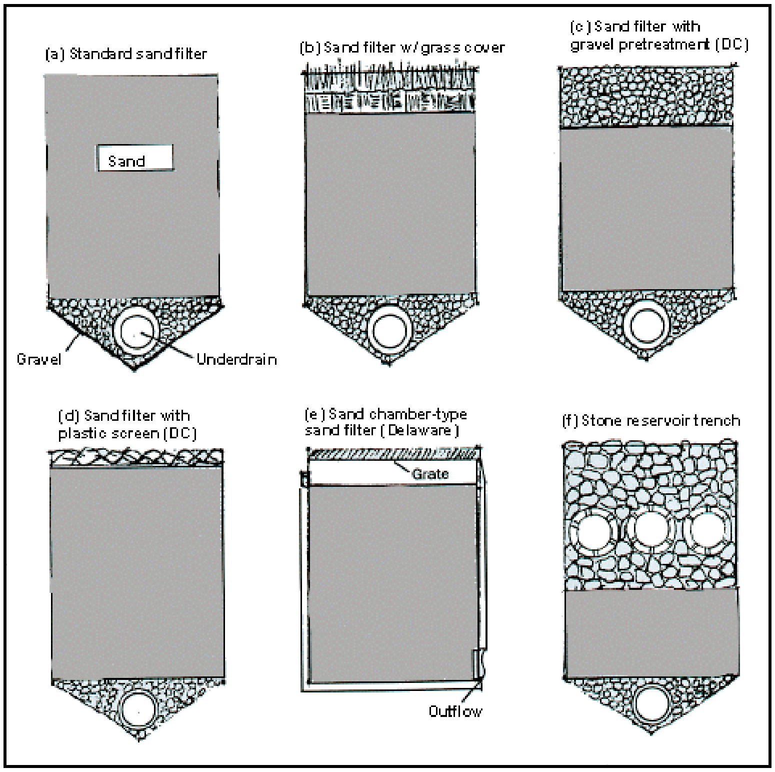


Figure C.4. Cross-section of sand filter design variations (Schueler, 1994).

Table C.2. Comparison of sand filter designs (Schueler, 1994).

DESIGN VARIABLES	Austin Sand Filter *(full sedimentation)*	Austin Sand Filter *(partial sedimentation)*	Delaware Sand Filter
Applicable Situations & Drainage Area	Most can serve 1 to 30 acres	Most can serve 1 to 30 acres	No more than 5 acres of impervious parking lot
Filter Bed Profile	18" sand, 4-6 inches gravel, optional sod layer on surface of bed	18" sand, 4-6 inches gravel, optional sod layer on surface of bed	18" of sand
Filter Bed Area (sf/Ia)*	100	180	360
Total Treatment Volume	First ½" of runoff with 24 hr. drawdown sediment chamber	First ½" of runoff, S.C. = 20% of Water Quality Volume	First 1" of runoff
Pretreatment Method	Dry sediment chamber	Dry sediment chamber	Shallow wet pool
Pretreatment Volume	sc >> fb**	sc ~= fb	sc = fb

* sf/Ia = square foot of filter bed area per impervious acre.
** sc = sedimentation chamber; fb = filter bed.

Maintenance

Sand filters must be maintained frequently, by hand. Maintenance includes removing surface sediment, trash, debris and leaf litter from the filters as it accumulates in order to prevent clogging. In areas that have heavy oil and grease loadings, replacing the top 2 to 3 inches of sand or overlying layers of geotextile is necessary every 3 to 5 years (CH2M Hill, 1998).

Water Quality Inlets

Siting and Design Criteria

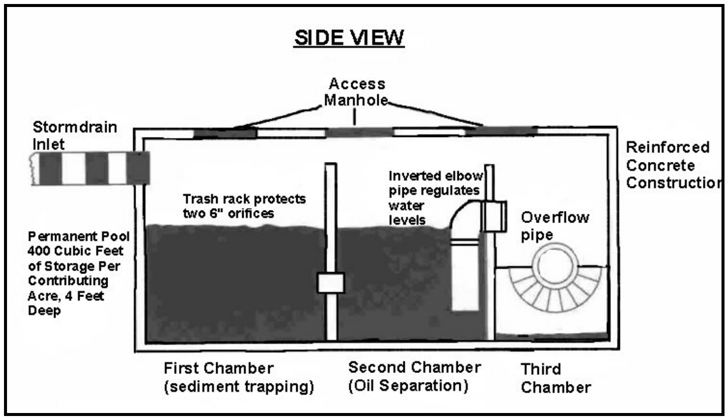


Figure C.5. Schematic design of a water quality inlet/oil-grit separator (Schueler, et al., 1992).

A common design of the water quality inlet has three chambers that pool stormwater, settle particulates (sediment), and remove oil (Figure C.5). As stormwater flows through the system, oil and grease separate either to the surface and are skimmed off, or attach to sediment and are held in the inlet. The quantity of pollutants removed by water quality inlet depends on the volume of the device, flow velocity and the depth of the baffles and elbows in the chambers. Because water quality inlets are relatively small, they can be placed throughout a drainage system to capture coarse sediment, floating wastes, and spills (CH2M Hill, 1998).

A second type of design removes higher levels of pollutants using simple skimmer and control structures in the first chamber of the inlet. This requires using an open water quality inlet with a skimmer plate extending below the ponding control elevation at the outlet. Runoff speed is reduced in the first chamber, dropping out course sediment and separating oil, grease and floatables that are held in the inlet by the skimmer.

Water quality inlets should be designed to provide wet storage for the first one-tenth of the water quality volume (the total runoff that will flow to the device during the water quality design storm, CH2M Hill, 1998). The storage requirement is calculated from the volume of the first two chambers to the top of the weirs only. If the length of the system exceeds 12 feet, the first two chambers should be proportioned so that the first chamber is ⅔ of the length and the second chamber is ⅓ of the length. The weir dividing the first and second chambers should be designed to pass the specified spillway design flood (usually the 10-year storm). The submerged opening between the first and second chambers should be rectangular and appropriately sized to pass the design storm. The opening should be protected by a trash rack bolted to the dividing wall. The second and third chambers should be connected by an inverted elbow pipe to trap petroleum hydrocarbons in the second chamber. A 90° elbow with a sealable access port in the top of the elbow should be used to permit cleaning.

Many types of commercial prefabricated water quality inlets, such as Stormceptor® (see Chapter 4), are available. Each manufacturer has design and installation guidelines for their products that can be used to identify the appropriate inlet for each site.

Maintenance

Water quality inlets should be inspected regularly and cleaned at least twice a year to remove accumulated sediment, oil and grease, floatables, and other pollutants. Sediment should be removed from skimmer structures less frequently, but the skimmers should still be inspected periodically. Wastes removed from the systems my be hazardous, and should be tested to determine proper disposal methods.

Extended Detention Ponds

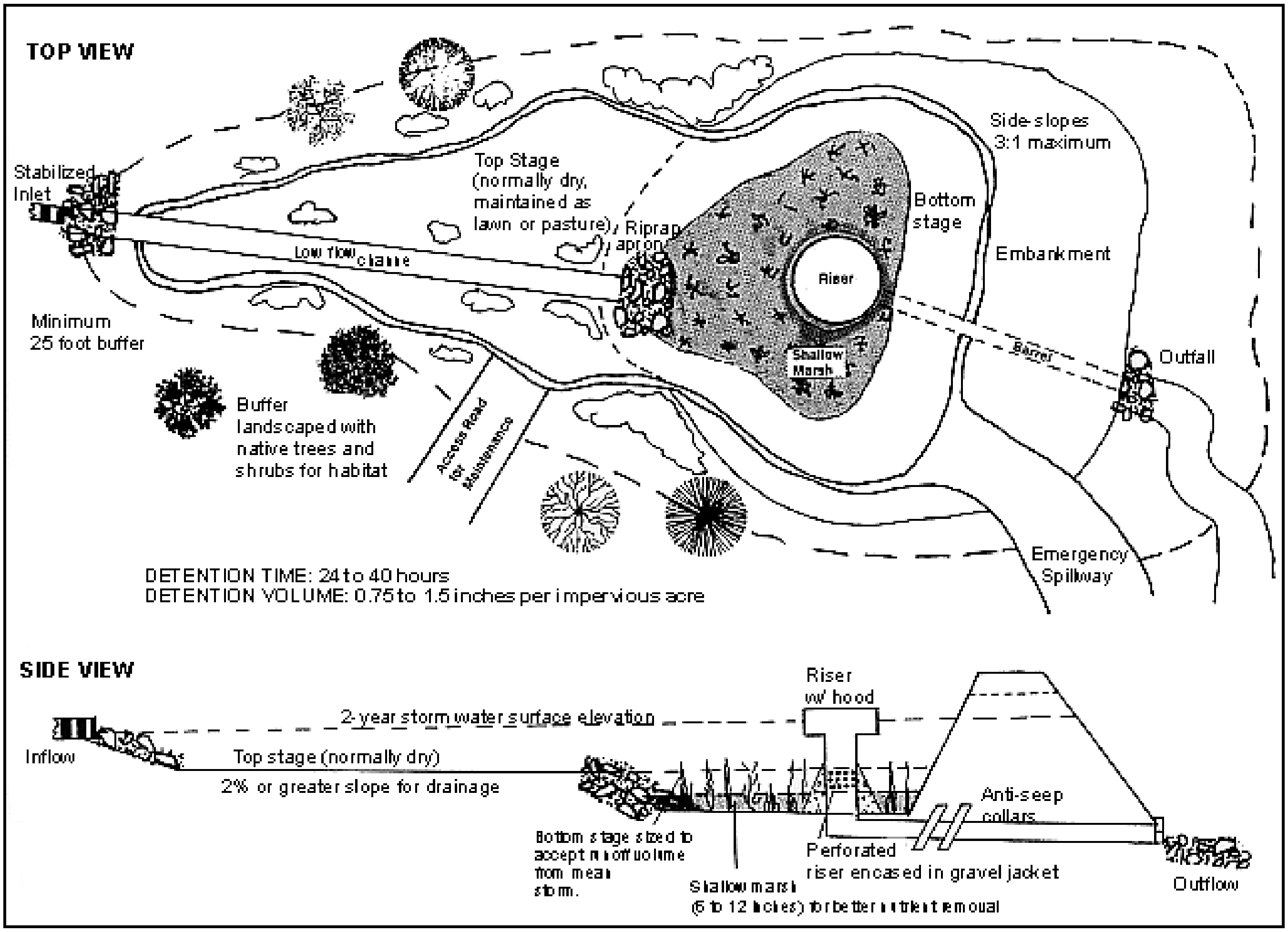


Figure C.6. Drawing of extended detention (ED) pond design features (Schueler, 1987).

Design & Construction Criteria

Quantity Detained: At a minimum, the extended detention pond (Figure C.6) should detain the volume of runoff produced by a one inch storm (see Chapter 6). This will ensure both removal of a large percentage of particulate pollutants and downstream channel erosion protection for most storms. Higher levels of control can be achieved when the runoff volume from the one or two-year storm is detained.

Duration: Twenty-four (24) hours of extra detention are needed for optimum pollutant removal. The outlet control device should be adjusted so that smaller runoff events (0.1 to 0.2 inches) are detained for at least six (6) hours. For larger watersheds, up to 40 hours of extended detention time may be needed to prevent erosion of the downstream channel. The runoff velocity exiting the extended detention pond to the downstream channel should be computed as follows to make sure that it is not erosive:

1. Determine average discharge (cfs) for extended detention release (Q_{ex}):

$$Q_{ex} = S / T \qquad \text{[EQ. C-1]}$$

where S = detention storage volume (cubic feet, ft^3)
T = detention time (hours x 3600 seconds/hour)

2. Determine discharge for natural channel segment (Q_c):

$$Q_c = 0.25\ X_c\ V_a \qquad \text{[EQ. C-2]}$$

where X_c = channel cross-sectional area (square feet, ft^2)
V_a = permissible velocity (3 - 5 feet per second, ft/sec)

3. If Q_{ex} is greater than Q_c, then repeat steps 1 and 2 using either a longer detention time (t) or a smaller detention storage volume (S) until Q_{ex} becomes less than Q_c.

Two-Stage Design: A two-stage pond design is recommended for dry ponds. The upper stage of the pond is sized and graded (2% minimum) to remain dry except during infrequent, large storms, while the bottom stage should be designed to be regularly flooded. The volume of the bottom stage should be set to store the runoff produced by the mean storm:

$$Volb = \frac{R_m\ R_v}{12} * A \qquad \text{[EQ. C-3]}$$

where Volb = volume of bottom stage (acre-feet)
R_m = volume of mean storm (0.4 to 0.5 inches)
R_v = rainfall/runoff coefficient (approximated by eq. C-4)
A = area of contributing watershed (acres).

$$R_v = 0.05 + 0.009\ I \qquad \text{[EQ. C-4]}$$

where I = the percent of site imperviousness

The bottom stage of the pond will usually be too wet to mow and so should be managed as a wetland or as a shallow pool. These management methods will prevent resuspension of deposited pollutants. Extra storage (in addition to stormwater and ED requirements) should be provided in the bottom stage or at the inlet to account for accumulation of sediment for up to 20 years.

Wetland Creation: Whenever possible, a wetland should be created in the bottom stage to help remove soluble pollutants from stormwater. Wetlands will also hide unsightly debris and sediment deposits that accumulate near the riser and provide wildlife habitat. Water depths of 6 - 12 inches are needed for optimum plant growth. The wetland should be planted with native species suited to its environment (see next section).

Extended Detention Control Device: A vertical, internally-controlled extension of the low flow orifice is the most trouble-free design; it can withstand partial clogging and gradual sediment accumulation, and can also be used to set water levels. Control devices installed below the ground surface should be protected with filter fabric and/or wire mesh and encased in a stone or gravel trench of diameter greater than the orifice. It should also have an above-ground extension with a tight-fitting cap to make clean-out easier.

Pilot Channels: A riprap, concrete or paved low flow channel is needed to route water through the upper stage of the pond. This channel should end at the lip of the lower stage and riprap or gabion baskets should be placed to reduce flow velocity and spread out the flow path of the runoff reaching the lower stage.

Slopes: Slopes leading to the pond should be shallow so that gully erosion of the pond banks does not occur during larger storms. Side slopes should not be steeper than 3:1 (horizontal:vertical) or flatter than 20:1. Banks that are steeper than 2:1 should be stabilized with riprap to prevent erosion. The slope of the upper stage of an extended detention pond should be between 2 and 5% to promote rapid drainage. The stream channel below the pond outlet should also be lined with large stone riprap and graded to a 0.5% slope to prevent scouring during larger events. A layer of filter cloth should be laid down that conforms to the natural dimensions of the channel, and then anchored with 18-30 inch stone riprap. Smaller riprap (9 - 12 inches) can be used if the diameter of the pipe outfall is less than 24 inches. The outfall pipe should discharge at the bottom of the embankment directly to the outflow channel.

Pond Buffer: A minimum 25 foot wide buffer strip should be maintained around the pond and landscaped using low-maintenance grasses, shrubs and trees.

Embankment: At least 10-15% extra fill should be allowed on the embankment to account for possible subsidence. The embankment should have at least one foot of freeboard above the emergency spillway. Anti-seep collars should be used to prevent seepage around the barrel. The embankment should be graded to allow access for heavy equipment and needs to be mowed twice a year to prevent tree/bush growth.

Site Access: Access from public or private rights-of-way to the pond should be at least 10 feet wide on a slope of 5:1 or less and stabilized to withstand heavy equipment traffic.

Dry ponds can be easily adapted to extend stormwater detention times. A two-stage design is recommended for dry ponds where the top portion of the pond remains dry most of the time, and a smaller part near the riser is regularly flooded (Figure C.6). The devices used to extend detention are usually attached to the low flow orifice or the riser. Some common methods used to extend detention are shown in Figure C.7, and include (from Schueler, 1987) the following:

Perforated Riser Enclosed in a Gravel Jacket (Figure C.7.a). A standard corrugated metal pipe riser is perforated with small holes and the normal low flow orifice is closed. The total diameter of all the holes regulates the outflow from the pond to achieve the design detention time for all storms smaller than the two-year design storm. A gravel jacket and wire mesh screen filter stormwater to prevent clogging. However, perforated risers have some drawbacks, including difficulty in achieving target detention time because of uncertainty of flow rates through the vertical riser and clogging of the bottom of the gravel jacket by deposited sediment.

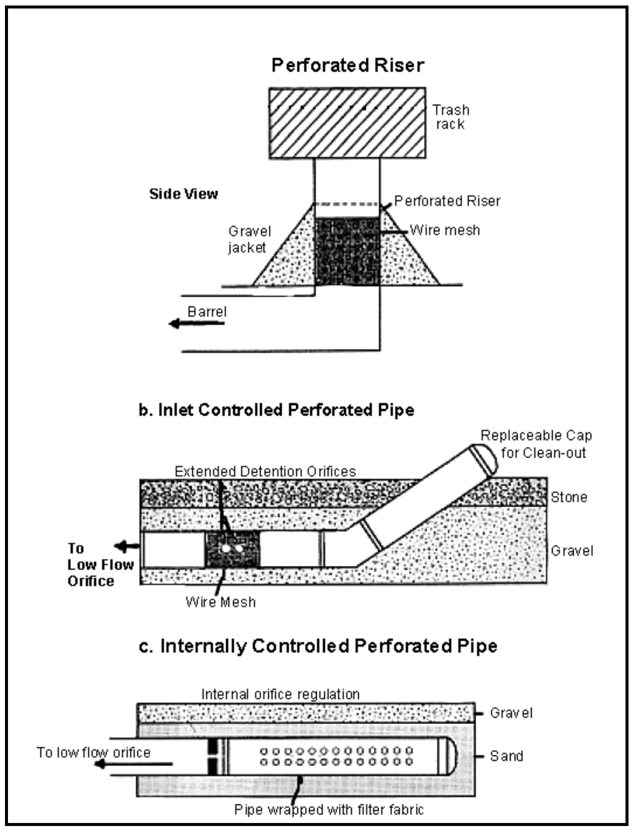


Figure C.7. Common approaches to extended detention times in ponds (Maryland Department of the Environment, 1987).

Perforated Extension of Low Flow Orifice, Inlet Controlled (Figure C.7.b). This design entails extending and capping the low flow orifice. Small diameter holes are drilled into the extended PVC pipe, these holes are protected by a 1/4" wire mesh and a layer of gravel and stone. An elbow joint is used to extend the pipe above the pond surface to facilitate cleaning with high velocity jet hoses. This design should only be used in areas where regular maintenance and cleaning is performed, because it is prone to clogging.

Perforated Extension of Low Flow Orifice, Outlet Controlled (Figure C.7.c). This method also uses a perforated pipe extended from the low flow orifice. The major difference between this method and the previous one is that the release rate of the pipe is regulated by an internal flange within the pipe, instead of holes drilled in the pipe. This provides additional protection from clogging. If sediment does partially clog the gravel/geotextile filters or the outside of the perforated pipe, enough water can flow through the remaining holes to release stormwater according to design.

Maintenance

Wet-weather inspections should be conducted annually. Inspectors should check condition of the extended detention control device and low flow channel. ED facilities should be maintained as a meadow to reduce mowing frequency and maintenance costs.

Sediment Removal: A five to ten year sediment removal cycle is recommended. Extra storage in the lower stage may be provided to accommodate sediment deposition.

Constructed Wetlands

Constructed wetlands are used in stormwater management to provide detention time during which stormwater quality can be enhanced. Artificial wetlands can be built as either **surface water systems** or **subsurface flow systems.**

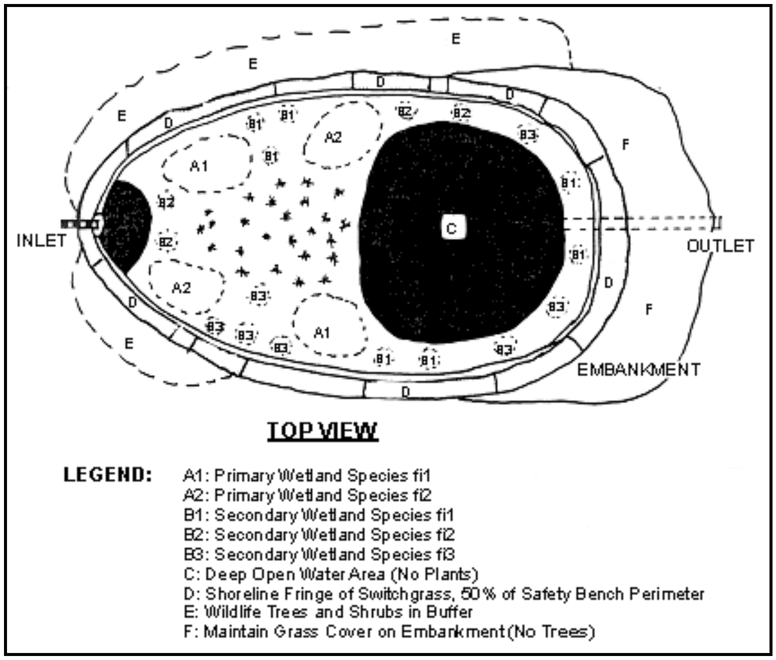


Figure C.8. Surface water wetland design — note the diversity of recommended plant species (Schueler, 1987).

Surface water systems are made up of basins or channels that can be constructed using an impoundment in a low-lying area (Figure C.8). They can also be constructed in the lower stage of a detention basin. These systems can provide a dense stand of aquatic vegetation that acts as a biological filter to remove pollutants from stormwater flowing through the wetland. In these systems, only 25% of the total surface area is open water. The rest of the wetland consists of submergent and emergent vegetation. Most surface water systems do not have a long retention period.

Subsurface flow systems are built of trenches or beds on impermeable soils or underlain with a constructed impermeable subsurface barrier (Figure C.9). Pea-size gravel or coarse sand is placed into the trench or bed to a depth of six inches to support submergent vegetation. The wetland is built on a slight inclination between the inlet and outlet. Pollutants present in stormwater runoff are removed by the vegetation's root system as the runoff infiltrates through the gravel or sand. This type of system is generally recommended for the predominately clayey soils of the Virgin Islands.

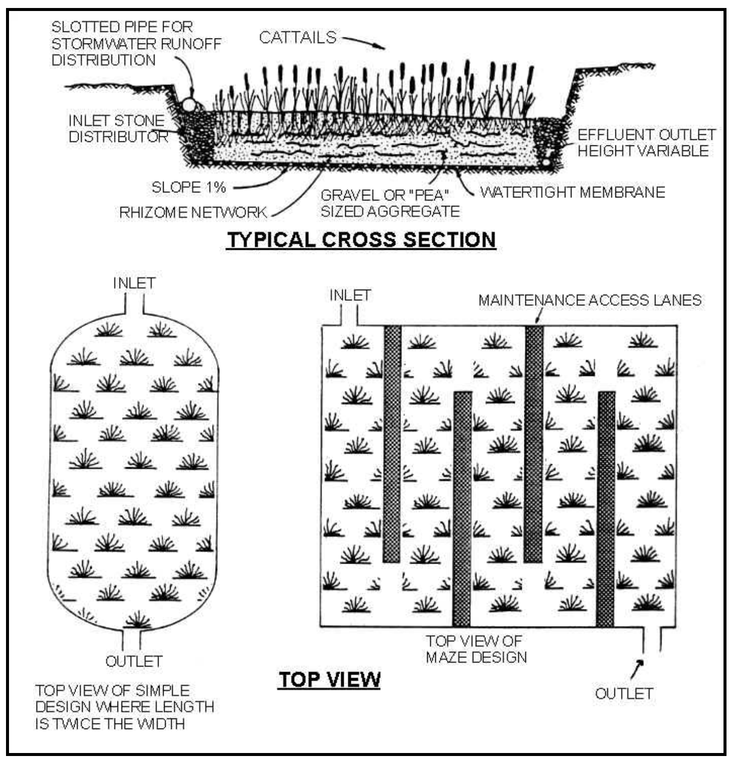


Figure C.9. Subsurface flow system design (New York State Department of Environmental Conservation, 1992).

Design & Construction Criteria

Surface Water Wetlands

1. Water inflow to the wetland must be maintained at a level greater than water outflow from the wetland through infiltration or evaporation in order to maintain a shallow pool of water in the wetland at all times. This requires sufficient stormwater runoff and/or baseflow inputs to the wetland and an infiltration/evaporation rate less than the sum of inflows.

2. Preferred locations for surface water wetlands are: low-lying areas adjacent to, but separated from, existing guts and wetlands by buffer strips; extended detention ponds; or a forebay to a detention pond or basin.

3. The wetland basin should be sized to have an extended detention time of 24 hours for the one-year storm.

4. Wetland basins will perform best when the wetland surface area is maximized. The surface area of the wetland should account for at least 3% of the area of the sub-watershed draining into it.

5. Extended detention wetlands are designed to have areas that are not entirely wetland and not entirely upland. This border area will be flooded whenever stormwater runoff enters the basin, but will not have standing water in it after the extended detention period is over. Diverse vegetation will be established in this area that thrive on damp soil and can tolerate brief flooding. This border area is the zone that is within 10 to 20 feet from the edge of the permanent pool.

6. The wetland basin design should incorporate water depths within the wetland that are conducive to the growth of emergent vegetation.

    a. The water level in 75% of the wetland should be less than or equal to 12 inches deep. Half of this area should also be less than 6 inches deep. The remainder (25%) of the wetland surface area should be open water with depths ranging 2 to 3 feet deep.
    b. This deep area of the wetland should include the outlet structure so that sediment build-up does not interfere with basin outflow.
    c. Stormwater inflow to the wetland should be maintained as sheet flow as much as possible to prevent scouring of the basin. As much vegetation and distance as possible should separate the basin inlet from outlet. The length to width ration should be at least 2:1.
    d. It is not necessary to have a smoothly graded substrate and precise depths, however, it is better to have a shallower wetland than a deeper one. Figure C.10 depicts different wetland layouts.

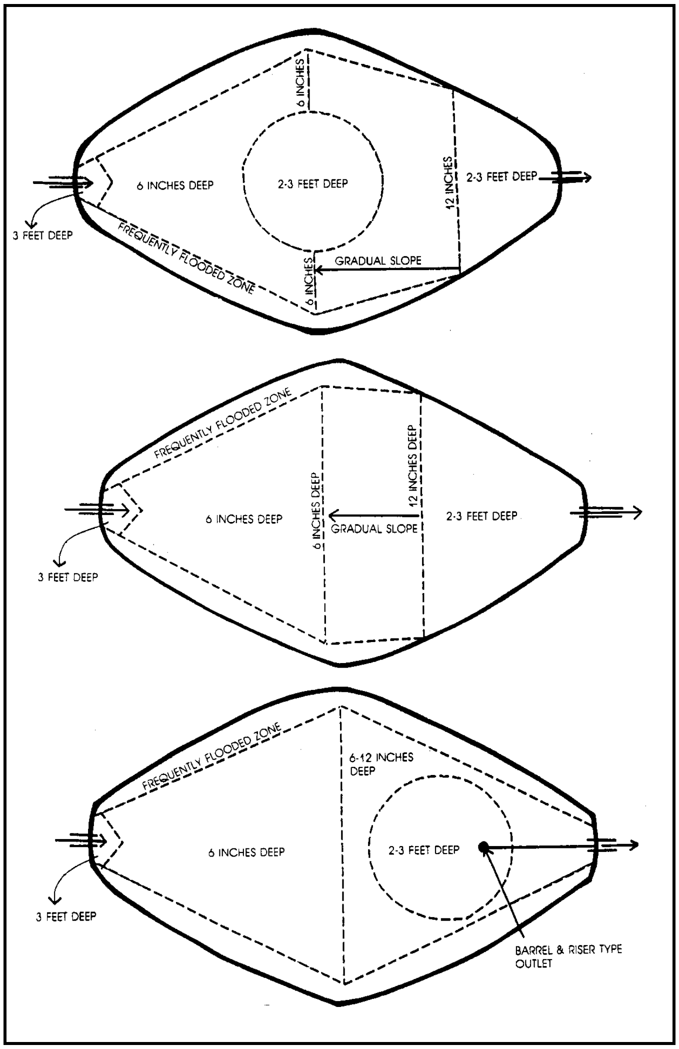


Figure C.10. Potential Surface Water Wetland Designs (Maryland Department of the Environment, 1987).

7. The wetland outlet structure must be capable of damming enough water to create the wetland and detain sufficient water to support wetland plants for extended time periods. The outlet also must be designed to permit water to flow out of the wetland without becoming blocked by debris (such as a barrel and riser). Orifices used for extended detention must be protected from blockage by plant material with wire mesh extending below the orifice and suspended at least one foot away from the riser.

8. Preserve topsoil at the wetland site when constructing the basin and then spread the topsoil over the excavated site to aid in the establishment of wetland vegetation.

9. The most reliable method of establishing a wetland is to transplant live plants or dormant rhizomes from nursery stock. Most plant species have very specific water depth requirements. Most species thrive in shallow water conditions (less than one foot deep). Sites for wetland creation must have a steady water flow in order to maintain plant species. Plant species that can be used in the Virgin Islands for surface water systems are listed in Table C.2. For further information on appropriate plant species for construction wetlands, contact the UVI Cooperative Extension Service or the USDA Natural Resources Conservation Service.

Subsurface Flow Wetlands

1. Construct the system on soils that are impermeable or on an impermeable synthetic liner. The most desirable soil permeability ranges from 0.14 to 0.014 inches per hour. Sandy clays and silty clay loams may be suitable when compacted.

2. Slope the floor of the subsurface flow system 1 percent from inlet to outlet.

3. Place approximately 12" of pea-sized or coarse gravel into the bed of the system to provide a medium to support the growth of emergent vegetation and for stormwater to flow through.

4. Construct a sediment basin, grit/oil separator or forebay at the inlet to capture sediment and prevent clogging of the aggregate medium.

5. Table C.3 provides suggestions of plant species suitable to the Virgin Islands. For more information on appropriate wetland plant species, contact the UVI Cooperative Extension Service or the USDA Natural Resources Conservation Service.

Table C.3. Plant species for surface and subsurface wetlands (USDA-SCS Caribbean Area, 1992 & 1993).

	Maximum Depth of Water Tolerated	Available Commercially
Species Acceptable for Surface Water Systems		
Primary Species		
Scirpus californicus (bulrush)		
Scirpus validus (softstem bulrush)	12 inches	Yes
Typha spp. (cattail)		
Panicum hemitomon (maidencane)		
Secondary Species		
Dieffenbachia spp.		
Cyperus spp.		
Colocasia spp. (malangas)		
Canna flacida (canna lily)		
Colocasia esculenta (elephant ear)		
Zizaneopsis miliacea (giant cutgrass)		
Species Acceptable for Subsurface Flow Systems		
Phragmites communis (common reed grass)	3 inches	Yes
	12 inches	Yes
Typha spp. (cattail)		
Brachiaria mutica (paragrass)		
Eriochloa polystachya (caribgrass)		
Brachiaria arrecta (taner grass)		
Echinochloa polystachya (aleman grass)		

6. Refer to the U.S. EPA *Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment Systems* for procedures on sizing subsurface flow systems.

Porous Pavers

Figure C.11. Concrete tire-track driveway example.

Concrete grid and modular pavement involves the use of special pervious paving materials in low-traffic areas (such as low-use parking lots, emergency areas, driveways, walkways). The paving consists of concrete grids, high-strength plastic grids, or other materials placed on a pervious base such as gravel or sand (Figure C.12). (The gravel or sand base may also be lined with filter fabric to prevent the rock material from becoming imbedded.) The grids or paving material is then filled with sand, gravel or soil. Grids filled with soil are typically seeded to attain a grassed or lawn surface. The resulting system provides an adequate bearing surface while allowing a significant amount of infiltration, thus reducing runoff volume and discharge rate and improving water quality. Concrete tire-tracks with grassed interiors can also be used for steeper driveways (Figure C.11).

There are many different types of porous pavers commercially available. A few brands are listed below, however, endorsement of any of these manufacturers is not intended. Design and construction guidelines for porous paving systems are specific to the paving type. See manufacturers technical specifications and design details instructions (provided at their websites) for details.

Figure C.12. Geoblock pavement installed at UVI-CES St. Thomas office, prior to filling with soil and seeding (*photo by Dale Morton, 1999*).

Geoblock® (produced by Presto Products Company, www.prestogeo.com) is a series of inter-locking, high-strength blocks made from a minimum of 50% post-consumer recycled plastic, using tongue-and-groove interlock forms to create a flexible, structural bridge that spreads concentrated loads. This system is designed to flex under loads that would break concrete (see Figures C.12 and C.13). This paving presents over 80% open area to the surface for infiltration. It supports heavy or concentrated loads by creating a flexible structural bridge over a prepared subbase. Geoblock® can be filled with soil and seeded with grass, or filled with gravel. For parking lots with frequent use, a grass surface is not recommended; gravel-filling is more appropriate. Daily vehicle use tends to kill grass and increase erosion potential. Grassed surfaces are more appropriate for overflow parking areas or emergency fire lanes or parking areas. Geoblock® is only recommended for use on level surfaces. Parking areas, driveways or walkways with slopes should use Geoweb®, GrassPave2®, or another more flexible system.

Figure C.13. Geoblock installation close-up, note j-bars used to anchor blocks in place (*photo by Dale Morton, 1999)*.

Figure C.14. Close-up of Geoweb® cells being filled with soil (left). Installation of Geoweb® at the UVI-CES St. Thomas driveway (*photos by Dale Morton, 1999*).

Geoweb®, ***TerraCell®*** (manufactured by Webtec, Inc., www.webtecgeos.com) and ***EnviroGrid®*** (manufactured by AGH Industries, Inc., www.aghindustries.com) are cellular confinement systems that use web-shaped, heavy-duty plastic containment material filled with native granular soil and covered with grass, or filled with gravel or crushed rock. These systems have over 98% open area and can be used for low-volume parking areas, driveways and emergency vehicle access lanes (see Figure C.14).

Grasscrete® (manufactured by Bomanite Corporation, www.bomanite.com/products/grasscrete.htm) - concrete block reinforced with steel bars that are formed so that spaces are left between for stormwater to infiltrate through. Reusable forms and steel reinforcing mesh are positioned first. Concrete is then poured and after initial setting, the forms are removed. After concrete has hardened sufficiently, openings in the slab are filled with soil and planted with grass seed or sod (Figure C.15).

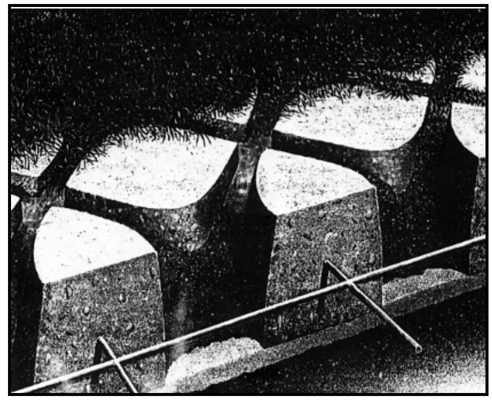


Figure C.15. Grasscrete paving system *(Bomanite Corp, 1988*).

GrassPave2® (manufactured by Invisible Structures, Inc., www.invisiblestructures.com/GP2/grasspave.htm) is a similar system to GeoBlock®, but with more flexibility. It provides load bearing strength while protecting vegetation root systems from compaction. High void spaces within the entire cross-section enable root development and storage capacity for rainfall from storm events. Stormwater runoff is slowed through and across Grasspave2 surfaces, depositing suspended sediment and increasing discharge time. Suspended pollutants and moderate amounts of engine oil are broken down by active soil bacteria, which are aided by the system's oxygen exchange capacity.

Design & Construction Criteria

(These instructions are for educational purposes only. Please refer to manufacturer's specifications for information on installing other types of porous pavers.)

Webbed Cellular Confinement Materials:

1. Prepare the site by removing vegetative cover and debris from the area to be stabilized. Complete other earth change, excavation and/or fills. Ensure that foundation soils meet minimum strength requirements (through proof rolling or other method). Remove in-situ soils that are unacceptable for load support and replace with suitable materials.
2. Place a suitable geotextile between the subgrade and infill materials to be stabilized (if needed). Install drainage materials, if needed or specified.
3. Expand web sections to proper dimension (20') and position (Figure C.16). Anchor web sections into position using j-bars (Figure C.17), a stretcher frame, straight stakes, or ATRA™ clips along the sides and ends of the section. (J-hooks shall be made from construction rebar, ¾" or ½" diameter and 18" long).

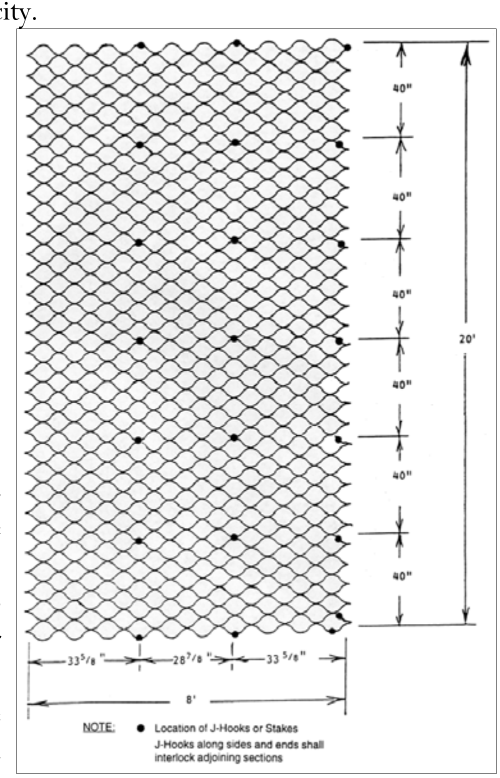


Figure C.16. EnviroGrid® light density staking diagram (AGH Industries, Inc., 1999).

4. Check each section to ensure that it is fully expanded. Full expansion will result in a better fitting and looking stabilization area.
5. Correctly align and interleaf edges of adjoining web sections and ensure that the upper surfaces of adjoining sections are flush.
6. Join web sections with industrial staples.
7. Filled expanded web cells with soil, sand, crushed stone or gravel with a backhoe, or front-end loader, or by hand. Overfill web sections to at least 2" above the cell walls.
8. Compact fill material to specified density.

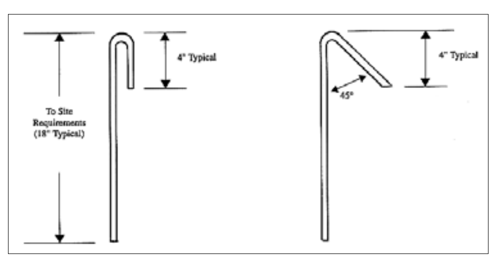


Figure C.17. Standard j-hook details (AGH Industries, Inc. 1999).

GeoBlock®:

1. Prepare the subgrade by excavating the area, allowing for unit thickness less ~ ¼" for settlement. If working with soils that have poor permeability (clayey soils) in an area that has potential to collect water, provide adequate drainage from the excavated area. Uniformly grade the base. Level and clear it of large objects such as rocks, wood, stumps, etc. this enables the block units to interlock properly and remain stationary after installation.
2. Prepare the base by installing a recommended "engineered base" consisting of coarse sand, clear-stone or crushed rock blended with topsoil to promote vegetative growth and provide required structural support (Figure C.18). The aggregate portion of the base should be free from fines and have a known percentage void-space when compacted.
3. Install the blocks with the round hole to the ground. For best performance under traffic loading, stagger the blocks so that the long direction of the block is perpendicular to the direction of traffic, as shown in Figure C.19. The staggered pattern is made by using half-blocks, cut from a full block. Cut the blocks with a hand or power saw to custom fit contours and around obstructions. The final seam pattern should have straight seams perpendicular to traffic flow and staggered seams parallel to traffic flow.
4. Place the blocks against a stationary edge, if available. Slide the blocks together so that they interlock tightly, as shown in Figure C.19.
5. Anchor the blocks in place to prevent them from shifting during installation. Blocks can be anchored with wood, metal stakes or j-bars.
6. Fill the blocks with a suitable topsoil, sand, gravel, or crushed rock immediately after block installation. This will minimize block separation. Spread or rake the material level by hand. If using topsoil for a grassed surface, remove any stones present. The surface of the fill should be level with the top of the blocks.
7. If a grassed surface is desired, seed or sod the area, using seeding rates, fertilizers and irrigation as is necessary for the area (see ***Temporary Seeding*** or ***Permanent Seeding and Planting***, Chapter 3 and Appendix B). Grass should be maintained by mowing and re-seeding of bare patches.

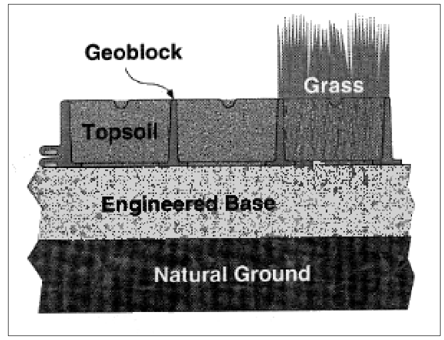


Figure C.18. Geoblock® porous pavement system (*Presto Products Company, 1997*).

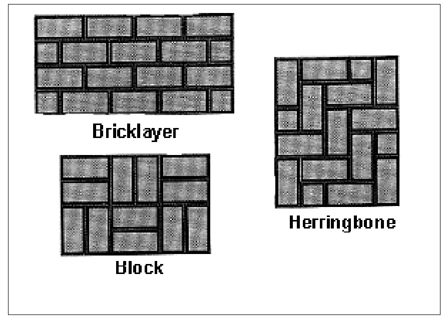


Figure C.19. Geoblock® installation - various laying patterns *(Presto Products Company, 1997*).

Infiltration Trenches

Siting & Design Criteria

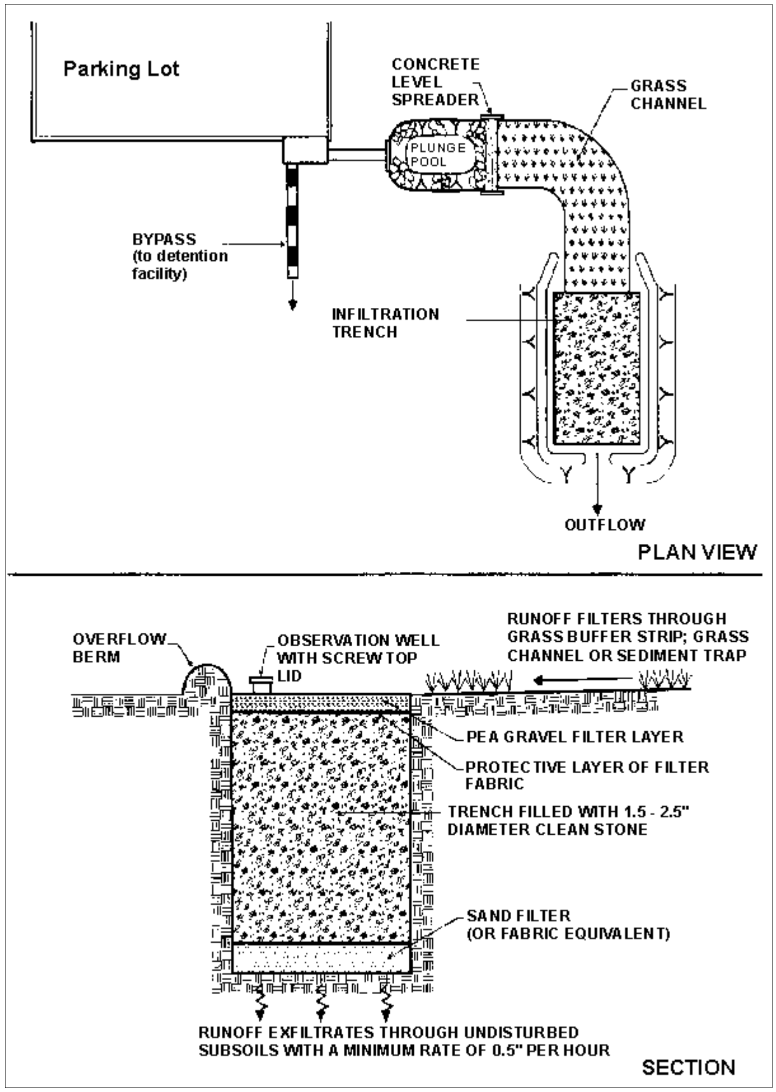


Figure C.20. Schematic design of an infiltration trench (CWP, 2001c).

Infiltration trenches should be sited to ensure that soils at the site are appropriate for infiltration and designed to minimize potential groundwater contamination. Infiltration trenches are typically used on smaller sites (less than 5 acres) that have relatively high impervious cover (Figure C.20, CWP, 2001c).

Surface Area of Trench Bottom: Pollutant removal can be enhanced by increasing the surface area of the trench bottom, i.e., making the trench more shallow and broad rather than deep and narrow.

Draining Time: Design the trench to completely drain within three days after the maximum design storm event. If a trench is constructed over soils with a marginal infiltration capacity (clayey soils), adjust the depth of the trench so that it drains in two days or less, as a safety margin. However, design the trench to retain stormwater for at least six hours in order to provide adequate pollutant removal.

Maintenance: Install a test well in the trench to monitor drain times after installation. If the trench does not completely drain within 3 days after a storm, it is likely that the bottom of the trench has clogged and corrective measures are needed. On the other hand, if a partial infiltration trench empties completely within a day, either the collection efficiency of the underdrain is too great, or the bottom of the trench has clogged, or both. Correct these problems.

Soils: Trenches are not a feasible option for sites with soils in Hydrologic Soil Group "D" (soils with infiltration rates less than 0.27 inches per hour. See Chapter 5 for a listing of V.I. soils and their hydrologic soil groups). Silt loams and sandy clay loams ("C" soils) provide marginal infiltration rates, and should only be considered for partial exfiltration systems (see Table C.4). Trenches are not suitable over fill soils that form an unstable subgrade, and are prone to slope failure.

In soils that meet the above criteria, take soil cores or trenches to a depth of at least five feet below the anticipated level of the stone reservoir bottom. Examine these cores for evidence of any impermeable soil layers that may impede infiltration, such as clay lenses, hardpans, or fragipans. The presence of such layers do not necessarily preclude a trench, as long as the stone reservoir completely penetrates the layer.

Slope: An underground trench is not feasible on sites with slopes greater than 20%. Surface trenches are not recommended for sites whose contributing slopes are greater than 15% (CWP, 2001c). Keep the slope of the bottom of the trench as close to zero as possible in order to evenly distribute exfiltration, unless the design includes a positive outlet.

Depth to Bedrock: Keep the bottom of the stone reservoir at least four feet above the bedrock level. Depth to rock can be estimated from soil maps, but should be confirmed by soil test borings.

Depth to Seasonally High Water Table: Keep the bottom of the stone reservoir a minimum of two to four feet from the seasonally high water table.

Proximity to Wells/Foundations: Locate trenches in commercial and industrial areas at least 100 feet away from a drinking water well to minimize the possibility of groundwater contamination, and at least 10 feet down-gradient and 100 feet up-gradient from building foundations.

Maximum Reservoir Depth: It may be necessary to limit the depth of the stone reservoir when underlying soils have relatively low exfiltration rates in order to insure that the stone reservoir will completely drain in 72 hours. These limits are shown for various soil textures in Table C.4. Dimensions of the infiltration trench may need to be modified in order to accommodate the necessary volume without exceeding maximum depth limits.

Table C.4. Soil limitations for infiltration trenches (Schueler, 1987).

Soil Texture	Minimum Infiltration Rate (fc, in/hr)	SCS Soil Group	Maximum Trench Depth (in.)	
			48 hours	72 hours
Sand	8.27	A	992	1489
Loamy Sand	2.41	A	290	434
Sandy Loam	1.02	B	122	183
Loam	0.52	B	62	93
Silt Loam	0.27	C	32	49
Sandy Clay Loam	0.17	C	20	31
Clay Loam	0.09	D	11	16
Silty Clay Loam	0.06	D	7	11
Sandy Clay	0.05	D	6	9
Silty Clay	0.04	D	6	7
Clay	0.02	D	2	4

Watershed Size: Trenches should **NOT** serve drainage areas greater than 5 acres in size.

Space Limitations: The application of surface trenches may be space-limited on some “tight” sites because of the 20 foot buffer strip requirement.

Construction Specifications

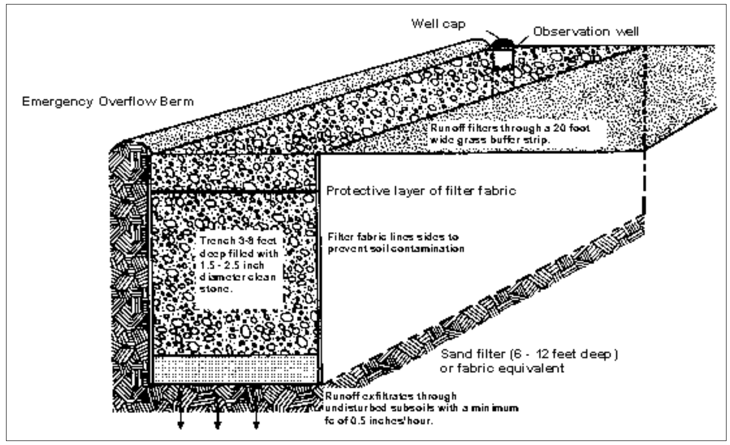


Figure C.21. Infiltration trench cross-section (Schueler, 1987).

Infiltration trench installation considerations include system location, depth and width, aggregate gradation, geotextile requirements, and installation, inspection and maintenance schedule.

The runoff storage capacity of an infiltration trench filled with drainage materials (Figure C.21) should be equal to the volume of the trench multiplied by the porosity of the media. Preferable drainage material types include uniform sand, gravel, or crushed stone. Uniform materials have high porosity and large storage capacities, therefore, less material is required for facility. Drainage materials should be hard, durable, inert particles free from slate, shale, clay, silt and plants. To increase the runoff storage capacity of trenches, plastic or concrete gallery frames can be inserted (CH2M Hill, 1998).

Drainage materials should be enclosed in geotextile. Use of an appropriate type of geotextile is necessary to prevent soil from penetrating the sides of the trench or clogging at the soil interface. Geotextiles should be carefully installed to minimize smearing of soil on the bottom and sides of trenches (this will reduce permeability through the trench). To minimize accumulation of sediment inside the trench, insert a geotextile 6 to 12 inches below the top of the drainage materials. The geotextile will intercept sediment, leaves and other debris before it can penetrate the gravel (or other material) and clog the trench (CH2M Hill, 1998).

Maintenance

Infiltration trenches need regular inspection and maintenance to perform properly. Table C.5 outlines required maintenance practices.

Table C.5. Typical maintenance activities for infiltration trenches (CWP, 2001c).

Activity	Schedule
C Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. C Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.	Semi-annual inspection
C Remove sediment and oil/grease from pretreatment practices, as well as overflow structures	standard maintenance
C if bypass capability is available, infiltration rate may be regained in the short term by using practices such as an extended dry period.	5-year maintenance
C Total rehabilitation of the trench to maintain storage capacity within 2/3 of the design treatment volume and 72-hour exfiltration rate limit. C Excavate trench walls to expose clean soil.	Upon failure

BioRetention

Siting & Design Criteria

Bioretention systems can be used in median strips, parking lot islands, and other small (less than 5 acres) drainage areas. Bioretention systems work best on shallow (~5%) slopes, but with proper design can be used on steeper slopes (up to 15-20%).

Planting soil ranging from 10 to 25% clay along with sandy loam, loamy sand or loam texture is recommended for offline bioretention systems (see Chapter 4, CH2M Hill, 1998). The soil pH should range between 5.5 and 6.5. A desirable planting soil is permeable to allow runoff to infiltrate and adsorbs organic nitrogen and phosphorus.

In areas with high clay contents (the soils are not conducive to infiltration), the bioretention practice can be modified with a collector pipe system installed beneath the basin to form a bioretention filter.

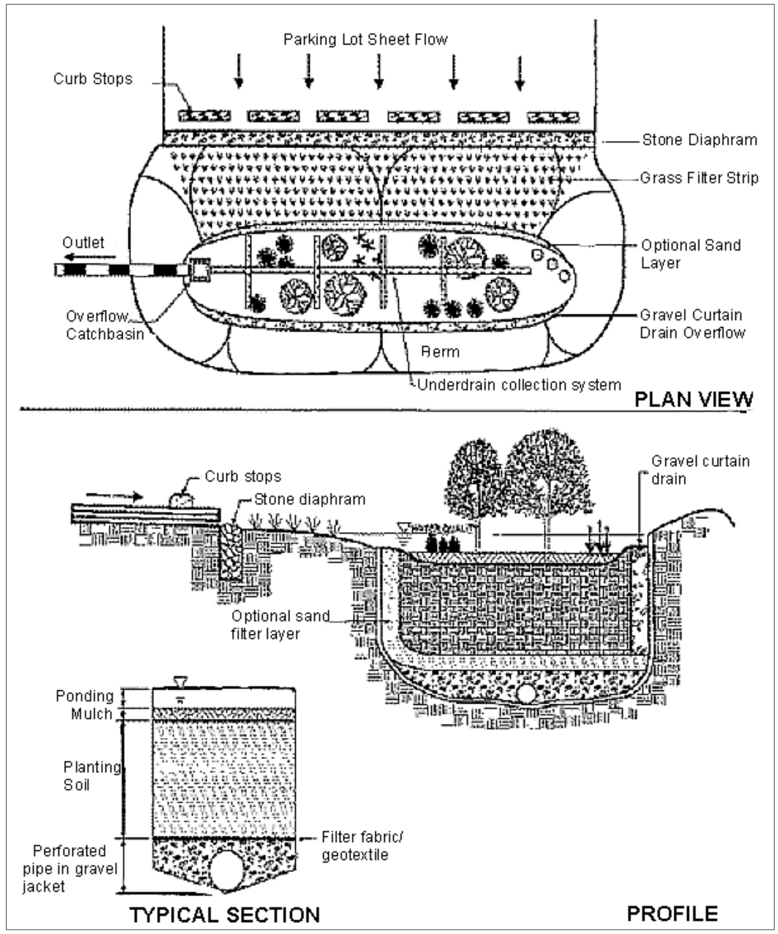


Figure C.22. Schematic design of a bioretention practice (CWP, 2001f).

Check dams can be used to reduce stormwater runoff speeds within grass swales, forming "on-line" bioretention areas that promote sedimentation behind the dam (Figure C.22). Properly anchored gabions, rock filter berms or large logs can be used as check dams on moderate slopes. Silt fences **must not** be used as check dams, because concentrated flows quickly wash out these materials (CH2M Hill, 1998).

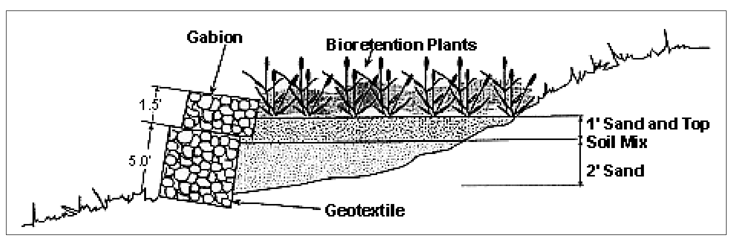


Figure C.23. Cross section of an on-line bioretention system formed by damming a grass swale with a mild to moderate slope with gabion baskets *(CH2M Hill, 1998)*.

On-line bioretention areas using check dams must be sized, built and maintained properly or they will either be washed out or contribute to flooding. The relationship between ponding depth behind the check dam and discharge rate can be computed by using the following critical-depth formula, which accounts for a generalized weir profile:

$$Q = ((A^3 \times g) / T)^{1/2}$$

Where
Q = Discharge rate
A = area subtended by top of check dam and ponding elevation
T = width of check dam
g = gravitational constant

Off-Line Bioretention Systems – these systems have six components: a grass filter strip or energy dissipation area, a ponding or treatment area, planting soil, sand bed (optional), mulch layer, and plant material (Figures C.24 and C.25). The grass filter strip (or energy dissipation area) filters sediment from runoff and reduces stormwater speed. The sand bed further slows runoff, spreads it over the basin, filters part of the water, provides drainage in the planting soil, and enhances seepage from the system (CH2M Hill, 1998).

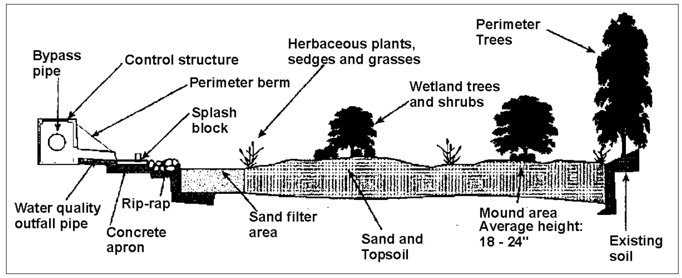


Figure C.24. Bioretention cross-section. Runoff from storms greater than 1-year storm is bypassed through main drainage system. Runoff from small storms is diverted at the control structure (manhole). Stormwater energy is dissipated by the splash block or rip-rap. Stormwater is filtered through an open sand filter. Excess stormwater is treated in the bioretention area (CH2M Hill, 1998).

The ponding area stores runoff waiting for treatment and also functions as a presettling basin for particulates not removed by the grass filter strip. The mulch layer filters pollutants, minimizes erosion, and provides a habitat for microorganisms to break-down hydrocarbons and other pollutants. The soil layer supports the plants and clay particles in the soil adsorb heavy metals, nutrients, hydrocarbons and other pollutants. The minimum depth of the soil layer should be 3 to 4 feet.

The number of tree and shrubs planted will vary based on site conditions, but a minimum of three different species each of shrubs and trees should be planted. The site conditions (slope, volume and velocity of runoff, climate, etc.) will also determine the size of the system, however, average recommendations are:

- C Minimum width of 10 to 15 feet
- C Minimum length of 30 to 40 feet
- C The ponded are should have a maximum dept of 6 inches. If collector pipes are used, the maximum ponded depth can increase to 12 inches.
- C The planting soil should have a minimum depth of 3 to 4 feet.

On-Line Bioretention Systems – a bioretention area in a swale upstream from a check dam is built with similar specifications as the off-line system. The planting soil depth can be reduced (1 to 2 feet) if the drainage area is small (less than 2 acres, CH2M Hill, 1998). Rock check dams should be build of 8" to 12" rock, placed by hand or mechanically. The dam must completely span the swale or channel to prevent it from being washed out. Log check dams should be built of 4" to 6" diameter logs and embedded at least 18" into the soil.

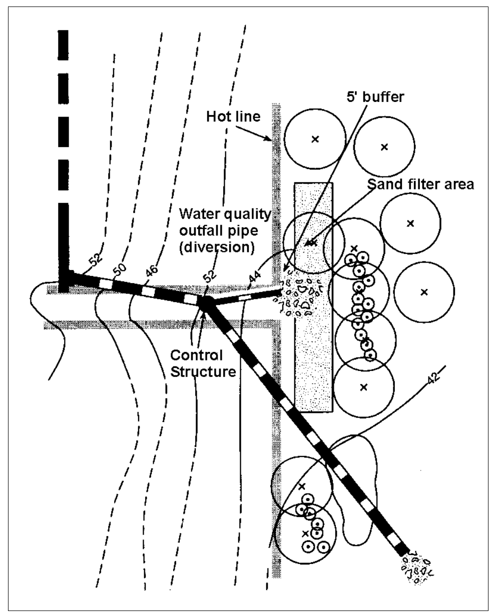


Figure C.25. Bioretention plan view (CH2M Hill, 1998).

Maintenance

Bioretention systems should be inspected on a monthly basis until plants are established. Inspections could then be conducted annually. Sediment should be removed from behind check dams when accumulations reach one-half the sump depth. See Table C.6 for maintenance details.

Table C.6. Typical maintenance activities for bioretention areas (CWP, 2001f).

Activity	Schedule
C Remulch void areas C Treat diseased trees and shrubs	as needed
C Water plants daily for two weeks	at project completion
C Inspect soil and repair eroded areas C Remove litter and debris	monthly
C Remove and replace dead and diseased plants	twice per year
C Add additional mulch C Replace tree stakes and wire	once per year

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APPENDIX D: ENVIRONMENTAL PROTECTION LAWS TABLE OF CONTENTS

APPENDIX D: ENABLING LEGISLATION

D.1 ENVIRONMENTAL PROTECTION LEGISLATION - Virgin Islands Code Title 12, Chapter 13. Environmental Protection (as amended May 14, 1985 and June 24, 1987)

§ 531. Declaration of Policy

The Legislature of the Virgin Islands hereby determines and finds that the lands and water comprising the watersheds of the Virgin Islands are great natural assets and resources; and that improper development of land results in changes watershed conditions such as: erosion and sediment deposition on lower-lying land and in the tidal waters, increased flooding, gut and drainage filling and alteration, pollution, and other harmful environmental changes to such a degree that fish, marine life, and recreational and other private and public uses of lands and waters are being adversely affected. In order to protect the natural resources of the Virgin Islands, promote the health, safety and general welfare of the citizens of the Virgin Islands, and to protect private and public property, the Legislature further finds and determines that it is necessary to establish by law an environmental protection program for land development to prevent soil erosion and for the conservation of beaches, shorelines, and the coastal zones of the Virgin Islands.

§ 532. Environmental Protection Program

(a) The Virgin Islands Soil and Water Conservation District shall prepare and adopt an Environmental Protection Program in collaboration with the Virgin Islands Departments of Planning and Natural Resources, Economic Development and Agriculture, Public Works, and Health. The Provisions of the Environmental Protection Program and any amendments hereto shall be filed and published in the same manner and subject to the same conditions as administrative regulations pursuant to Chapter 35 of Title 3 of this Code. Thereafter, such Program shall have the force and effect of law.

(b) The Environmental Protection Program shall be in the form of rules and regulations designed to prevent improper development of land and harmful environment changes and in accordance with the declaration of policy as stated in section 532 of this chapter. This Program shall include comprehensive erosion and sediment control measures applicable to both public and private developments including the construction and maintenance of streets and roads.

§ 533. Earth Change Plans

Before any real property is cleared, graded, filled or otherwise disturbed for any purpose or use including, but not limited to, the erection of any building or structure, the quarrying of stone or the construction of roads and streets by any:

(1) person or other legal entity; or

(2) department, agency, board, authority or other instrumentality of the Government of the Virgin Islands or the United States Government;

an Earth Change Plan shall be approved by the Department of Planning and Natural Resources as conforming to the Environmental Protection Program adopted pursuant to this chapter.

§ 534. Earth Change Permits

(a) Upon approval of an Earth Change Plan and certification by the applicant that all earth changes shall be in accordance with such Plan, the Department of Planning and Natural Resources shall issue an Earth Change Permit to the applicant.

(b) Notwithstanding any law to the contrary, the Department of Planning and Natural Resources shall not issue any building or other permit until the applicant for such permit has presented to the Department an approved Earth Change Permit obtained in accordance with this chapter.

§ 535. Exemptions

The provisions of this chapter shall not apply to common household gardening, truck farming and the cultivation of property for agricultural purposes under approved soil and water conservation practices.

§ 536. Inspection and Enforcement

(a) The Commissioner of Planning and Natural Resources shall enforce the provisions of this chapter. The Commissioner or his authorized representatives may, for the purpose of performing their official duties under this chapter, enter upon and inspect any parcel of property or premises at all reasonable hours. Upon notice that property is being graded, cleared or otherwise disturbed in violation of this chapter, the Commissioner shall order the immediate stoppage thereof until the illegality is canceled.

(b) Upon the start of the activity for which an Earth Change Permit has been issued, the owner of the property or his authorized agent shall so notify the Commissioner so that he may schedule the inspection that may be deemed necessary for the effective enforcement of the provisions of the chapter.

(c) The Commissioner shall maintain accurate records of inspections made, notices issued and actions taken by property owners or authorized agents pursuant to notices resulting from inspection.

§ 537. Appeals

Decisions of the Commissioner of Planning and Natural Resources under the provisions of this chapter shall be subject to review by the District Court of the Virgin Islands provided an appeal is filed within thirty days of the receipt of any such decision.

§ 538. Violations

(a) Any violation of this chapter shall be deemed a misdemeanor, and the person, partnership, or corporation who is found guilty of such violation shall be subject to a fine not exceeding $5,000 or one year's imprisonment for each and every violation.

(b) The Attorney General shall prosecute all actions required for the enforcement of the provisions of this chapter.

(c) The Attorney General, in addition to other remedies, may institute any appropriate action or proceedings to prevent any violation of this chapter or to restrain, correct or abate such violation or to prevent the occupancy of developments involving land cleared, graded or otherwise disturbed in violation of this chapter.

D.2 ENVIRONMENTAL PROTECTION RULES AND REGULATIONS Chapter 13. Environmental Protection; Subchapter 532. Environmental Protection Program

D.2.1 Division 1. Practices and Procedures

§ 532-1. General Principles

The following are the general principles on which this program is based:

(1) The objectives of this program are stated public policy. The Environmental Protection Law declares the intent of the Virgin Islands Government to safeguard the environment and that the water and land in the watershed are an asset, and natural resources, and are to be protected. To implement this, the increased runoff of soil and water, and the destruction of natural ground water recharge by alteration of the land surfaces, watercourses, etc., must be controlled in the public interest.

(2) Workable procedures are available for carrying out this program. Details of these aspects will be worked out with the construction industry (engineers, architects, and builders), the Planning Board, the Departments of Planning and Natural Resources, Health, and Public Works.

(3) Technical conservation principles and practices, skillfully but flexibly planned and applied, will reduce sediment and runoff, and protect the ground water supply. These principles must be flexible applied because of the variation of soils, topography, and densities used in developments.

(4) Conservation objectives must be kept in mind in connection with comprehensive planning, as well as specific development plans. Conservation measures in construction activities must be decided on in the planning stage and applied at the beginning of the construction stage. It is feasible to plan for proper land use and the handling of excess water and sediment during and after construction and to install the needed measures, thus preventing damage. The conservation work must be planned before any grading is done.

(5) Enforcement is essential to an effective environmental conservation program. Due to the short duration and complexity of construction activities, it is necessary to enforce the installation of the needed measures or other requirements of the program to be sure that they are effectively applied. Such enforcement is used in the building industry from the standpoint of their construction requirements, and the industry is normally accustomed to inspections and enforcement of this general nature. Moreover, since the developer also benefits from the conservation program, enforcement problems are reduced.

(6) Informational and educational work on this program is essential to its understanding and acceptance by the general public and by the construction industry.

(7) Review and evaluation of the program is essential for its continued effectiveness. As new procedures and techniques are developed, they must be added to the program to make it more effective. Similarly, observations of the effectiveness of planned programs will be made for further improvement.

(8) Technical assistance is essential to the industry to try to plan and apply effective conservation measures during and after development. The Soil and Water Conservation District, in consultation with the Departments of Planning and Natural Resources, Agriculture, Public Works, and Health, has adapted the conservation measures and techniques available from the agricultural program to the other uses of the land. Consultive technical assistance is planning is available to the developers and their engineers through the Soil and Water Conservation District.

§ 532-2. Technical Principles

The following technical principles are the basis for an effective conservation program in land development.

(1) Fit the development to the topography and soils as closely as possible.
(2) Save trees and other natural vegetation wherever possible.
(3) Avoid unnecessary disturbance of the soil.
(4) Install permanent storm drains and roads as early as possible.

(5) Protect denuded soils with mulch where permanent protection is delayed.
(6) Install permanent vegetation *immediately* after final grades are established.
(7) Use sediment basins to trap sediment on-site.
(8) Provide proper water disposition. This may involve direct disposal and/or retention depending on the site, location and quantity of water involved.
(9) Schedule the construction operations so as to expose only that area of land at a time that can be developed in a reasonable length of time; and
(10) Develop sites which are located in natural recharge areas so as not to diminish the sites overall capacity for recharge and storage of ground water.

The application of these principles to fit the particular type of development will result in a practical program of environmental protection acceptable to the industry and to the Virgin Islands Government.

§ 532-3. Conservation practices

Many conservation practices have proven effective in avoiding or lessening damage from sediment and runoff, and in protecting ground water. These include:
(1) Careful land clearing and protection of desirable shade trees and other plants;
(2) Proper land grading with maximum slopes;
(3) Retaining walls and slope stabilization structures where needed;
(4) Permanent vegetation applied rapidly to critical areas following the establishment of final grades;
(5) Mulching;
(6) Waterways, diversions, outlets;
(7) Sediment basins; and
(8) Water storage structures (ponds and gray water cisterns).

Standards and specifications for these practices are included in the ENVIRONMENTAL PROTECTION HANDBOOK available from the Department of Planning and Natural Resources. Reasonable and well-planned use of these measures will reduce erosion and uncontrolled runoff from construction areas during and after construction.

§ 532-4. Procedures

Procedures for soil and water conservation on nonagricultural developments include the following:
(1) Planners and individual developers should obtain information on soils, topography and soil and water conservation measures from the Department of Planning and Natural Resources. They should be familiar with the requirements prior to planning the development.
(2) Earth change plans will be reviewed by the Department of Planning and Natural Resources to determine if they meet the minimum standards required for the adequate protection and conservation of the soil and water, and for water disposal in and from the construction area. Technical assistance to meet the requirements of the conservation program on nonagricultural development will be available through the Soil and Water Conservation District to planners, developers and their architects and engineers.
(3) Technical assistance from the Soil and Water Conservation District will also be available to the developers and their engineers during the installation of the necessary conservation measures.

§ 532-5. Enforcement

Conservation requirements placed on a development during the grading and construction stages will be inspected and enforced by the Department of Planning and Natural Resources. Such inspection and enforcement will be performed in the same manner and time as the enforcement of other requirements and standards. Penalties for the failure to comply with the application of conservation measure requirements are as called for in the law.

§ 532-6. Public relations

An information and educational program for the industry and the general public in connection with the Environmental Protection Program will be conducted by the Department of Planning and Natural Resources. This program will include news releases, brochures, publication of this program and of the practice standards and specifications, meetings, slide talks for service clubs and for builder organizations, etc. It will also include recognition of those developers who do excellent work in connection with conservation during development.

§ 532-7. Research evaluation

This program will be accompanied by necessary research, observation, and evaluation to assure its effectiveness and improvement. For this purpose and to facilitate this program, the Soil and Water Conservation District Board will invite each of the following agencies and groups to assign a representative to a task force for environmental protection:

V.I. Department of Planning and Natural Resources
V.I. Department of Public Works
V.I. Department of Economic Development and Agriculture
V.I. Forestry Division
V.I. Cooperative Extension Service
U.S. Forest Service
U.S. Geologic Survey
V.I. Home Builders Association
V.I. Architects, Engineers and Surveyors
V.I. Department of Health
American Institute of Architects
Contractors' Association
Realtors Association
U.S. National Park Service
and others.

This task force will meet as needed but at least annually to furnish guidance to the responsible agencies for the conduct and improvement of the program. In addition, the task force will provide training for inspectors and other agency people.

D.2.2 Division 2. Applications for Permits, Review, Filing, Signs

§ 532-11. Applications

(1) **Private Sector.** Earth Change Applications and Permits as well as Earth Change Plans shall be received at the Department of Planning and Natural Resources for review and approval.

(2) **Public Sector.** Earth Change Applications and Permits as well as Earth Change Plans shall be received at the Department of Planning and Natural Resources for review and approval.

§ 532-12. Review

(1) **Private Sector.** A thirty (30) day period shall apply to the review of an Earth Change Plan by the Department of Planning and Natural Resources. The thirty (30) day period shall begin with the date of reception indicated on the bottom of the Earth Change Application and Permit. However, termination of the thirty (30) day period shall not give inferred or automatic approval to the Earth Change Application.

§ 532-13. Filing

(1) **Private Sector.** A copy of the Earth Change Plan and Permit shall remain on file with the Department of Planning and Natural Resources to become a part of the record of inspections for a particular land development.

(2) **Public Sector.** A copy of the Earth Change Plan and Permit shall remain on file with the Department of Planning and Natural Resources to become a part of the record of inspection for a particular land development.

§ 532-14. Signs

(1) **Private Sector.** A sign shall be posted at the construction site in clear view of the general public. This sign shall state in large block letters, "EARTH CHANGE PERMIT NO. ___." A sign will be furnished the developer when the Earth Change Permit is issued by the Department of Planning and Natural Resources. This sign may be used to satisfy the sign posting requirement.

(2) **Public Sector.** A sign shall be posted at the construction site in clear view of the general public. This sign shall state in large block letters, "EARTH CHANGE PERMIT NO. ___." A sign will be furnished the developer when the Earth Change Permit is issued by the Department of Planning and Natural Resources. This sign may be used to satisfy the sign posting requirement.

D.3.3 Division 3. Classes of Land Development and Earth Change Plan Requirements in Private and Governmental Construction

§ 532-21. Single residential lots under ½ acre when not a part of a major subdivision

Department of Planning and Natural Resources Earth Change Application or Coastal Zone Magagement Forms may be used. This form requires the rough estimation of 5-foot contours in addition to the detailing of such things as slope stabilization measures, trees to be protected and other simple conservation treatment measures. This form may be obtained at the Department of Planning and Natural Resources.

§ 532-22. Single residential lots larger than ½ acre when not a part of a major subdivision

(1) Plan view detail at a scale no smaller than 1"=50' showing lot layout, road layout, position of structures, storm drainage, proposed soil erosion and sediment control measures, proposed water conservation measures.

(2) A maximum contour interval of 5 feet, both existing and proposed, reflecting the proposed earth change.

(3) A statement giving the proposed time of establishment for strategic environmental protection measures.

(4) Soils information from the SOIL SURVEY, VIRGIN ISLANDS OF THE UNITED STATES for the land area to be developed.

§ 532-23. Major subdivisions (the development of more than one residential building lot)

(1) Plan view detail at a scale no smaller than 1"=100' showing road and lot layout, position of structures, storm drainage, proposed soil erosion and sediment control measures, proposed water conservation measures.

(2) A maximum contour interval of 5 feet, both existing and proposed, reflecting the proposed earth change. (10-foot contours will be permitted in the case of relatively steep topography, i.e., 25% + slopes.)

(3) Design detail and profiles on complex measures such as sediment basins, ponds, gray water cisterns, slope protection structures, retaining walls, etc., shall be included.

(4) A Statement giving the proposed time of establishment for strategic environmental protection measures.

(5) Soils information from the SOIL SURVEY, VIRGIN ISLANDS OF THE UNITED STATES for the land area to be developed.

§ 532-24. Site plans (includes multi-family residential structures, hotels, commercial structures, light and heavy industrial land development)

(1) The plan view detail at a scale no smaller than 1"=100' showing road and lot layout, position of structures, storm drainage, proposed soil erosion and sediment control measures, proposed water conservation measures.

(2) A maximum contour interval of 5 feet, both existing and proposed, reflecting the proposed earth change. (10-foot contours will be permitted in the case of relatively steep topography, i.e., 25% + slopes.)

(3) Design detail and profiles on complex measures such as sediment basins, ponds, gray water cisterns, slope protection structures, retaining walls, etc., shall be included.

(4) A Statement giving the proposed time of establishment for strategic environmental protection measures.

(5) Soils information from the SOIL SURVEY, VIRGIN ISLANDS OF THE UNITED STATES for the land area to be developed.

§ 532-25. Governmental construction not covered in preceding classes of land development

(1) The plan view detail at a scale no smaller than 1"=100' showing road and lot layout, position of structures, storm drainage, proposed soil erosion and sediment control measures, proposed water conservation measures.

(2) A maximum contour interval of 5 feet, both existing and proposed, reflecting the proposed earth change. (10-foot contours will be permitted in the case of relatively steep topography, i.e., 25% + slopes.)

(3) Design detail and profiles on complex measures such as sediment basins, ponds, gray water cisterns, slope protection structures, retaining walls, etc., shall be included.

(4) A Statement giving the proposed time of establishment for strategic environmental protection measures.

(5) Soils information from the SOIL SURVEY, VIRGIN ISLANDS OF THE UNITED STATES for the land area to be developed.

§ 532-26. Land clearing

A brief earth change plan in written form detailing the proposed method, equipment and purpose of land clearing.

§ 532-27. Public, private road and driveway construction

A road and driveway permit shall be obtained from the Department of Planning and Natural Resources and a copy submitted with an earth change plan detailing bank stabilization measures, proposed road bank grades, and any special slope treatment. Temporary measures to be installed during the construction period shall also be detailed.

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