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SEDIMENT & EROSION CONTROL ON CONSTRUCTION SITES FIELD GUIDE

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Funded by a federal Clean Water Act grant from the Virgin Islands Department of Planning and Natural Resources §319(h) Nonpoint Source Pollution Management Program.

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INTRODUCTION

Sediment eroded from dirt roads, construction sites and other cleared areas is the number one pollutant harming water quality in the Virgin Islands (DPNR-DEP & USDA-NRCS, 1998). A 1986 study of erosion rates on St. Thomas and St. Croix estimated erosion from dirt roads to be 591 tons/acre/year (Wernicke, Seymour & Mangold, 1986). Studies of erosion rates in St. John's Fish Bay watershed found soil loss from dirt roads to be between 100 to 600 tons per year (MacDonald, et al., 1997; Sampson, 1997). Therefore, controlling erosion and soil loss on construction sites, dirt roads and other cleared areas is key to protecting V.I. coastal waters.

There is a big difference between practices that prevent or reduce erosion and those that remove soil (or sediment) from stormwater. ***Erosion control practices*** hold soil in place and reduce soil removal by storm water. **The most effective way to control erosion is to preserve existing vegetation and replant cleared or bare areas as soon as possible.**

Sediment control practices remove eroded soil from runoff before it leaves the property. These practices are **NOT** as effective as erosion control because they do not remove most clay particles, and most of the soils in the Virgin Islands are clay. For example, clay particles pass through silt fence material and take a very long time to settle out of runoff in holding ponds. **It is much easier and more cost-effective to keep the soil in place than it is to attempt to remove soil from stormwater.**

An effective sediment and erosion control plan should:

- **Minimize clearing:** use site fingerprinting, buffers/setbacks, construction phasing.
- **Prevent off-site runoff from flowing across bare soils:** use perimeter dikes/swales, diversions.
- **Stabilize bare soils on the site:** use erosion control mats, planting, retaining walls.
- **Remove sediment from runoff before it leaves the site:** use stabilized construction entrances/exits, silt fences, sediment traps, check dams.
- **Plan soil disturbance activities for the dry season.**

This field guide provides a brief description of and installation information for sediment and erosion control practices that should be installed during all phases of construction: before land clearing (or earth change), during land clearing and construction, and after construction. Some practices can be used in more than one phase of construction, and so are introduced at the first instance where they can be used. Sediment & erosion control practice selection for construction sites should be based on the type of construction activity and the site conditions (soils, slope, vegetation). More detailed practice design and installation information can be found in the ***2002 V.I. Environmental Protection Handbook*** (Wright, 2002).

Best Management Practices to Control Sediment & Erosion on Construction Sites

BEFORE EARTH CHANGE

Planning before clearing and construction is important to conserve valuable topsoil, prevent costly landslide and flooding problems, conserve natural areas and native species, reduce paved areas (impervious cover), prevent property damage and minimize stormwater runoff and downstream pollution. The first step in this planning process is to identify the physical characteristics of the property: soils, topography (slopes, rock outcrops, etc.), hydrology (guts, ponds, water flow paths), and vegetation (endangered species, large trees).

Knowing ***soil properties*** on site prior to construction (or even purchase) is important to select the best site for intended use and prevent costly mistakes. The USDA Natural Resources Conservation Service, through it's Soil Survey of the U.S. Virgin Islands, has rated soils for limitations for different uses such as septic systems, construction fill, road beds, and building foundations. Common soil limitations found in the Virgin Islands include high shrink-swell clays, high soil erodibility, very steep slopes, shallow or stony soils, and excessively dry climate.

Knowing the site's ***topography*** is important so that the building designer and contractor can work with the natural contour of the land to reduce erosion, minimize excavation, reduce flooding and minimize costs. The topographic site features that should be mapped for the site include slope, rock outcrops, water features and floodplains.

The ***hydrology*** of a site is very important to minimize flooding, erosion and property damage both on and off site. The information that is important to know includes the water pathways across the property, whether or not guts or wetlands are present on the property, the depth to the groundwater, the distance to nearby surface waters *(guts, ponds, wetlands, coastal waters)* and whether or not the property is in a floodplain.

It is also important to scout the ***vegetation*** on the property to observe the existing vegetation types (to know what kinds of vegetation are native and also what can be planted after construction), and to determine if and where there are endangered species, critical habitats, and large trees located on the site.

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.

Preserve & Protect Natural Vegetation

Vegetation preservation and protection minimizes the amount of disturbed soil exposed to the erosive forces of wind and rain, and provides natural buffers to slow runoff and filter sediment. 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.

Vegetation Preservation Practices

- Physically mark limits of earth change activities with **clearly visible** tape or flags, placed at eye level of equipment operators.
- Clear only areas essential for construction activities (building footprint, driveway, roadway, septic system). Consider alternate, less disruptive designs, such as smaller units connected by walkways.
- Use 150' buffers or setbacks adjacent to shorelines; 25' buffers or setbacks adjacent to guts; 50'-150' setbacks adjacent to ponds.
- Do not allow equipment, vehicles or construction materials to traverse or be stored in buffer or setback areas. Identify and clearly mark areas to exclude equipment and avoid spilling oil, gas and other contaminants.

Tree Protection Practices

- Identify and clearly mark trees to preserve and protect.
- **Do not nail boards or other materials to trees.**
- **Build sturdy fences, wood or steel barriers around valuable vegetation to protect it from construction equipment.** Place barriers far enough from trees so that tall equipment (backhoes and dump trucks) does not injure branches (Figures 1&2).
- Do not pile more than 3" of soil over existing tree and shrub roots.
- Avoid heavy equipment damage to tree trunks and roots during land-clearing.
- Use retaining walls or terraces to protect tree and shrub roots when lowering grades (Figure 2, see also ***Retaining Walls***). Begin lowered grades outside the tree drip-line. For narrow-canopied trees and shrubs, convert the stem diameter in inches to feet (ex. 10" to 10') and double (10' x 2), so that a 10" diameter tree is protected to 20'.
- Do not trench across tree root systems within the drip line.
- Start tunnels under root systems for underground utilities at least 18" below the normal ground surface. Tree roots that must be cut should be cut cleanly.
- Identify and clearly mark construction areas to exclude equipment.
- Avoid spilling oil, gas and other contaminants.
- Prune obstructive and broken branches properly. (Contact the UVI Cooperative Extension Service for more information on proper pruning.)

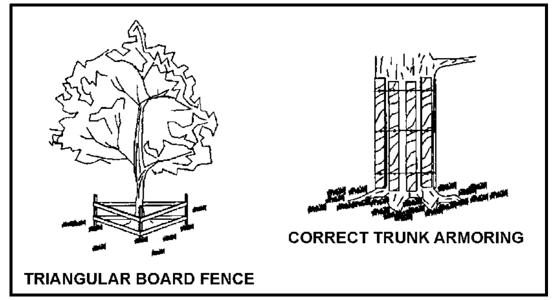

Figure 1. Tree armoring (*CH2M Hill, 1998, adapted from Virginia*).

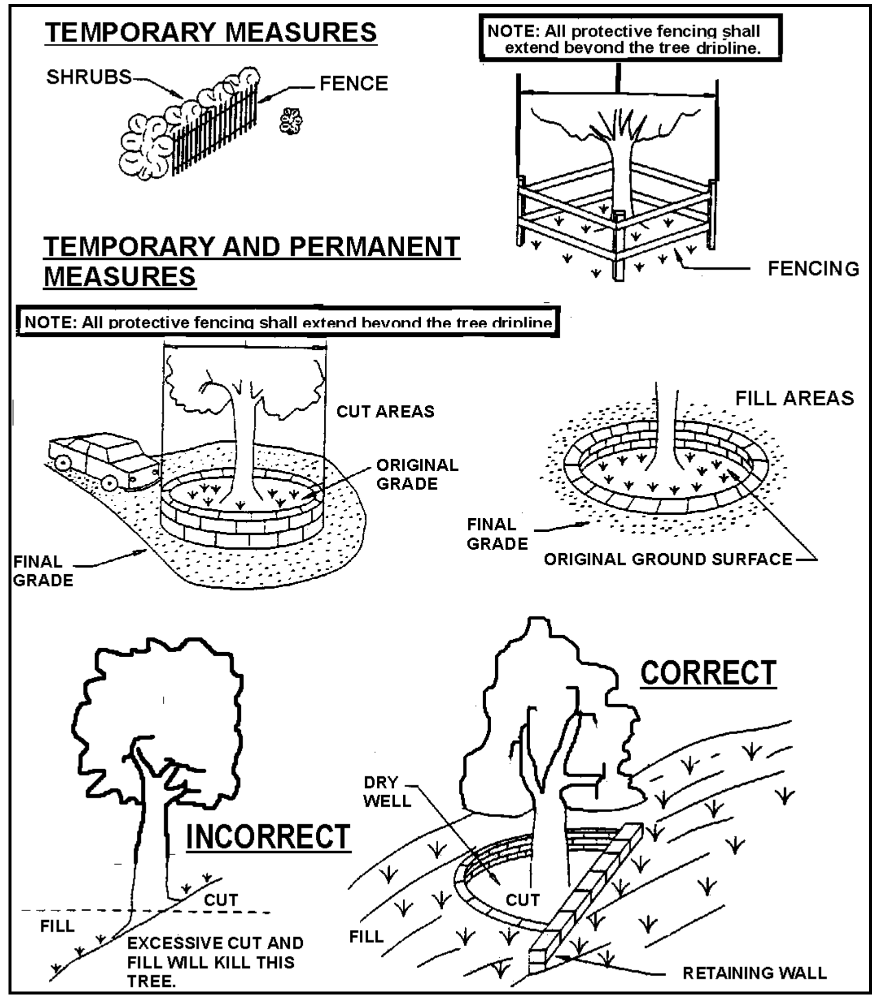

Figure 2. Tree protection practices (*Maryland Department of the Environment, 1994*).

Perimeter Dike/Swale

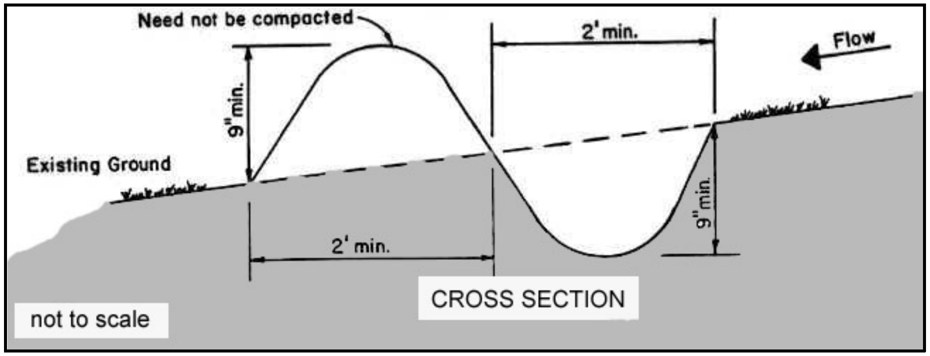

Figure 3. Perimeter dike/swale details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

Perimeter dike/swales divert runoff from drainage areas of **2 acres or less**. They are usually installed uphill of areas to be cleared to divert runoff around bare soils to minimize erosion. Keep perimeter dikes/swales in place until disturbed areas are permanently stabilized.

- The minimum height from the bottom of the swale to the top of the dike is 18", divided evenly between dike height and swale depth (Figure 3).
- The widths of the swale and the bottom of the dike must be ≥ 2' (Figure 3).
- Dike/swale grades should not exceed 20%. The swale grade depends on topography, but should be sloped enough to drain to an adequate outlet.
- Swales in place longer than 10 days must be stabilized with vegetation, erosion control mats, stone or other material (see ***Drainage Swales***, page 22).
- Inspect and repair swales after each heavy rain event.

Dike Outlet

- Route diverted runoff from a protected or stabilized upland area (i.e. "clean" runoff) directly onto an undisturbed, stabilized area or into storm drain system.
- 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.
- The outlet for a dike/swale system should be stabilized to prevent erosion (see ***Outlet Protection***, page 31).

Silt Fence

Silt fences are a **<u>temporary</u>** practice for sediment control on small (1 acre or less) construction sites. For larger sites, the area contributing runoff to each silt fence should not be greater than 1 acre. Silt fences consist of permeable filter fabric (geotextile) anchored by wood or preferably steel posts.

Silt fences MUST BE:

- Installed before earth change activities begin.
- Placed away from the slope base (Figure 4).
- Trenched into the soil and covered with backfill (Figure 5).
- Placed so that the area below the fence is undisturbed or stabilized.
- **Anchored with steel.** In the V.I., steel posts or rebar should be used to anchor silt fencing instead of wood stakes, which often break when hammered into stony, clayey soils. Posts must be on down-stream side of fence.
- Reinforced with steel posts and wire mesh backing, and installed in rows spaced 100' apart for slopes > 25%. (Use standard T- or U-section steel posts or ⅜" rebar. Use a minimum 14½-gage woven wire fence with maximum 6" mesh opening.)

Table 1. 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

The ends of a silt fence must curve uphill to prevent re-routing of stormwater around the fence. Do not exceed slope lengths listed in Table 1. For longer slope lengths, break length up by installing rows of fences.

Never place silt fences across natural guts.

Silt fences are not designed to resist the force of concentrated water, and so should not be built across man-made channels or swales, unless no other practice can be used.

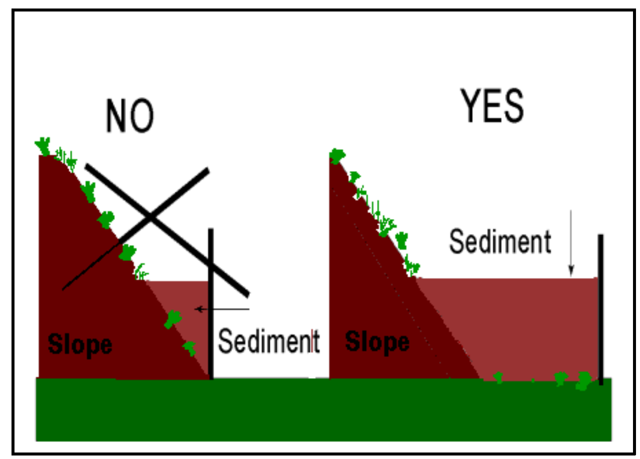

Figure 4. Poor silt fence placement (left) vs. proper silt fence placement (right) (*Fifield, 1996*).

Follow the specifications below to install silt fences in **swales** or **channels** if no other practice is feasible:

- Fencing must be reinforced with steel mesh backing and steel stakes.
- Fencing must be two fabric layers in height.
- There must be a level enough area behind the fence to hold accumulated runoff (Figure 4).

Silt fences must be inspected after each storm and repaired and have accumulated sediment removed when necessary.

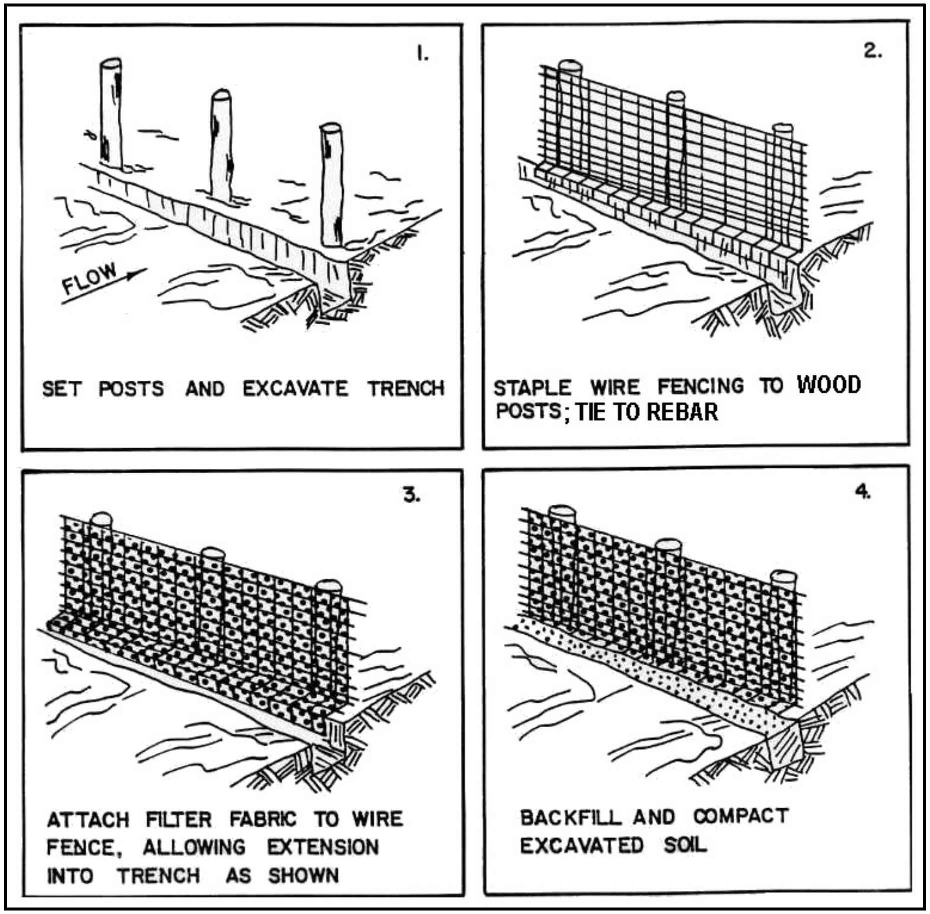

Figure 5. A step-by-step procedure for building a silt fence (*USDA-SCS, 1993b*).

DURING EARTH CHANGE

Vegetative and other erosion control 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.

Erosion control practices should be installed as soon as possible in areas of the site where construction activities have temporarily or permanently stopped for more than 14 days. Temporary grass cover is most commonly used because grasses grow quickly and have fibrous root systems that can rapidly stabilize soils. Other erosion control practices such as mulching or matting may be used during the dry season when it is hard to establish grasses.

Temporary sediment control practices are used during clearing and construction to divert stormwater runoff away from bare soils, convey runoff, prevent sediment from moving offsite, and reduce the erosive forces of stormwater runoff. The length of time that temporary practices are in place may vary from site to site, depending on conditions. Permanent sediment control practices are used to convey stormwater runoff to a safe outlet away from erodible areas and/or to treat stormwater runoff to remove sediment. These practices remain in place and continue to be used after construction is completed.

In general, sediment control practices are less effective than erosion control – 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 most of our soil types have high clay content. Clays are particularly difficult to remove from stormwater because of their very small particle size and tendency 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.**

Land Grading

Grading reshapes or alters the land surface for better use, drainage improvement, and erosion control. The site plan must show pre- and post-construction location and slope elevation of surface to be graded. Use serrated cut slopes on steep (greater than 50%) cuts behind buildings, and next to driveways and roads. Use benches to break long (greater than 20'-40', depending on slope) slopes and route runoff to a sediment trap or stabilized outlet.

Construction Considerations

- Clear only those areas required for construction (building, septic, drive-way footprints, Figure 6).
- Grade fill and cut side slopes no steeper than 2:1 (horizontal: vertical). Cut side slopes in rock or unerodible material may be at the angle of repose for the material.
- Install reverse benches (Figure 7) to break up slope length (therefore reducing runoff speed). Use benches to divide the slope face equally and route runoff to a stable outlet.

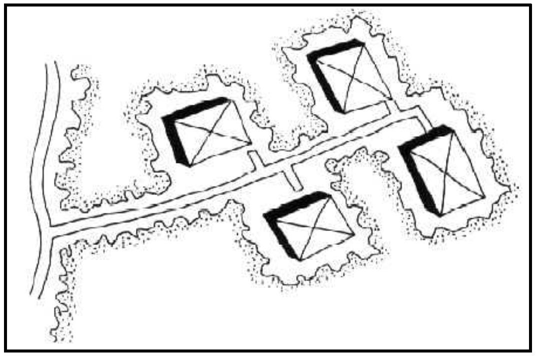

Figure 6. Site fingerprinting example: clearing only areas needed for construction (*CWP, 2001a*).

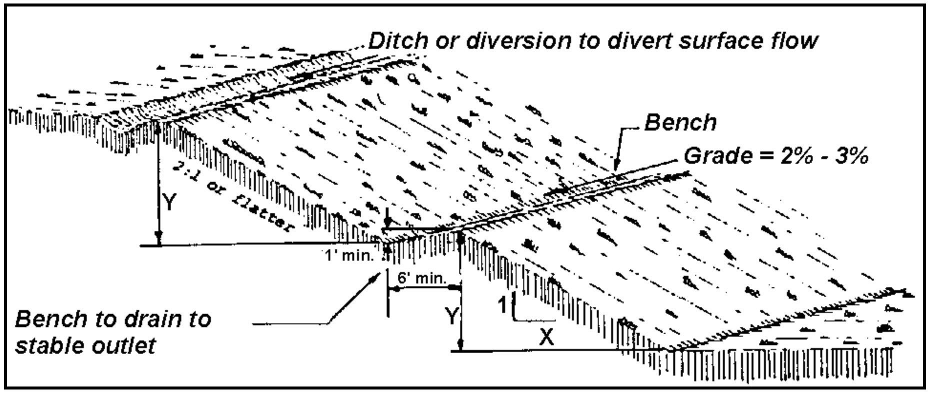

Figure 7. Land grading — benched slope details *(Maryland Department of the Environment, 1994*).

- Temporarily stabilize all graded or disturbed areas, including slopes, with vegetation or erosion control mats during clearing and construction (see ***Temporary Seeding***, page 16; ***Mulch & Matting***, page 18).
- Stockpile & temporarily seed or cover topsoil with tarp or erosion control mat (see ***Mulch & Matting***, page 18).
- For sites where larger areas have to be cleared, run the bulldozer up and down the slope to create grooves perpendicular to the slope (Figure 8). This will channel water laterally across the slope to minimize erosion, instead of in grooves, or gullies, up and down the slope.
- Compact all fills to reduce erosion, slippage, settlement, and subsidence.
- Keep fill material free of brush, rubbish, rocks, logs, stumps, and building debris.
- Provide adequate drainage for seeps or springs encountered during construction so that excess water does not cause slope failure.

- Permanently stabilize all graded areas immediately following finished grading (see ***Permanent Seeding & Planting***, page 34).
- Show all stockpiles, borrow areas, and spoil areas on site plans and stabilize according to the provisions of the ***2002 V.I. Environmental Protection Handbook***.
- Try to minimize clearing and grading as much as possible by exploring alternate site designs.

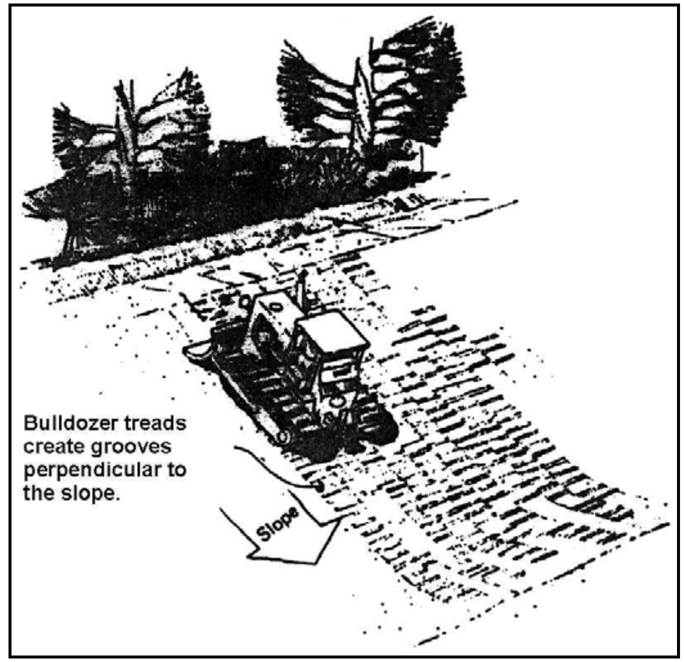

Figure 8. Bulldozer treads create grooves perpendicular to the slope.

Stabilized Construction Entrance

Stabilized entrances are installed at every site entrance/exit to prevent soil from being tracked or washed off-site onto public roadways. Install stabilized construction entrances according to the following guidelines:

- **Length:** Minimum 30' for single residence lot, 50' for other sites, Figure 9.
- **Width:** 10' to 12' foot minimum, flared at existing road to provide turning radius.
- Place filter fabric (geotextile) over existing ground prior to placing stone. Geotextile is not necessary for individual home sites.

C **Stone:** Place 2"-3" crushed aggregate at least 6" deep over the length and width of the entrance.

C **Surface Water:** Pipe all surface water flowing to or diverted toward construction entrances underneath the entrance. Protect the pipe under the construction entrance with a mountable berm. Size the pipe according to the drainage area, with a minimum 6" diameter (see ***2002 V.I. Environmental Protection Handbook*** for details). If piping is impractical, use a mountable berm with 5:1 slopes.

C Regularly maintain the construction entrance to prevent tracking or flowing of sediment onto public roadways. Immediately remove all sediment spilled, dropped, washed or tracked onto public roadways.

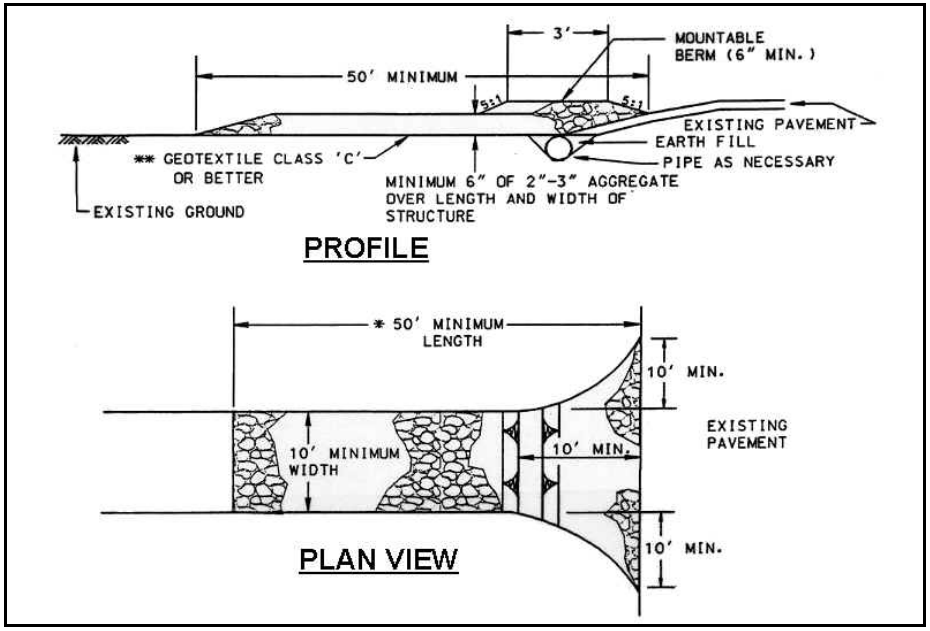

Figure 9. Stabilized construction entrance details *(Maryland Department of the Environment, 1994)*.

Soil Sealers / Binders

Soil binders, sealers and tackifiers are chemical polymers or emulsions (like glue) sprayed onto the soil surface for dust control and to prevent erosion. This practice is especially useful to minimize dust and erosion on dirt roads. Different chemicals can be used for either temporary or long-term stabilization; however, **contractors must ensure that the chemicals selected are environmentally-safe**. Binders, sealers and tackifiers are also

used on very steep slopes or for very dry soils or other areas where it is difficult to establish vegetation.

Binders, sealers and tackifiers can be applied with a hydroseeder or tank truck, with or without mulch and/or seed (see ***Temporary Seeding***, page 16). Pay careful attention to chemical persistence and toxicity in the environment when choosing materials. The compound used should be selected based upon site slope, soils, climate, material longevity, and primary purpose.

The following are specifications for dirt road stabilization with soil binders:

C Select granular fill either from an on-site source (previously off-graded material from the existing road fill slope) or purchase crusher run material from the local quarry.

C Apply 4" of select granular fill to the eroded road surface.

C Saturate the granular fill with the selected product and compact with a roller or vibrating roller.

The end result is a durable driving surface that is dust-free. It is estimated that the total cost of using soil sealers to stabilize dirt roads is approximately ⅛ of the cost of traditional reinforced concrete paving. Once completed, the benefits of using soil sealers should include:

C An elevated roadbed for improved drainage,

C A tough non-eroding, dust-free driving surface,

C A roadway that could be repaired (when and if needed), and

C A good structural foundation for future hard surfacing.

Dirt Road Drainage

There are a number of practices that can be used to divert runoff from the surface of dirt roads to a stabilized area to minimize erosion. These practices include: ***cross drains*** (or ***water bars***), ***broad-based dips***, ***water turn-outs***, and ***pipe culverts***.

Cross-drains or ***water bars*** are earthen fill "mound-trenches" placed diagonally across the surface of a dirt road at a 15 to 30 degree downslope. They divert rainwater off the road to a stabilized area (such as a ***Drainage Swale***, page 22 or ***Sediment Trap***, page 26) to minimize erosion from stormwater runoff. Cross-drains are built with a bulldozer or tractor. The water bar should be built so that the uphill end of the

Table 2. Spacing guide for cross-drains or water bars *(North Carolina Forest Service, 2002)*.

Slope (Degrees)	Spacing Between Water Bars
5	135 feet
10	80 feet
15	60
20	45
30	35 feet

bar ties into the adjacent bank or cutwall to capture ditch or swale flow. An energy absorber is needed on the downslope out-fall, such as stone, rip-rap or brush, to slow and dissipate stormwater. Cross drain spacing depends on road slope, soil erodibility and rainfall intensity (see Table 2). Reinforce and slightly raise the lower lip of the water bar so that it is not washed out or eroded by road traffic (Figure 10).

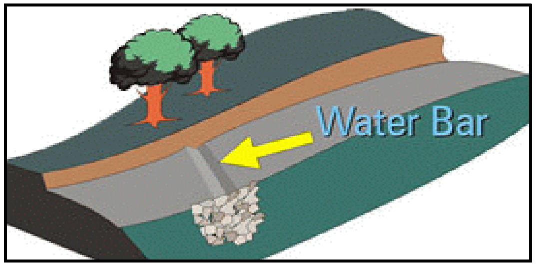

Figure 10. Cross-drain or water bar installation schematic (*North Carolina Forest Service, 2002*).

A ***broad-based dip*** is a broad, earthen dip-hump combination built into the surface of a flat or in-sloped access road. The dip forms a reverse or out-sloped cross-drain to divert flowing water from one side of the road to the other. This practice is used on dirt roads with 12% slopes or less. Dips are preferred over water bars because they allow traffic to maintain a fairly uniform speed as opposed to the stop and go "speed bump" charac-teristics of water bars. A broad-based dip is not a substitute stream crossing method (*North Carolina Forest Service, 2002*).

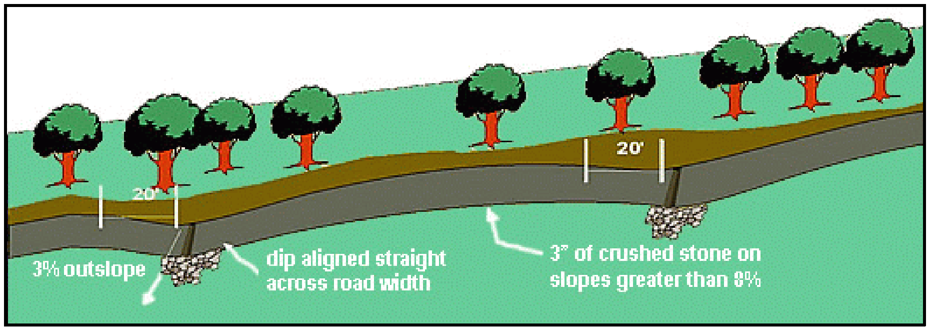

Figure 11. Broad-based dip schematic (*North Carolina Forest Service, 2002*).

- Road slope determines dip spacing as follows: 2-4% road grade: 200-300' dip spacing; 5-7% grade: 160-180' dip spacing; 8-10% grade: 140-150' dip spacing.
- Install dips at a 30-degree angle downslope, tying the upper end of the dip into an adjacent bank to avoid water by-passing the dip (Figure 11).
- Outslope the dips about 3%, and provide energy absorbers as described under water bars.
- Armor broad-based dips with crushed stone or rock ballast on highly erodible soils.

Water turnouts are ditches, trenches, or swales used to divert stormwater runoff away from a road surface or adjacent ditch. Turnouts can be the width of a backhoe bucket or a bulldozer blade, and carry water into undisturbed, vegetated areas to dissipate energy and

disperse water onto the forest floor, or to an outlet stabilized with grass, stone or rip-rap. Water turnouts should intersect a ditch line at the same depth and be outsloped 1-3%. On sloping roads, turnouts should be 30-45 degrees downslope. Water turnout use depends on the road slope and the availability of suitable outlet areas. Space water turnouts to provide good road drainage, avoid-ing water pooling that leads to soil compaction, soup-ing, or rutting. A water turnout can also function as a small sediment trap, so maintenance is important to prevent the turnout from eroding or filling in to the point of becoming non-functional. Water turnouts must not empty directly into guts or other water channels leading directly to Territorial waters.

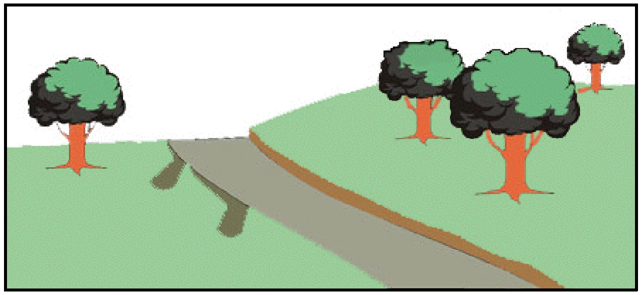

Figure 12. Schematic of water turnouts (*North Carolina Forest Service, 2002*).

Soil Retaining Walls

Soil retaining walls are 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 including concrete retaining walls, gabion basket retaining walls, stone terraces / rock walls and vegetated rock walls. Refer to the ***2002 V.I. Environmental Protection Handbook*** for design and construction specifications.

Use retaining walls where other soil retention methods are not practical; i.e. to stabilize cut slopes along roads and drive ways, parking lots, building sites, and other cut and fill areas where slopes or soils are not suitable for vegetative stabilization. Retaining wall design must address foundation bearing capacity, sliding, overturning, drainage, and loading systems. **These are complex systems; walls higher than 4' should be designed by a licensed engineer.**

Vegetated Rock Wall

A vegetated rock wall (Figure 13) uses a combination of rock and live plant cuttings to stabilize and protect the toe of steep slopes. Vegetated rock walls differ from retaining walls in that they are placed against relatively undisturbed earth and cannot resist large lateral earth pressures.

Excavate the minimum amount from the existing slope to provide a suitable recess for the wall. The wall should be slightly angled back into the slope for stability. Use 8"-24" diameter rock for the wall and large boulders for the base. Place rocks with at least a three-point bearing on the foundation material or underlying rock. Place rocks so that their center of gravity is as low as possible, with their long axis slanting inward toward the slope.

For rock walls built adjacent to an impervious surface (driveway, house, etc.), place a drainage system (gravel and perforated pipes) at the back of the foundation and outside the toe of the wall to provide an appropriate drainage outlet. Do not build rock walls higher than 5' (inclu-ding footing). Place the live plant cuttings perpendicular to the slope with growing tips protruding slightly from the finished rock wall face (see Figure 13).

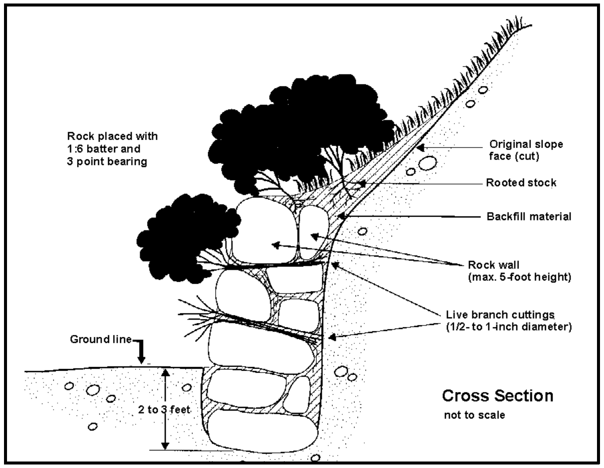

Figure 13. Vegetated rock wall details (*USDA-SCS, 1992*).

Low Wall/Slope Face Plantings

A low retaining wall 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 from surface erosion and landslides (Figure 14).

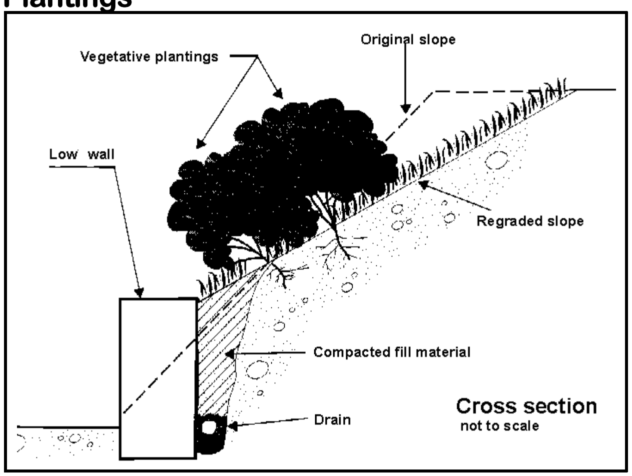

Figure 14. A low wall with plantings above (*USDA-SCS, 1992*).

Several basic types of retaining structures can be used as low walls: masonry and concrete walls, stone terraces, rock walls, or reinforced earth and geogrid walls. Each of these can be modified a number of ways to fit almost any condition or requirement. Refer to the ***2002 V.I. Environmental Protection Handbook*** for detailed design and construction specifications.

Temporary Seeding

Temporary seeding provides a short-term cover of fast-growing grasses on a cleared or disturbed area. It is used to reduce erosion on areas that either won't be worked on for a long time or where permanent vegetation is not necessary or appropriate. Contact the USDA Natural Resources Conservation Service or UVI Cooperative Extension Service for grass information.

Site Preparation

- The surface grade should be at least 1% or more and directed away from buildings.
- On relatively level, un-graded areas where the soil is unsuitable for growing vegetation, spread a 2"-6" layer of good topsoil before planting (see Table 3 for topsoil volumes).
- Use annual grasses (such as rye or fescue) to provide temporary cover. Common bermuda or bahia grass (or other perennials, see Table 4) can also be added to the seed mix to provide longer-term stabilization on bare soils that will be redisturbed before construction is complete, but not for a considerable amount of time.
- The best slopes for grass maintenance are 3:1 (33%) or flatter. Steep, vegetated slopes may also require structural stabilization, such as retaining walls, terraces, diversions, etc.

Table 3. Topsoil volume 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

Table 4. Suitable perennial grass species for the Caribbean *(USDA-SCS, 1990b)*.

Plant Species	Propagation	Adaptation
	-------*Widely Adapted Grasses*-------	
Carpetgrass	By seed	Wet and shaded areas
Common bermuda grass	By seed	Throughout the island
Guinea grass	By seed or vegetative	Dry areas & alkaline soils; shady areas; Intolerant to wet, acid soils
Paragrass	Vegetative	Throughout islands, 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	By seed	All dry sites
	-------*Grasses Especially Adapted to Saline Sites*-------	
Beach Grass (*Sporobolus virginicus*)	Vegetative	

Seedbed Preparation

- Disturb these areas as little as possible, especially on very steep slopes.
- Remove all debris, such as rocks, stumps, scrap lumber, and concrete.
- Scarify soil if compacted.
- After applying topsoil, if required, loosen soil to a depth of several inches.
- Perform all tillage operations across the slope to reduce erosion.

Seeding

- Plant grasses during the rainy season, if possible, and according to manufacturer's specifications. Supplemental water will be needed if grass is planted during dry season. It may also be necessary to increase the seed rate to account for loss to birds and pests.
- On steeper slopes or highly erodible soils, hold the soil and seed in place with mulch and tackifier (for Hydroseeding applications) or erosion control mats (see ***Mulches, Mats & Geotextiles***, page 18) to prevent erosion and seed loss.
- Table 4 provides a comparison of lawn grasses for use in the Virgin Islands.
- Do **NOT** allow livestock to graze the grass.
- Do **NOT** allow equipment to travel over newly vegetated areas.

Hydroseeding

Contact the UVI Cooperative Extension Service or DPNR's Coastal Zone Management Program for a list of individuals certified as trained hydroseeders in the Virgin Islands.

1. **Seeds:** Any lawn or roadside seed can be used. Consult seed manufacturer's recommendations for seeding rate.
2. **Mulch:** Cellulose mulch (made from chopped up newspaper with green dye) is recommended for general use in hydroseeders. Mulch usually comes in 50-pound bales. Use 175-200 pounds of mulch for a full 750 gallon hydroseeder tank. The seed, mulch & water slurry should have 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 mulch as much as possible as it is added to the tank.
3. **Fertilizer:** Most fertilizers intended for lawn applications can be used. For new seeding, a starter fertilizer high in phosphorus (the middle number on a fertilizer bag, such as 5-10-5), may be needed. Use the fertilizer amount recommended by the manufacturer for the desired coverage.
4. **Tackifier:** (see ***Soil Binders/Sealers***, page 11) Tackifier is used to hold seed in place on steep slopes or during stormy weather. Add it to the tank right before spraying.
5. **Lime: DO NOT** use lime in the hydroseeder. Use liquid products to alter pH.

Maintenance

- Repair small bare spots by reseeding and/or mulching.
- Mow grassed swales and embankments frequently to control weeds and unwanted woody vegetation. Mowing height should be at least 3" above ground.

Best Management Practices to Control Sediment & Erosion on Construction Sites

Mulches, Mats & Geotextiles

Mulch Application Specifications

Mulching is a temporary erosion control measure and can be used alone or in conjunction with temporary seeding or permanent seeding and planting. Refer to the ***2002 V.I. Environmental Protection Handbook*** for guidelines for mulching rates and slope length limits for different types of mulch used on construction sites.

Types of Mulch

- **Straw or hay:** 1½ to 2 tons per acre with seeding; 3 tons per acre used alone.
- **Wood fiber (jute):** 1,000 to 2,000 pounds per acre.
- **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.
- **Crushed stone:** 135 to 240 tons per acre.
- **Wood chips:** 7 to 25 tons per acre.

Mulch Anchoring & Application

- **Straw or Hay Mulch:** anchor with plastic or jute netting and either staple into place or use a tackifier or a crimper. Mulch can be applied with a blower or by hand.
- **Wood Fiber Mulch:** can be anchored with a tackifier and applied by hydroseeder.
- **Mulch Netting:** anchor with staples spaced at the manufacturers's recommendation, according to slope. Crushed stone and wood chips are also applied by hand.

Erosion Control Mats

The basic types of erosion control mats are the permanent turf reinforcement mat, the 100% biodegradable mat or blanket, the extended or long-term degradable mat, and the short-term photodegradable mat. Mat selection depends on site conditions (slope, runoff speed, project duration, and the area where the mat will be installed (slope, channel or shoreline). Refer to the ***2002 V.I. Environmental Protection Handbook*** or manufacturer specifications for guidelines on the proper purpose, selection and use of each mat.

In general, mats are trenched and anchored into the top of the slope to be stabilized, rolled down the slope and anchored in place using 6" - 12" long metal staples (Figure 15). Refer to the ***2002 V.I. Environmental Protection Handbook*** for design and construction specifications depending on type of installation.

- Divert runoff away from the application area.
- Remove tree stumps, rocks and debris to prepare a smooth surface.

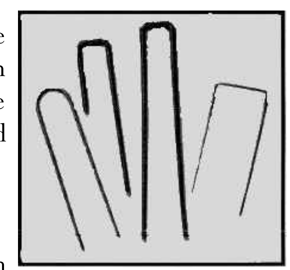

Figure 15. Different types of staples used to anchor erosion control mats.

- Fill holes and depressions; grade and compact area (for permanent stabilization).
- Mats may also be installed and covered with 1" of topsoil before seed application.

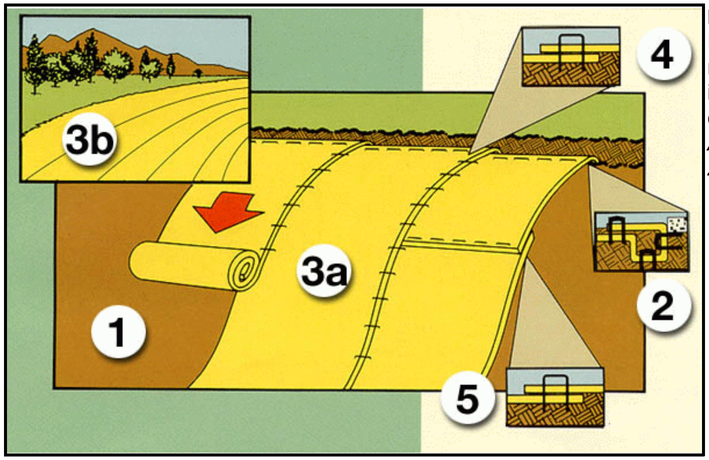

Figure 16. Erosion control mat slope installation example (*North American Green, 2002*).

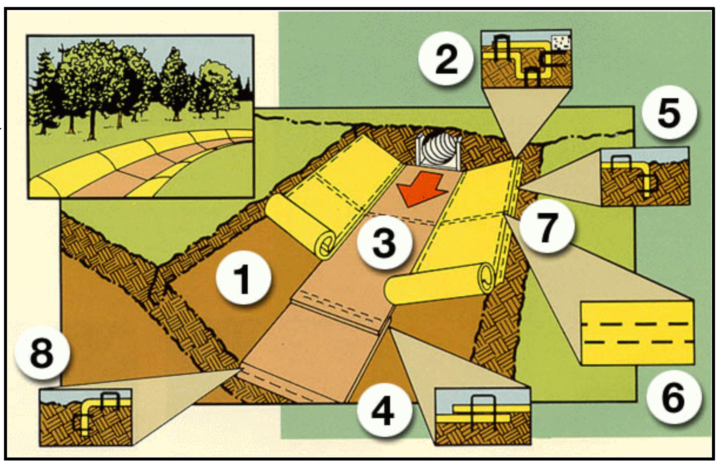

Figure 17. Example erosion control mat installation in a channel or drainage swale (*North American Green, 2002*).

Filter Strips

Filter strips are vegetated land areas that remove sediment from stormwater by slowing runoff speeds, filtering out sediment and other pollutants, and providing some infiltration. Filter strips differ from buffer strips (as described in ***Preserve & Protect Natural Vegetation***, page 3) because they can be newly planted grasses or an area of vegetation that is left undisturbed during construction. Filter strips can be either temporary or permanent practices.

Construction Specifications

- Build filter strip during the dry season, when soil moisture is low.
- For grass filter strips, remove all trees, stumps, roots, rocks, brush, etc. that can interfere with filter strip installation.
- Removed bruxh can be chipped or shredded and used for mulch.
- Grade the filter strip to a uniform, even and relatively shallow slope (< 10%). The top edge of the filter strip should follow the same elevational contour as, and directly join, the contributing impervious area (Figure 18).

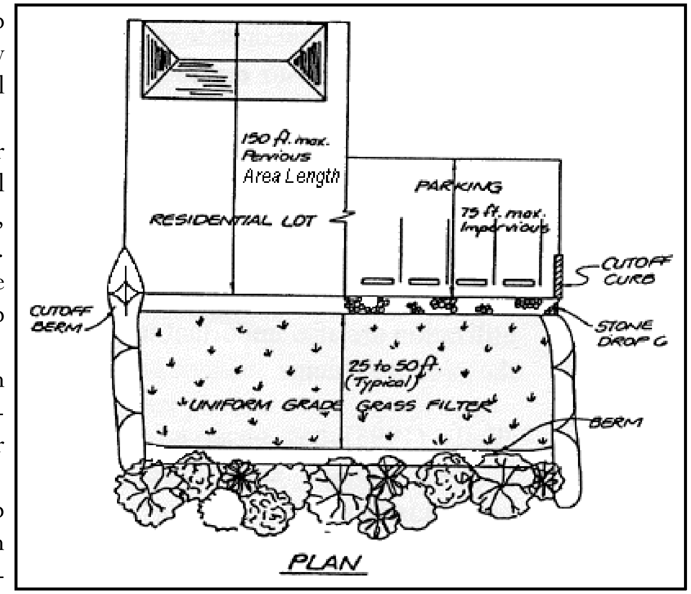

Figure 18. Up to 75 feet of parking lot can be treated in a filter strip. Allow a drop from the parking lot to the grass filter to avoid sediment buildup at the edge (*Schueler, 1995*).

- Avoid compacting the soil, to maximize stormwater infiltration. Use erosion control mats or mulch on steeper slopes to stabilize the strip until vegetation can be established (see ***Permanent Vegetation***).
- Absolute minimum filter strip length is 20'. However, strip length usually ranges from 50'-75' (Figure 19).
- The strip should be at least as wide as the contributing runoff area.
- The level spreader at the top of the strip (Figure 19) should be at least 1' wide and 3" deep.

- Berms can be placed at 50'-100' intervals perpendicular to the top edge of the strip to prevent runoff from bypassing the strip.
- Seed the strip according to seed manufacturer's recommendations. Seeding can be done either by hand-broadcasting or hydroseeding. For the Caribbean area, the following grasses 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, see Table 7, page 35).

Maintenance

- Corrective maintenance is needed around the edge of the strip to prevent concentrated flows from forming.
- Mow strips 2 - 3 times per year to suppress weeds and keep bush cut back.
- Spot repairs may be needed to maintain a dense vigorous vegetative growth.
- Manually remove accumulated sediment at the top of the strip.
- Inspect strips annually and examine for damage by vehicle traffic, gully erosion and evidence of concentrated flows through or around strip.

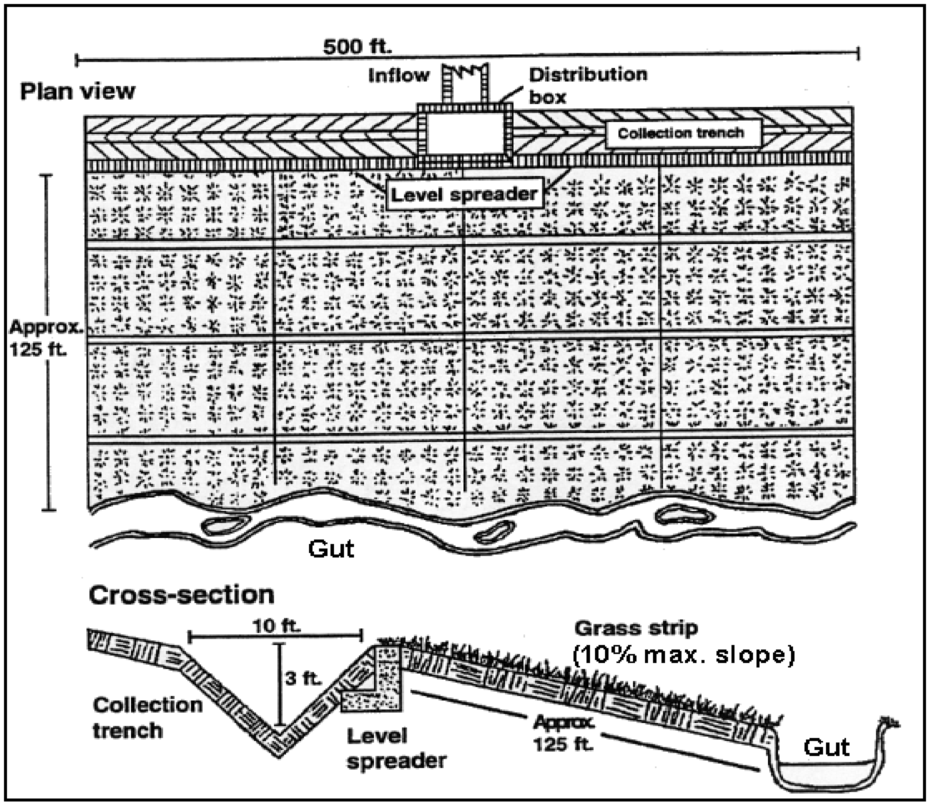

Figure 19. Schematic design of a vegetated filter strip (*Delaware DNREC, 1997*).

Drainage Swales

Drainage swales are stabilized channels that route stormwater at non-erosive speeds to a stabilized outlet. Swales and outlets are lined with grass or other vegetation, erosion control matting, geotextile, rip-rap, concrete or other materials.

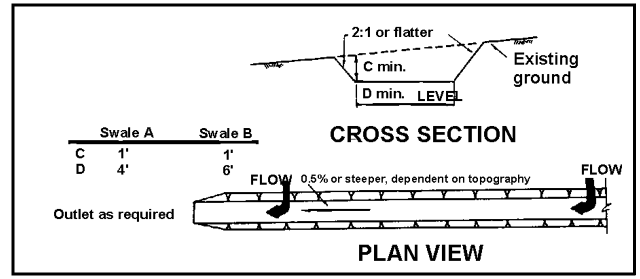

Figure 20. Temporary drainage swale schematic *(Empire State Chapter Soil & Water Conservation Society, 1997)*.

Table 5 shows dimensions for two sample drainage swales: Swale A routes runoff from drainage areas less than 5 acres; Swale B routes runoff from 5-10 acre drainage areas (Figure 20).

Table 5. 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

Stabilization

Stabilize swales with grass or erosion control mats within 10 days of installation, according to the specifications provided for ***Temporary Seeding*** (page 16) and/or ***Mulches, Mats & Geotextiles*** (page 18). Stabilize the swale according to the methods in Table 6. Figure 21 shows how grassed swales can be used along roadways.

Table 6. Swale stabilization methods *(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.***

Construction Specifications

1. All temporary swales must have an uninterrupted positive grade to an outlet.
2. Route diverted runoff from a disturbed area to a sediment-trapping device such as a sediment trap or basin, until the drainage area above the swale is adequately stablized. (If the swale is used to divert runoff around a disturbed area, a sediment-trapping device may not be needed.)
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 material in the swale so that water flow is not blocked.
5. Excavate or shape the swale in accordance with the design criteria. Eliminate bank projections or other irregularities that may impede normal water flow.
6. Place all soil removed and not needed for the project so that it will not interfere with the functioning of the swale.
7. Compact fill with earth-moving equipment.
8. Stabilize swales according to the volume and velocity of water to be handled (i.e., up to 5% slope, seed and install ESC blankets; 5-10% slope, seed and install turf reinforcement mats; over 10% slope, install rip-rap or have engineer design).
9. Periodically inspect and repair swales after each significant rain event.

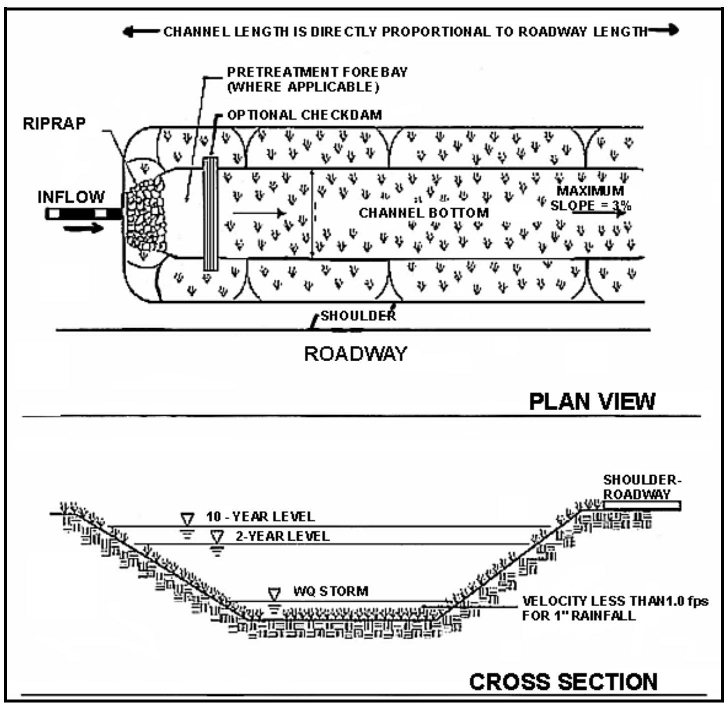

Figure 21. Grassed drainage swale details (*Schueler, 1995*).

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. Inlet protection is not required if storm drain diversions have been installed and are functioning properly. There are four ways to install storm drain diversions:

1. **A sediment trap below permanent storm drain outfall:** The storm drain system is routed into a temporary trap built below the permanent outfall channel.
2. **In-line diversion of storm drain at an inlet or manhole:** A pipe stub is installed in the side of a manhole or inlet to temporarily block the permanent outfall pipe from that structure. A temporary outfall ditch or pipe may be used to route stormwater from the pipe stub to a sediment trap. This practice can 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 trap:** An earth dike, swale or designed diversion can be used, depending on the drainage area, to direct flow into a sediment trap.
4. **Install 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 is not necessary.

Removal and Restoration

To restore the permanent storm drain system when areas contributing sediment have been stabilized:

1. Remove any accumulated sediment in the sediment trap.
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, dikes, swales, etc.).
5. Restore the area to grades shown on the engineering plan and stabilize with vegetation.
6. For traps that will be converted to stormwater management, remove the accumulated sediment, opening the orifice, and seed all disturbed areas to permanent vegetation.

Check Dams

Check dams are installed in man-made swales, channels and ditches to slow runoff, allow soil to settle out and minimize erosion potential. The maximum drainage area above a check dam must not be greater than 2 acres.

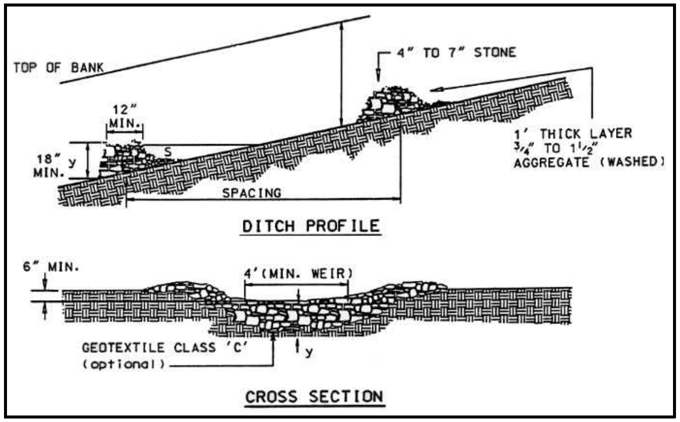

Figure 22. Check dam schematic (*Maryland Department of the Environment, 1994*).

Only use check dams in drainage channels, swales and ditches, NOT in natural guts.

Construction Specifications

1. Build swales and ditches in accordance with ***Drainage Swale*** specifications (page 22).
2. Place check dams in reasonably straight ditch sections to minimize erosion potential in channel bends.
3. Key stone check dams into the sides and bottom of the channel.
4. The maximum height of the check dam at the center must not exceed 2'.
5. Build the top of the check dam so that the center is about 9" lower than the outer edges, forming a weir that water can flow across.
6. Grade side slopes to 2:1 or less.
7. Space check dams so that the crest of the downstream dam is at the same height as the toe of the upstream dam (Table 7). Spacing is equal to the height of the check dam divided by the slope (in feet).
8. Use 4"-7" washed stone to build check dams. Place stone so that it completely covers the width of the channel and is keyed into the channel banks (Figure 22).
9. Line the upstream side of the check dam with one foot of ¾" to 1½" aggregate.
10. Toe check dams a minimum of 1 ½' into the sides of the channel to prevent erosion around dam edges.

Table 7. 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

11. Protect the channel downstream of the lowest check dam from scour and erosion with stone or channel liner as appropriate.
12. Ensure that channel openings, such as culvert entrances, below check dams are not subject to damage or blockage from displaced stones.
13. Remove accumulated sediment when it has built up to one-half of the original height of the dam crest.

Triangular Dikes/Berms can be used for check dams in place of stone. Materials such as Triangular Silt Dike™ or Enviro-Berm® 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 product installation information. An example of a triangular dike check dam installation is shown in Figure 23.

Figure 23. Erosion & Sediment Control Workshop trainees install a *Triangular Silt Dike™* check dam in Estate St. George's Hill, St. Croix, June 1998.

Sediment Traps

Sediment traps are used at the outlet of perimeter diversions installed during the first stage of construction; at the outlet of any structure that carries sediment-laden runoff (diversions, channels, slope drains, etc.); or above a storm water inlet that is in the path of sediment-laden runoff. Sediment traps can handle runoff from drainage areas between 2 and 5 acres, depending upon the type of sediment trap used. They are temporary practices and should not remain in place longer than 18 to 24 months. Sediment traps can be built as either single or double chamber systems (Figures 24 and 25, 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

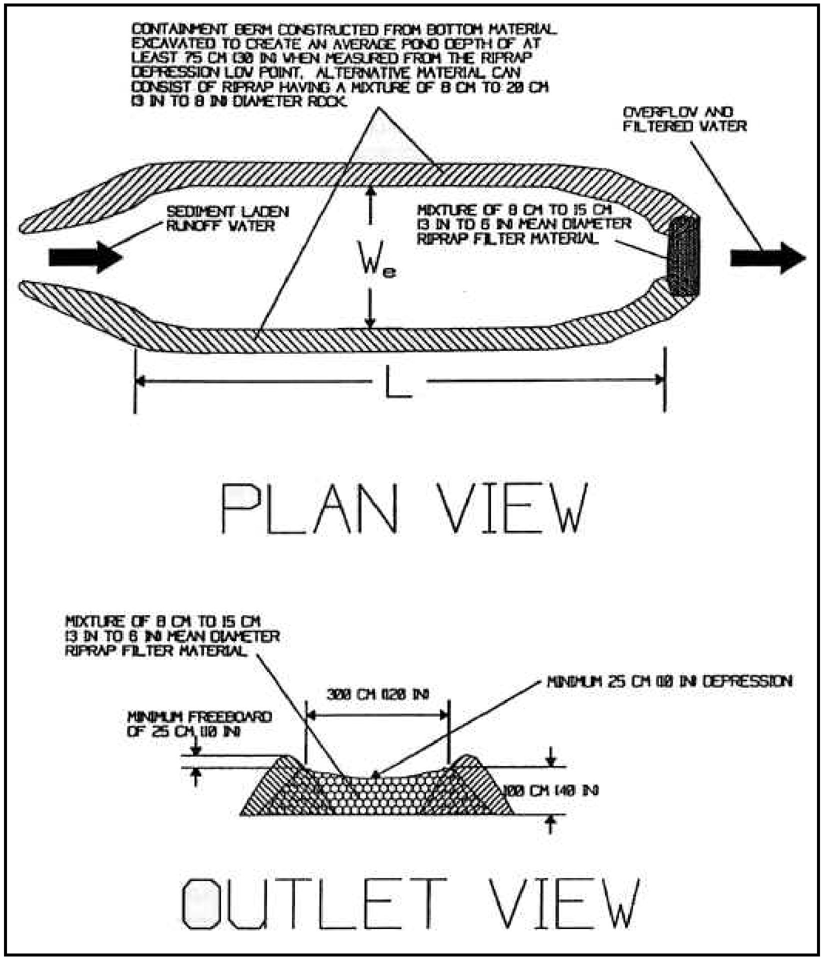

Figure 24. Single chamber sediment trap design schematic (*Fifield, 1996*).

are: pipe outlet, rip-rap outlet, stone outlet, swale outlet, grass outlet and storm inlet sediment traps. See the ***2002 V.I. Environmental Protection Handbook*** for construction details.

Construction Considerations

1. Locate sediment traps in the drainage area they are to protect and install prior to grading or filling. Locate traps at least 20' away from proposed building foundations if they are to be used during building construction.
2. Excavate sediment traps to 1:1 or flatter slopes, minimizing erosion and soil loss.

Best Management Practices to Control Sediment & Erosion on Construction Sites

3. Design, build and maintain trap outlets so that sediment cannot escape and so that erosion does not occur at or below the outlet. Sediment traps must outlet onto stabilized (preferably undisturbed) soil or into a watercourse, stabilized channel, or storm drain system.

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. Remove traps when construction is completed by regrading and installing permanent vegetation (see ***Permanent Seeding & Planting***, page 34).

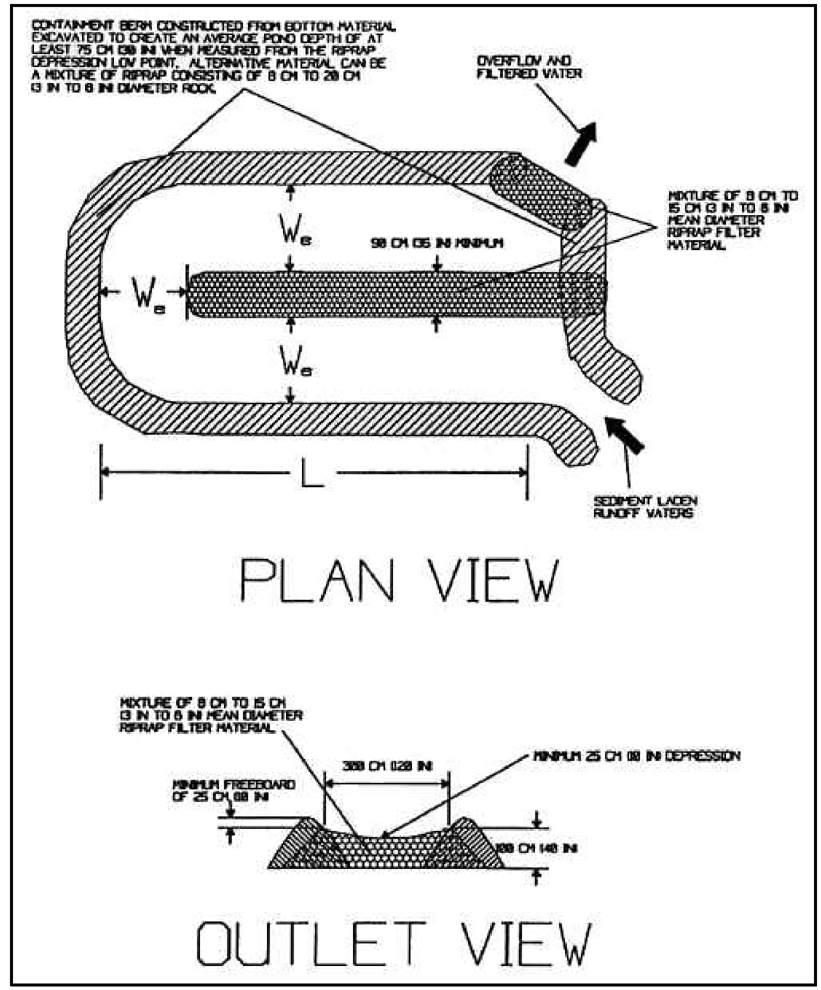

Figure 25. Double chamber sediment trap design schematic (*Fifiled, 1996*).

Temporary Sediment Basin

A sediment basin is a settling pond with a controlled stormwater release outlet that is used to collect and store sediment produced by construction activities. A sediment basin can be built by excavation and/or by placing an earthen embankment across a low area, 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. Standard sediment basin designs can be used for drainage areas of 10 or 20 acres, see Figure 26 and the ***2002 V.I. Environmental Protection Handbook*** for design and construction details.

Location & Size

Locate sediment basins in an area that maximizes water storage, for easy maintenance, so that storm drains can outfall or be diverted into the basin, and to minimize interference with construction activities and utilities. **DO NOT** locate sediment basins in natural drainage channels (guts). The sediment storage volume of the basin must be at least 3,600 cubic feet per acre of disturbed area draining to the basin. (3,600 cubic feet is equivalent to 1" of sediment per acre of drainage area).

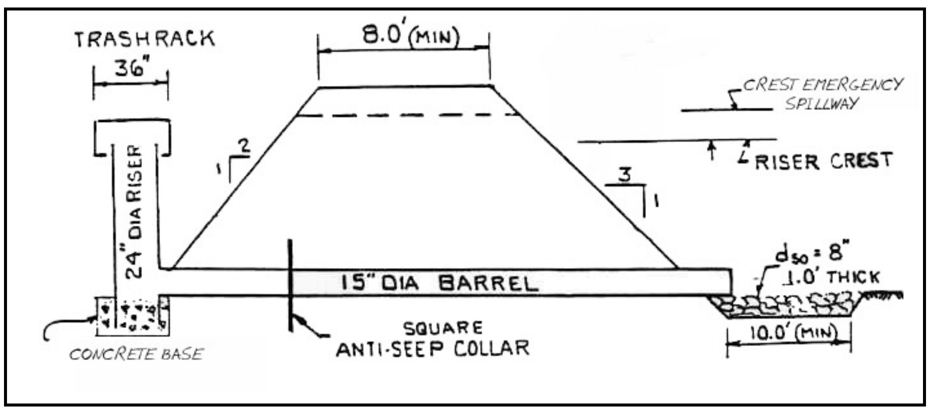

Figure 26. Schematic design of a standard sediment basin (*adapted from Empire State Chapter Soil & Water Conservation Society, 1991*).

Vegetative Treatment

Stabilize basin embankments and emergency spillway according to the specifications for ***Temporary Seeding*** (page 16) and/or ***Mulch, Mats and Geotextiles*** (page 18). **DO NOT** allow embankments to remain unstabilized for more than 14 days.

Maintenance

Repair all damage caused by soil erosion and construction equipment at or before the end of each working day. Clean out sediment basins when they are 50% full, by volume. **DO NOT** allow sediment to build up higher than 1' below the principal spillway crest. Dispose of this sediment in such a manner that it will not erode from the site. **DO NOT** deposit sediment downstream from the embankment, adjacent to a drainageway, or in a floodplain. 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.

Storm Drain Inlet Protection

Storm drain inlet protection places a permeable barrier around an inlet or drain to filter sediment out of stormwater. It prevents the silting-in of inlets, storm drainage systems, or receiving channels. There are four basic types of storm drain inlet protection practices that vary according to their function, location, and availability of materials. These types are: excavated (Figure 27), filter fabric, stone and block (Figure 28), and curb drop inlet protection. See the ***2002 V.I. Environmental Protection Handbook*** for construction details.

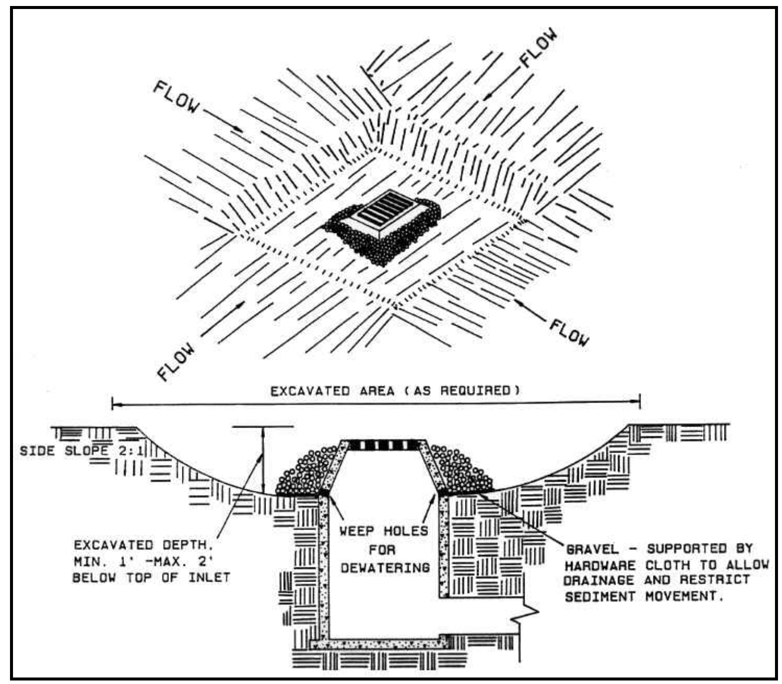

Figure 27. Excavated drop inlet schematic (*Empire State Chapter Soil & Water Conservation Society, 1997*).

All types can handle runoff from a maximum 1 acre drainage area. Manufactured inlet inserts are also used to reduce sediment loads to storm drains. Design and installation specifications for these practices are provided by the manufacturer. Endorsement of any of these manufacturers is not intended.

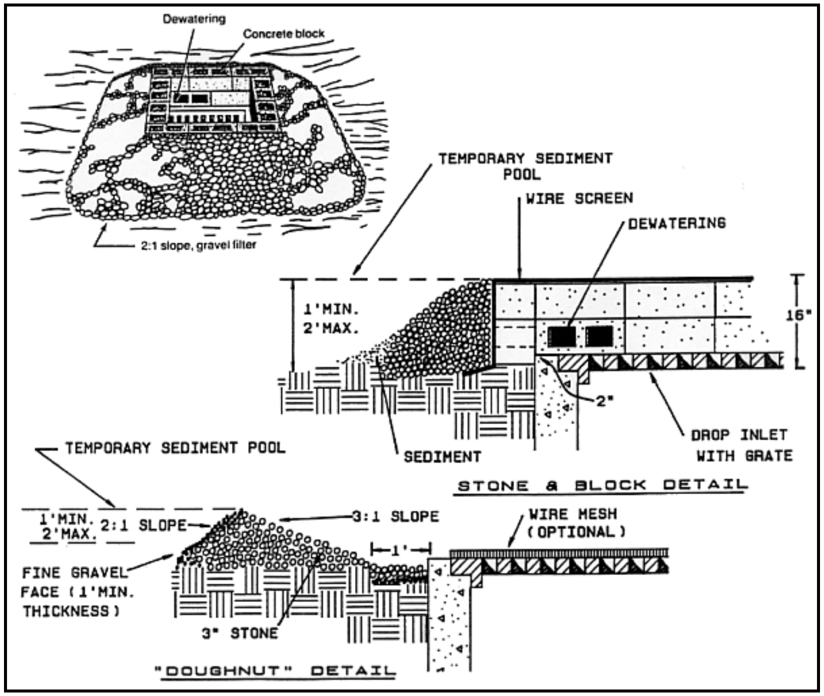

Figure 28. Stone and block drop inlet protection details (*Empire State Chapter, 1997*).

Outlet Protection

Rock outlet protection uses stone, rip-rap, grouted rip-rap, or gabions installed below a storm drain outlet to reduce the depth, speed and energy of concentrated stormwater flows and reduce erosion and scouring at stormwater outlets of culverts, swale and drainage channels. Outlet protection also reduces the potential for downstream erosion. Design specifications are detailed in the ***2002 V.I. Environmental Protection Handbook***.

Materials

Rip-rap must be composed of a well-graded mixture of stone sizes so that 50% of the pieces, by weight, are larger than the d_{50} size determined by using the charts provided in the ***2002***

V.I. Environmental Protection Handbook. Use field stone or rough unhewn quarry stone for rip-rap. The stone must be hard and angular and not disintegrate from water or weather exposure. Always place a filter layer under rip-rap. A filter can be either a gravel layer or filter fabric.

Gabions

Gabions are made of hexagonal, triple-twist mesh with heavily galvanized steel wire. See the ***2002 V.I. Environmental Protection Handbook*** or manufacturer's specifications for material details. Build gabions so that the sides, ends, and lid can be assembled at the construction site. Grade the area where the gabion is to be installed as shown on the drawings. Place filter fabric under all gabions. Gabions may need to be keyed in to the slope to prevent undermining.

1. Prepare the subgrade for the filter, rip-rap, or gabion to the required lines, denstiy and grades on engineering plans.
2. Protect the filter fabric from punching, cutting or tearing. Repair any damage other than occasional small holes by placing another piece of fabric over the damaged part or by completely replacing the fabric. Minimum width for all overlaps, whether for repairs or for joining two pieces of fabric, is 1'.
3. Stone for the rip-rap or gabion outlets may be placed by equipment. Build outlets to full thickness in one operation to avoid displacing underlying materials (i.e., filter fabric). 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 larger stones. Place rip-rap carefully to prevent damage to the filter blanket or filter fabric. Hand placement of some stone may be necessary to prevent damage to the permanent structure (see Figure 29).

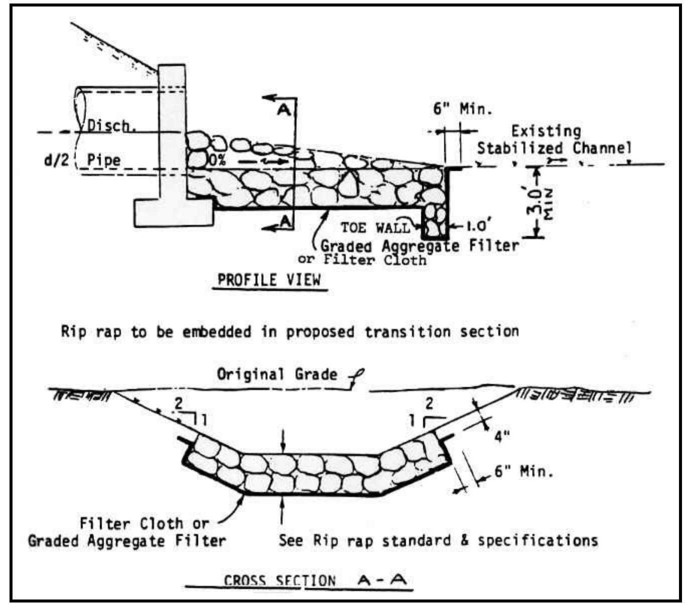

Figure 29. Rip-rap outlet protection for full pipe flow (*Empire State Chapter Soil & Water Conservation Society, 1991*).

Gabion Inflow Protection

Gabion inflow protection provides stable transport of concentrated runoff down steep slopes to prevent channel erosion. It is used in place of grass or erosion control mats when channel slopes contributing to a sediment trap or basin exceed 25%, or on other steep areas as applicable.

1. Use minimum 4"-7" stone for gabion inflow protection and place in wire baskets, underlain by Class C filter fabric (geotextile). Place baskets from the end of the swale to the bottom of the trap or basin. Use this practice only for inflow slopes between 2:1 and 4:1.
2. Stabilize slopes flatter than 10:1 according to ***Temporary Swale*** criteria described above and in the ***2002 V.I Environmental Protection Handbook***. Use rip-rap protection for slopes between 10:1 and 4:1.
3. Build by arranging 9' x 3' x 9" gabion baskets in a trapezoidal cross section with 2:1 side slopes and 3' bottom width (Figure 30).
4. Install gabions according to manufacturer's specifications.

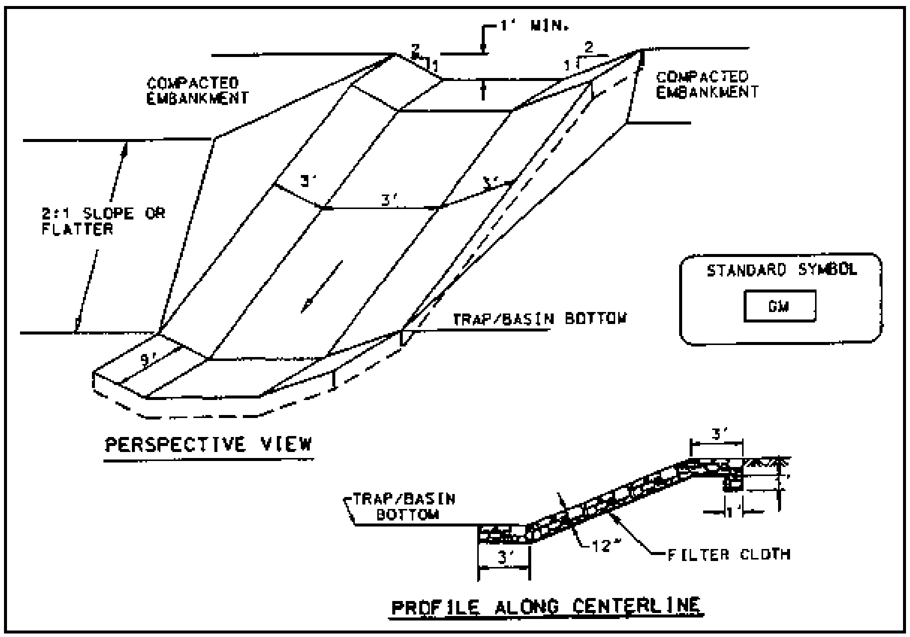

Figure 30. Gabion inflow protection details *(Maryland Department of the Environment, 1994)*.

Best Management Practices to Control Sediment & Erosion on Construction Sites

AFTER CONSTRUCTION

After construction activities have been completed, the site should be permanently stabilized and landscaped. Practices that should be used include permanent seeding and planting, final retaining walls on cut or steep slopes that cannot be planted, porous paving to reduce erosion and stormwater runoff, and rain gardens (also known as bioretention) to help absorb stormwater onsite. All of these practices are presented below, and discussed in further detail in the ***2002 V.I. Environmental Protection Handbook***.

Permanent Seeding & Planting

Installation specifications for permanent seeding and planting are similar to those for temporary seeding. Establish permanent grass or other vegetation by seeding, sodding or planting immed-iately after seedbed preparation is completed. See Table 8 for information on lawn grasses appropriate for use in the Virgin Islands. Contact the UVI Cooperative Extension Service for information on native plants and other suitable vegetation. Apply grass seed uniformly by hand, seeder, or hydroseeder. If seeding on steep (>15%) slopes or during the rainy season, protect the grass seed, plants and soil with mulch or erosion control matting (see ***Mulches, Mats & Geotextiles*** page 18).

Sod

- Plant sod or plugs on 12" centers. Use sod strips on erodible slopes and other critical areas.
- Lay sod along the contour, starting at the bottom of the slope and working up.
- Place sod strips with snug, even joints and stagger the joints from strip to strip.
- 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.
- On steep slopes, secure sod to surface soil with wooden pegs or wire staples.
- Immediately following planting, water sod until moisture penetrates the soil layer beneath the sod. Maintain optimum moisture for at least 2 weeks. Watering to a 6" depth is more effective than frequent light watering.

Maintenance

- Repair small bare spots by re-seeding and/or mulching.
- Mow grass frequently to control weeds. Mowing height should be at least 2" above ground (height should be higher during the dry season and drought).
- New vegetation may need to be fertilized for the first 2 or 3 years after planting to maintain density and improve vigor. Fertilize according to soil test results.
- Use herbicides as directed by manufacturer and according to territorial and federal rules and regulations (contact DPNR-DEP or UVI Cooperative Extension Service for details).

Table 8. A tabular comparison of lawn grasses (*USDA-SCS, 1990b*).

Grass	Maintenance Frequency		Soil Type	Tolerance to:		Resistance to:		Establishment		Mower type	Mowing Height (in.)	Insect Problems	Disease Problems
	Mowing	Fertilizer (times/yr)		Shade	Salt	Drought	Wear	Method	Rate				
St. Augustine grass	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	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	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	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	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	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	weekly	1	wet, poorly drained, acid	good	poor	very poor	fair	seed or vegetative	medium	rotary	1¼ - 2	Armyworms Mole-crickets	Brown patch

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Porous Pavers

Porous pavers are concrete grids, high-strength plastic grids, or other materials placed on a pervious base such as gravel or sand. The grids or pavers are then filled with sand, gravel or soil. Grids filled with soil are typically seeded to attain a grassed or lawn surface. Porous paving is used in low-traffic areas (such as low-use parking lots, emergency areas, driveways, walkways). Concrete tire-tracks with grassed interiors can also be used for steeper driveways.

There are many different types of porous pavers commercially available. Installation specifications for a few brands are listed below **for illustrative purposes only**. 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 installation instructions (provided at their websites) for details.

Example Construction Criteria

Webbed Cellular Confinement:

1. Complete other earth change, excavation and/or fills. Make sure foundation soils meet minimum strength requirements (by rolling, compacting, etc.). Remove soils that are cannot support loads and replace with suitable materials.
2. Place geotextile between subgrade and fill materials and install drainage materials, if needed.
3. Expand web sections to proper dimension and position (Figure 31). Anchor web sections into position using j-bars, a stretcher frame, or straight stakes along the sides and ends of the section. (J-bars are made from construction rebar, ¾" or ½" diameter, 18" long). Make sure each section is fully expanded.
4. Correctly align and interleaf edges of adjoining web sections and ensure that the upper surfaces of adjoining sections are flush. Join web sections with industrial staples.
5. Filled expanded web cells with soil,

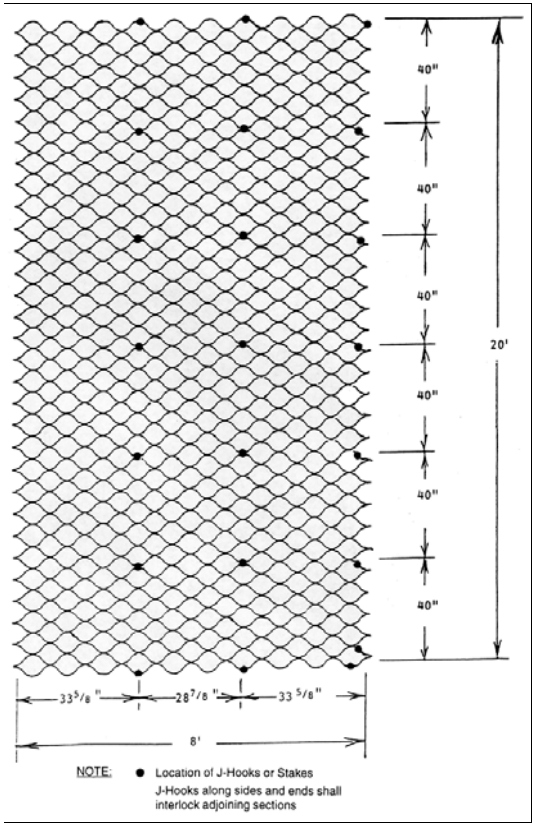

Figure 31. EnviroGrid® light density staking diagram (AGH Industries, Inc., 1999).

sand, crushed stone or gravel with a backhoe, front-end loader, or by hand. Overfill web sections to at least 2" above cell walls. Compact fill.

GeoBlock® :

1. Prepare the subgrade by excavating the area. If working with poor permeability soils (clay soils) in an area that collects 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 allows blocks to interlock properly and remain stationary after installation.
2. Install a recommended "engineered base" of coarse sand, washed stone or crushed rock mixed with topsoil to promote grass growth and provide required structural support (Figure 32). The aggregate portion of the base should be free from fines.
3. Install blocks with round hole to the ground. For best performance, stagger blocks so that the long direction of the block is perpendicular to the direction of traffic (Figure 33). The final seam pattern should have straight seams perpendicular to traffic flow and staggered seams parallel to traffic flow.
4. Place blocks against a stationary edge, if available. Slide blocks together so that they interlock tightly.
5. Anchor blocks in place to prevent them from shifting during installation. Blocks can be anchored with wood, metal stakes or j-bars.
6. Fill blocks with a suitable topsoil, sand, gravel, or crushed rock immediately after 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***, page 16, or ***Permanent Seeding and Planting***, page 34). Grass should be maintained by mowing and re-seeding of bare patches.

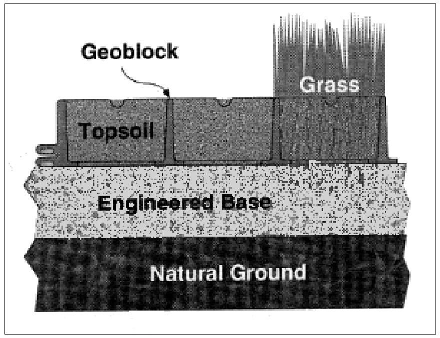

Figure 32. Geoblock® porous pavement system (*Presto Products Company, 1997*).

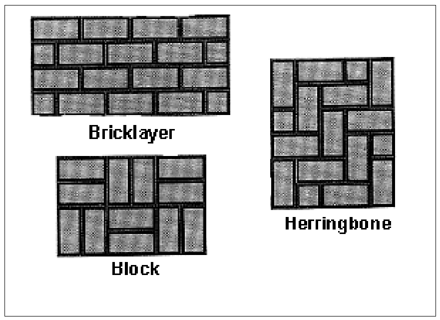

Figure 33. Geoblock® installation - laying patterns *(Presto Products Company, 1997*).

Rain Gardens

Rain gardens (also known as "bioretention systems") are used in roadway median strips, parking lot islands, and other small (less than 5 acres) drainage areas to absorb excess stormwater and filter sediment. They work best on shallow (~5%) slopes, but properly designed can be used on slopes up to 20%. Rain gardens require good planting soils ranging from 10 to 25% clay along with sandy loam, loamy sand or loam texture (CH2M Hill, 1998). In areas with high clay content (the soils do not infiltrate will), the practice can be modified by installing a collector pipe system beneath the garden to form a bioretention filter.

Check dams can be used to reduce stormwater runoff speeds within grass swales, forming "on-line" rain gardens or bioretention areas that promote sedimentation behind the dam (Figure 34). Use properly anchored gabions, rock filter berms or large logs as check dams on moderate slopes. **DO NOT USE SILT FENCES AS CHECK DAMS**, because concentrated flows quickly wash out these materials (CH2M Hill, 1998).

On-Line Rain Gardens – a rain garden in a swale upstream from a check dam is built with the following specifications:

C Planting soil depth is 1' - 2' for small drainage areas (less than 2 acres, CH2M Hill, 1998).
C Rock check dams should be built of 8"-12" rock, placed by hand or mechanically. The dam must completely span the swale or channel to prevent it from being washed out.
C Build log check dams with 4"-6" diameter logs and embed logs at least 18" into the soil.

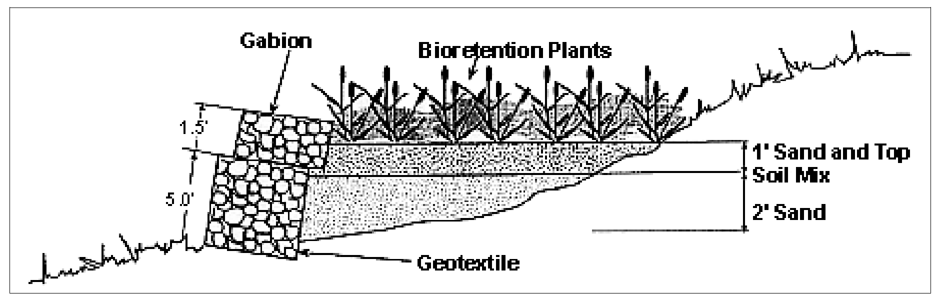

Figure 34. Cross section of an on-line rain garden formed by damming a grass swale with a mild to moderate slope with gabion baskets *(CH2M Hill, 1998*).

Off-Line Rain Gardens – these systems are more complex, having 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 (Figure 35). The grass filter strip (or energy dissipation area) removes 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).

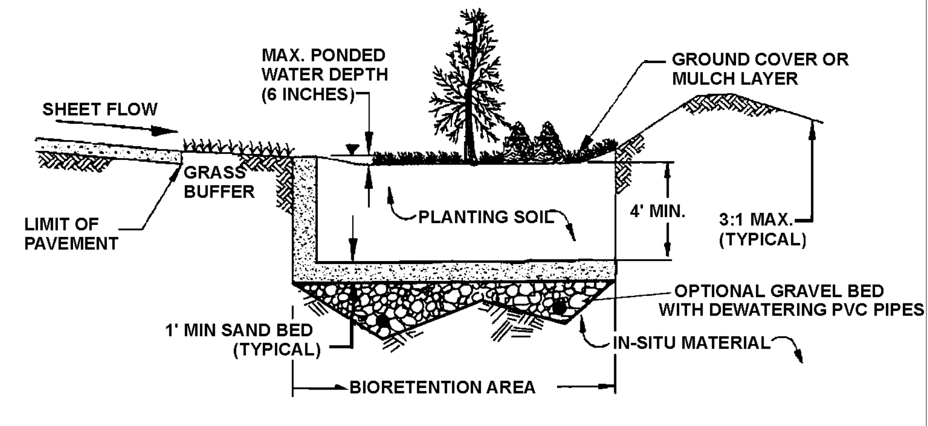

Figure 35. Off-line rain garden cross-section (CH2M Hill, 1998).

The ponding area stores runoff waiting for treatment and also functions as a presettling basin for sediment not removed by the grass filter strip. The mulch layer filters pollutants, minimizes erosion, and provides a habitat for microorganisms to break down oil, grease and other pollutants. The soil layer supports the plants and clays in the soil adsorb heavy metals, nutrients, hydrocarbons and other pollutants. Plant at least three different species each of shrubs and trees. Site conditions (slope, volume and velocity of runoff, climate) will determine the size of the garden, however, average recommendations are:

- Minimum width of 10'-15'.
- Minimum length of 30'-40'
- Maximum ponded area depth should be 6". If collector pipes are used, maximum ponded depth can increase to 12".
- Minimum planting soil depth of 3'-4'.

Maintenance

Inspect rain gardens monthly until plants are established. Then inspect annually. Remove sediment from behind check dams when accumulations reach one-half the dam depth.

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