# 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

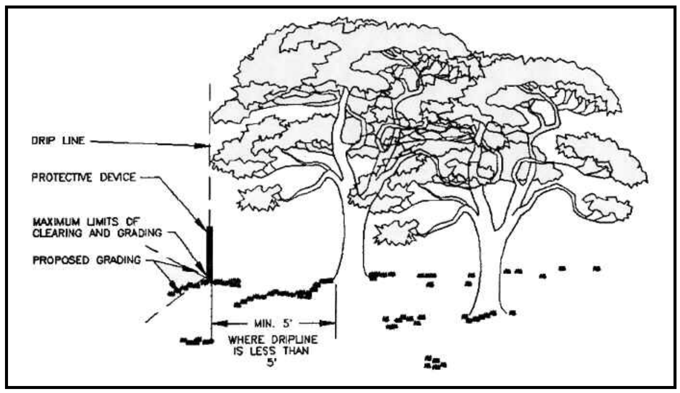



**Figure B.1.** Construction operations relative to the location of protected trees (*CH2M Hill, 1998, adapted from Virginia*).

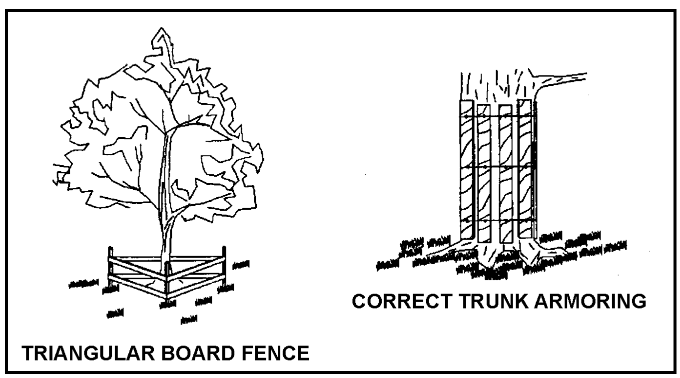



**Figure B.2.** Tree fencing and armoring (*CH2M Hill, 1998, adapted from Virginia*).

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.

# 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.

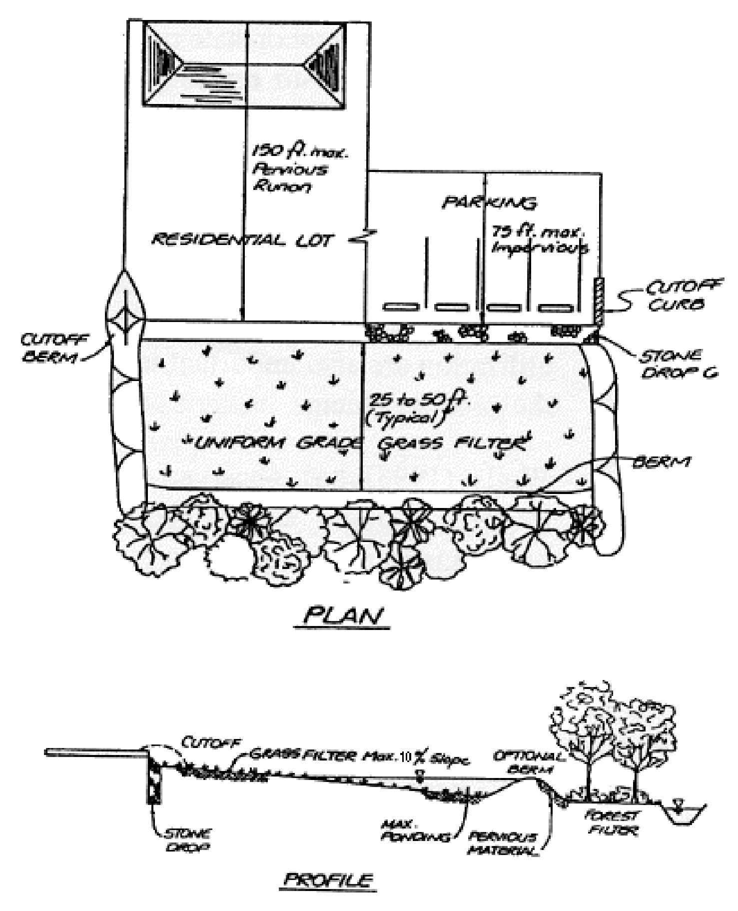



**Figure B.3.** Up to 75 feet of parking lot can be treated in a filter strip. A key design principle is to allow a drop from the parking lot to the grass filter to avoid sediment buildup at the edge (*Schueler, 1995*).

## 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

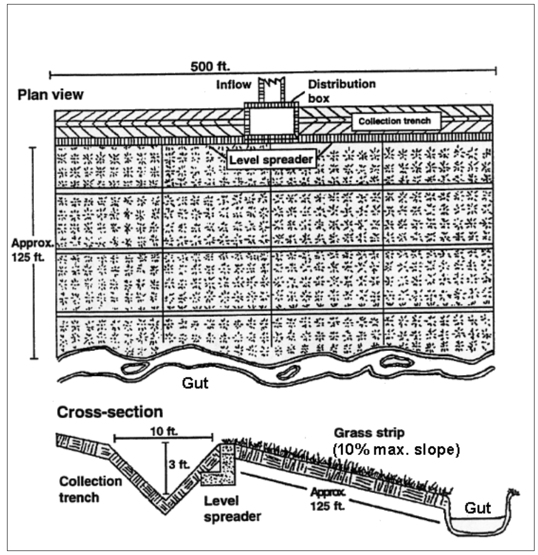



**Figure B.4.** Schematic design of a vegetated filter strip (*Delaware DNREC, 1997*).

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***).

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

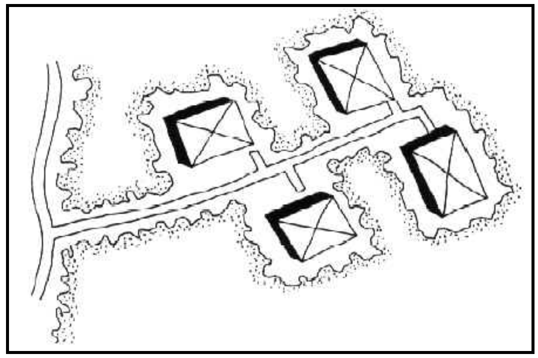


Figure B.5. Example of site fingerprinting - clearing only the area needed for construction (*CWP, 2001e*).

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).

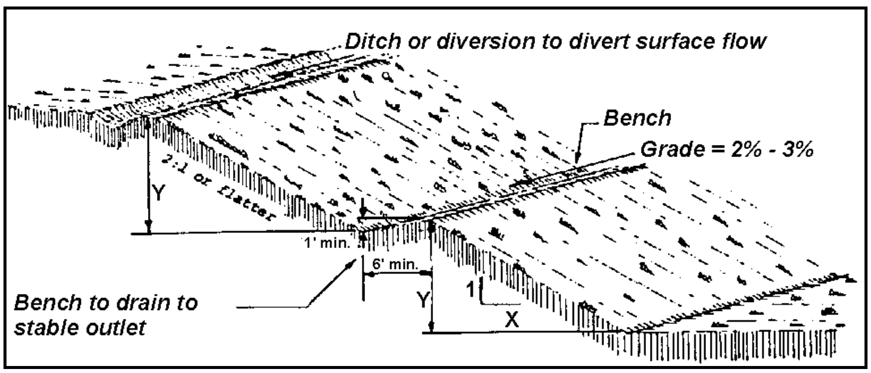



Figure B.6. Land grading — benched slope details *(Maryland Department of the Environment, 1994)*.

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.

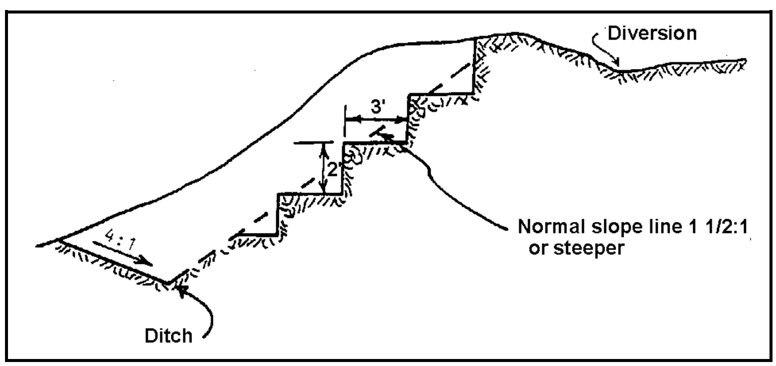



Figure B.7. Typical section of a serrated cut slope (*Empire State Chapter Soil & Water Conservation Society, 1991*).

## 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.

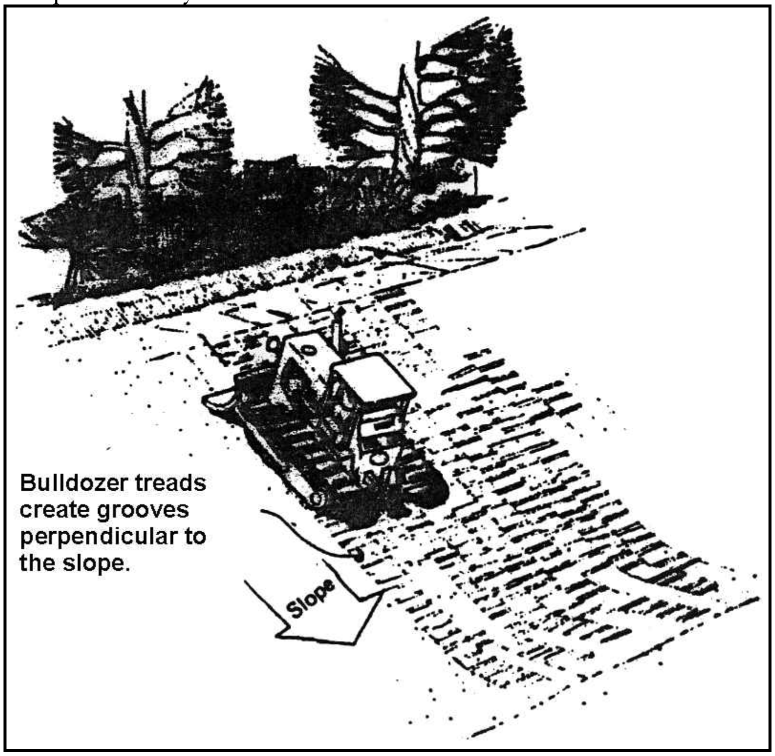



**Figure B.8.** Bulldozer treads create grooves perpendicular to the slope.

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.

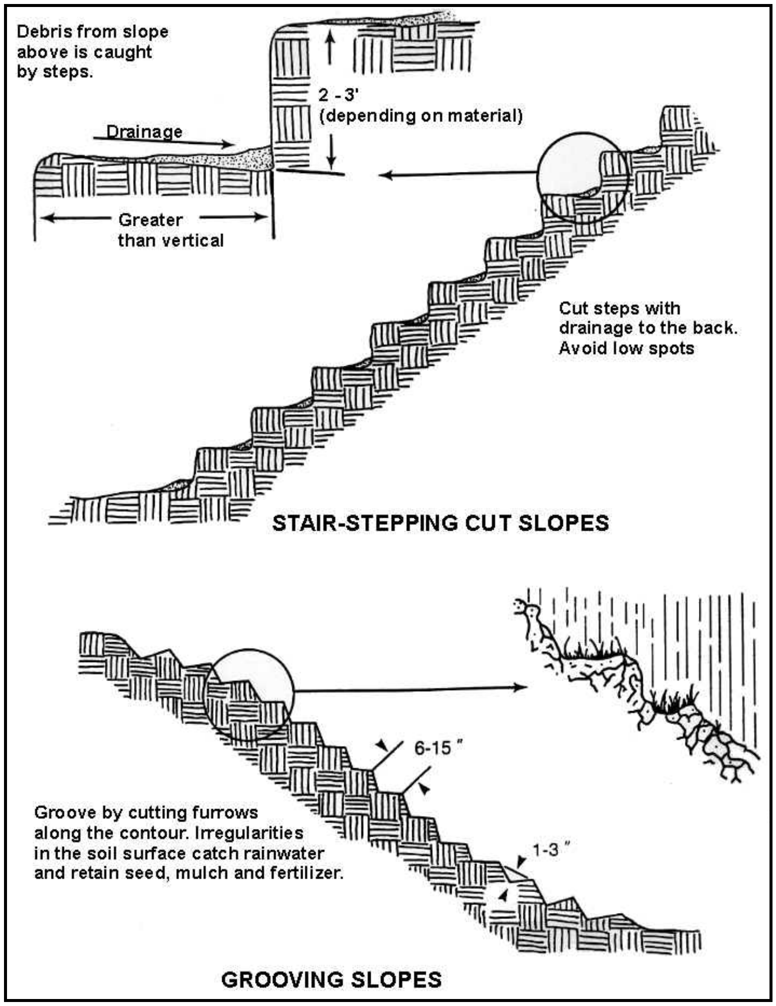



**Figure B.9.** Surface roughening details *(Empire State Chapter Soil & Water Conservation Society, 1991)*.

## 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<br>Armyworms<br>Mole-crickets | Brown patch<br>Grey leafspot |
| Centipede grass | medium | bimonthly | 1 | acid | fair | poor | good | poor | vegetative | medium | reel or rotary | 1¼ - 2 | Ground pearls<br>Armyworms<br>Spittle bugs<br>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<br>Billbugs<br>Mole-crickets | Brown patch<br>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<br>Scale insects<br>Mole-crickets | Dollar spot<br>Brown patch<br>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<br>Scale insects<br>Mole-crickets | Dollar spot<br>Brown patch<br>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<br>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<br>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

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.

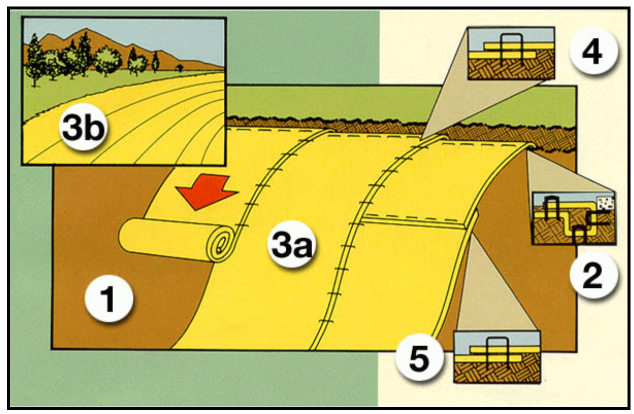


**Figure B.10.** Erosion control mat slope installation example (*North American Green, 2002*).

### *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.

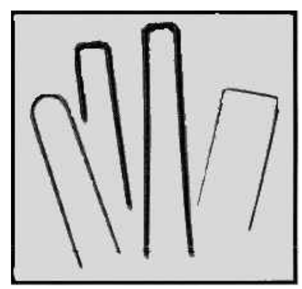


**Figure B.11.** Different types of staples used to anchor erosion control mats.

Note: 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)

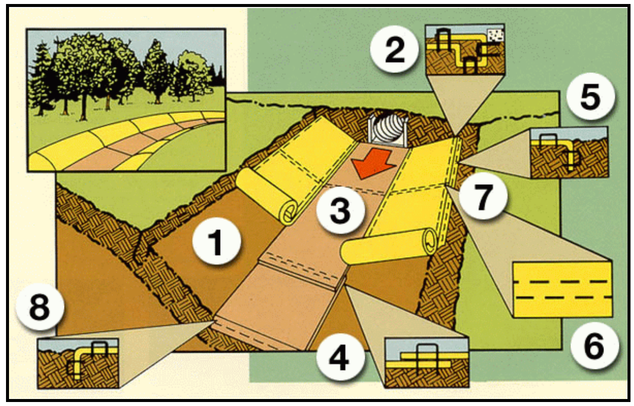



**Figure B.12.** Example erosion control mat installation in a channel or drainage swale (*North American Green, 2002*).

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.

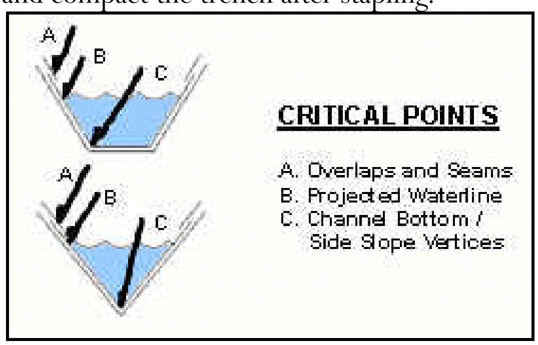



**Figure B.13.** Critical stress points for erosion control mat applications in channels *(North American Green, 2002*).

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)

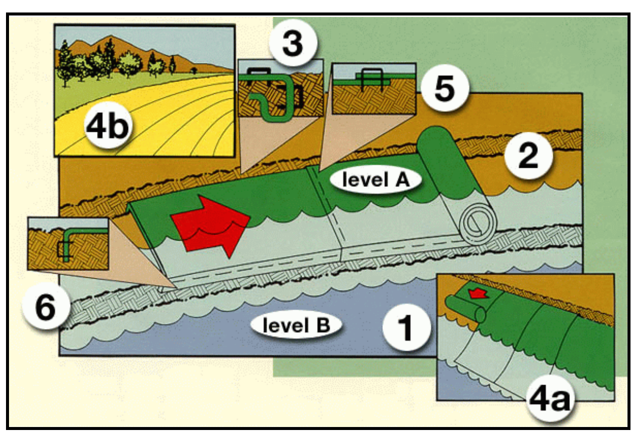



**Figure B.14.** Example erosion control mat installation for shorelines (*North American Green, 2002*).

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).

<u>Note:</u> 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.

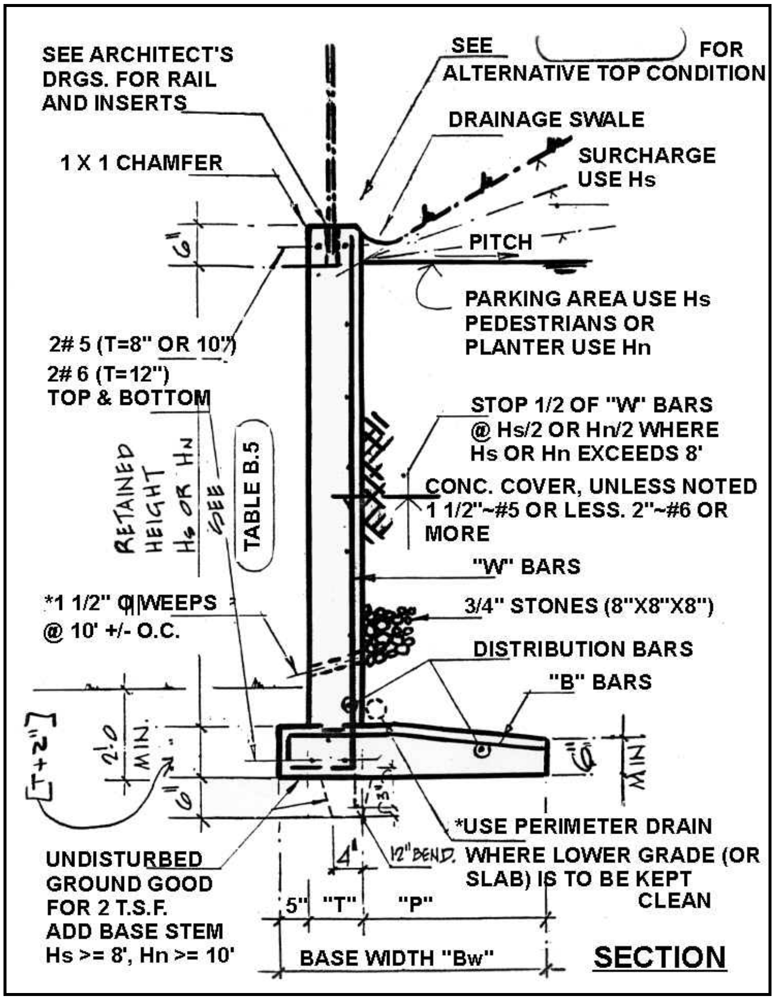



**Figure B.15.** Concrete cantilever retaining wall, toe in. Height = 4 to 14 feet (*Bernier, 1995*).

**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.

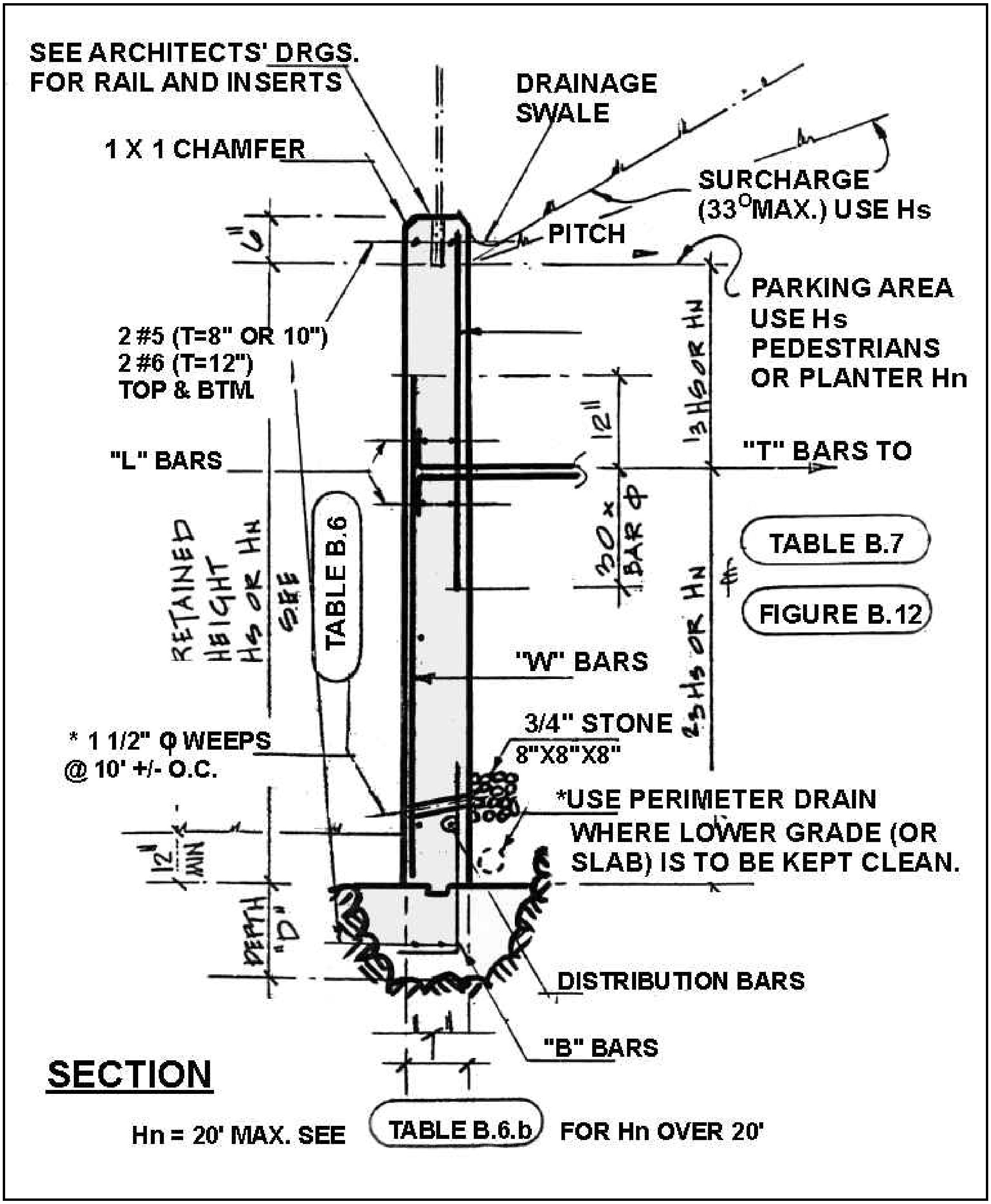



**Figure B.16.** Concrete retaining wall with tie-back to anchor. H = 0 to 16 feet (*Bernier, 1995*).

**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.

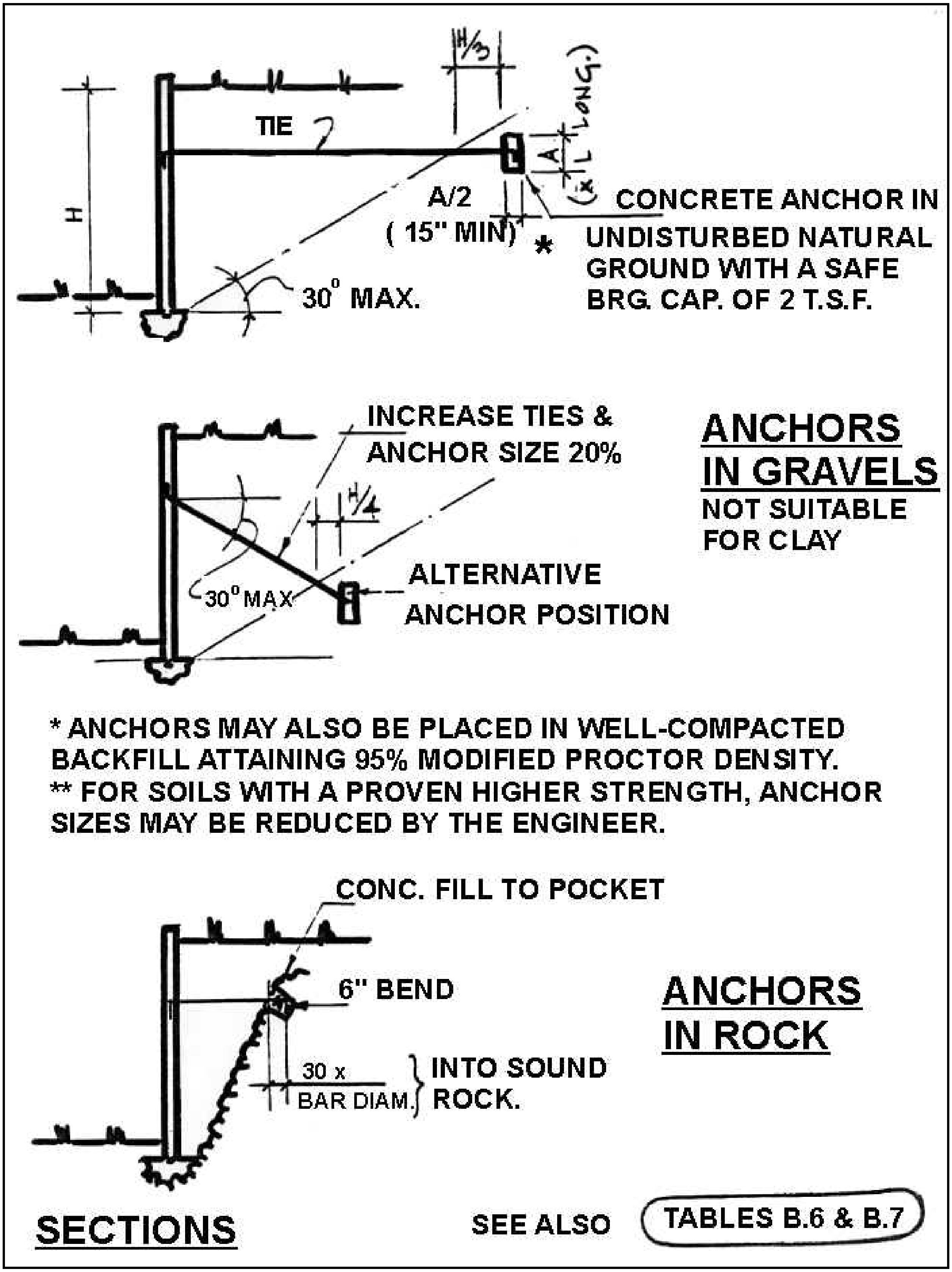



**Figure B.17.** Concrete retaining wall with tie-back to anchor, H = 0 to 32 feet (*Bernier, 1995*).

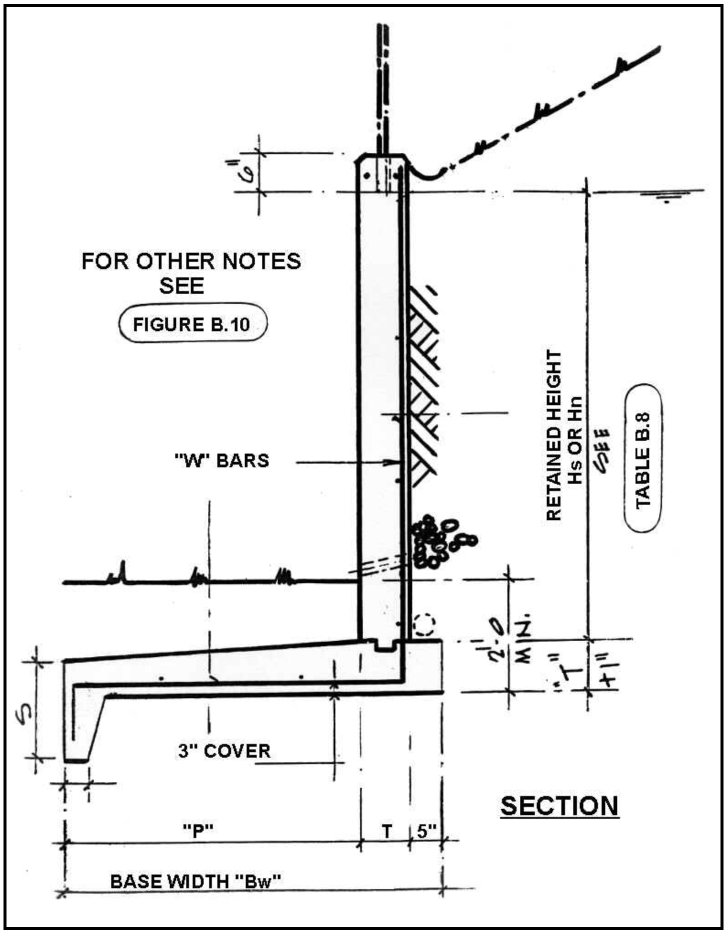



**Figure B.18.** Concrete cantilever retaining wall, toe out, H = 4' to 14 feet (*Bernier, 1995*).

**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).

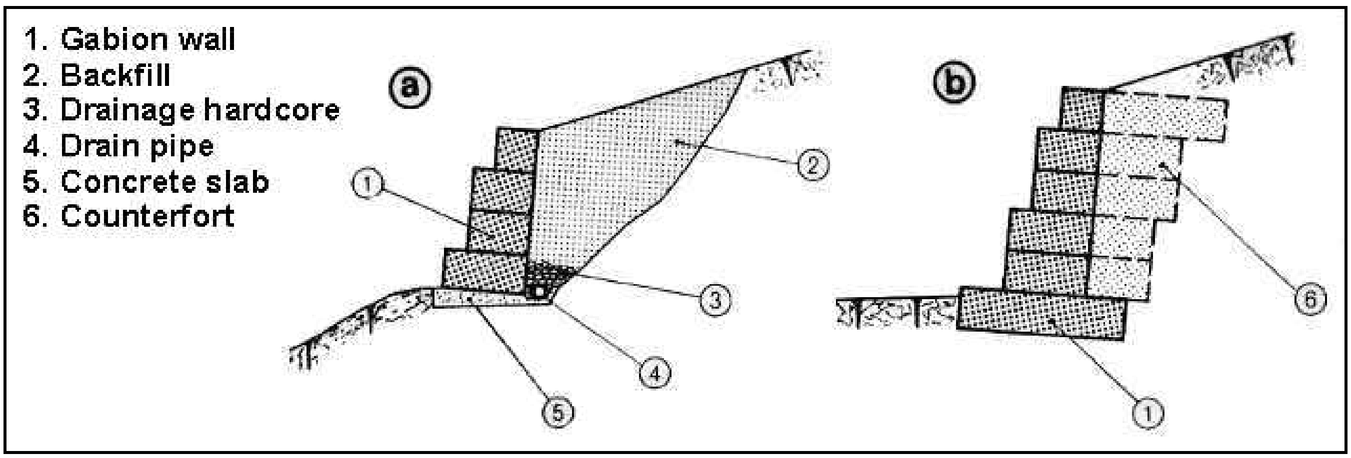



**Figure B.19.** Two possible methods of draining a gabion box wall (*Maccaferri Gabions, Inc., 1994*).

# 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 $\gamma_s$ the soil unit weight)

$$s' = x_g \cos\alpha + y_g \sin\alpha$$

($x_g$ e $y_g$ 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 $\sigma_{am}$ is in lb/in$^2$ and $\gamma_g$ in lb/ft$^3$)

The average shear stress is:

$$\tau = T/B$$

and it must not exceed

$$\tau_{am} = N\tan\varphi^*/B + c_g$$

where $\varphi^* = 0.398\,\gamma_g - 9.80°$ ($\gamma_g$ in lb/ft$^3$) and $c_g$, the coefficient of cohesion, is

$c_g = 6.837\,P_u - 0.717$ where $c_g$ is in lb/in$^2$ and $P_u$ (weight of the steel mesh per cubic yard of gabion) is in lb/ft$^3$

The value of $c_g$ is normally from 2 to 6 lb/in$^2$.

## 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.

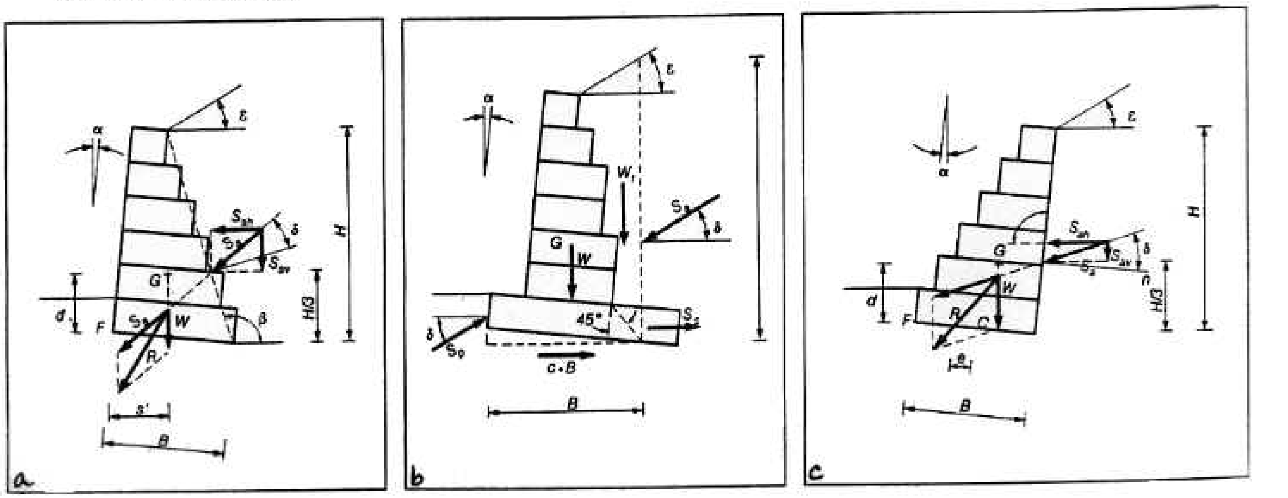



**Figure B.20.** Forces to be considered when checking a gabion structure (*Maccaferri Gabions, Inc., 1994*).

# 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.

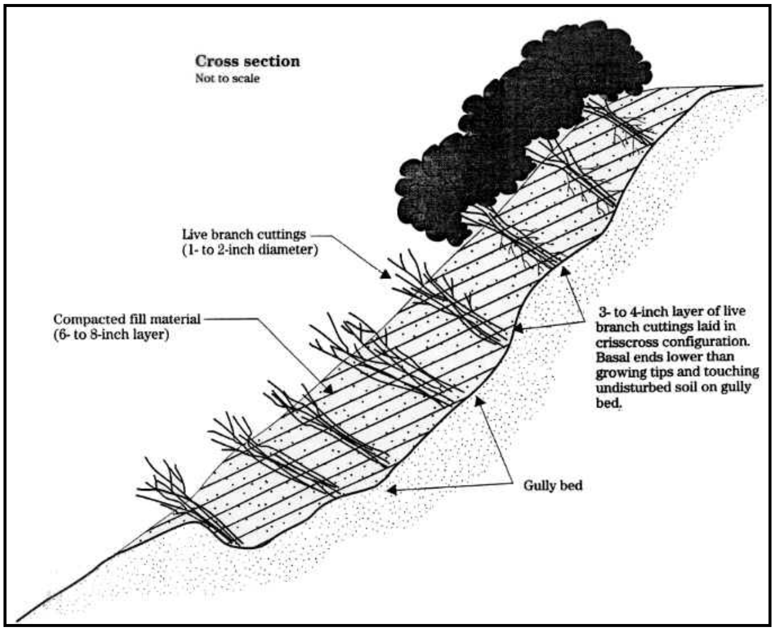



**Figure B.21.** Live gully repair details; Note: rooted/leafed condition of the living plant material is not representative of the time of installation *(USDA-SCS, 1992*).

## 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

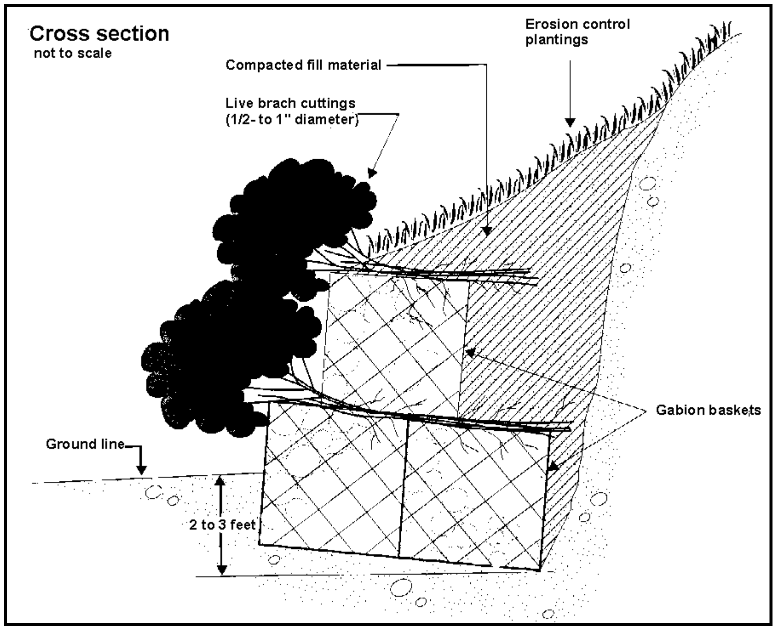



**Figure B.22.** Vegetated rock gabion details (Note: rooted/leafed condition of the living plant material is not representative of the time of installation; *USDA-SCS, 1992*).

### 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.

### 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.

### *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.

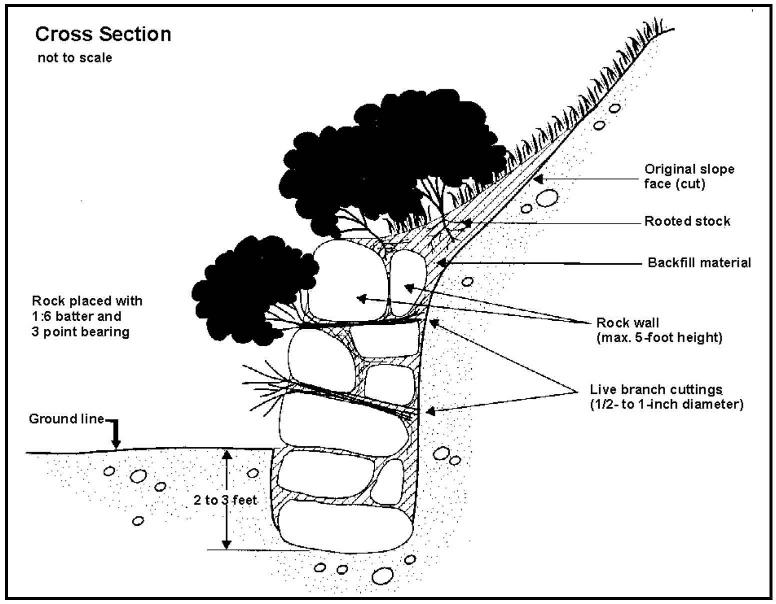



**Figure B.23.** Vegetated rock wall details (*USDA-SCS, 1992*).

## 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:

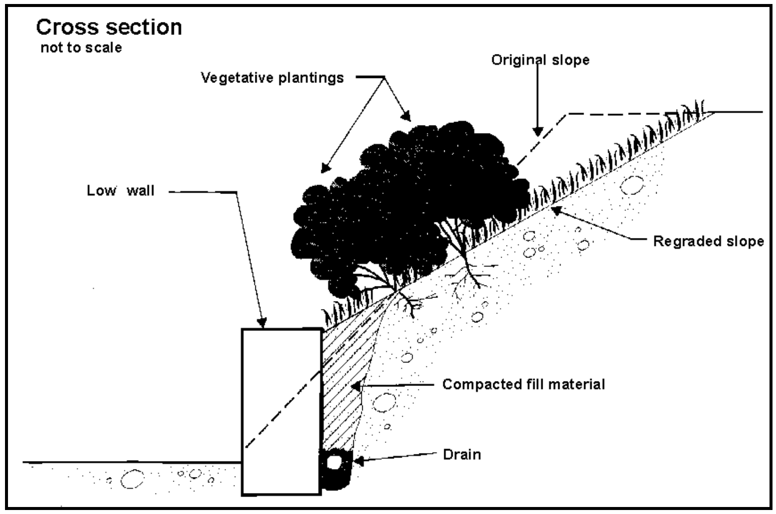



**Figure B.24.** A low wall with plantings above (*USDA-SCS, 1992*).

- 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

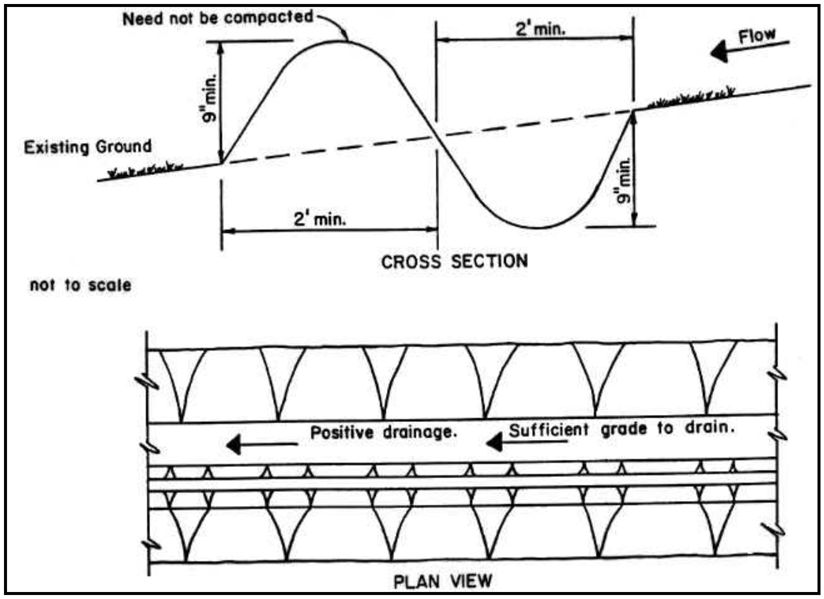



**Figure B.25.** Perimeter dike/swale details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

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<br>20% maximum | 0.5% minimum<br>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.

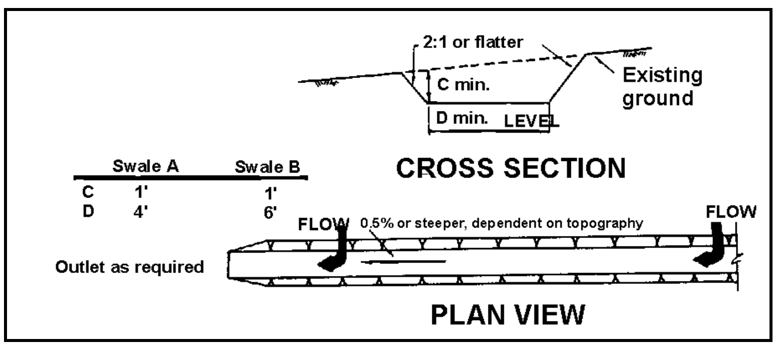



**Figure B.26.** Temporary drainage swale details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

## 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.

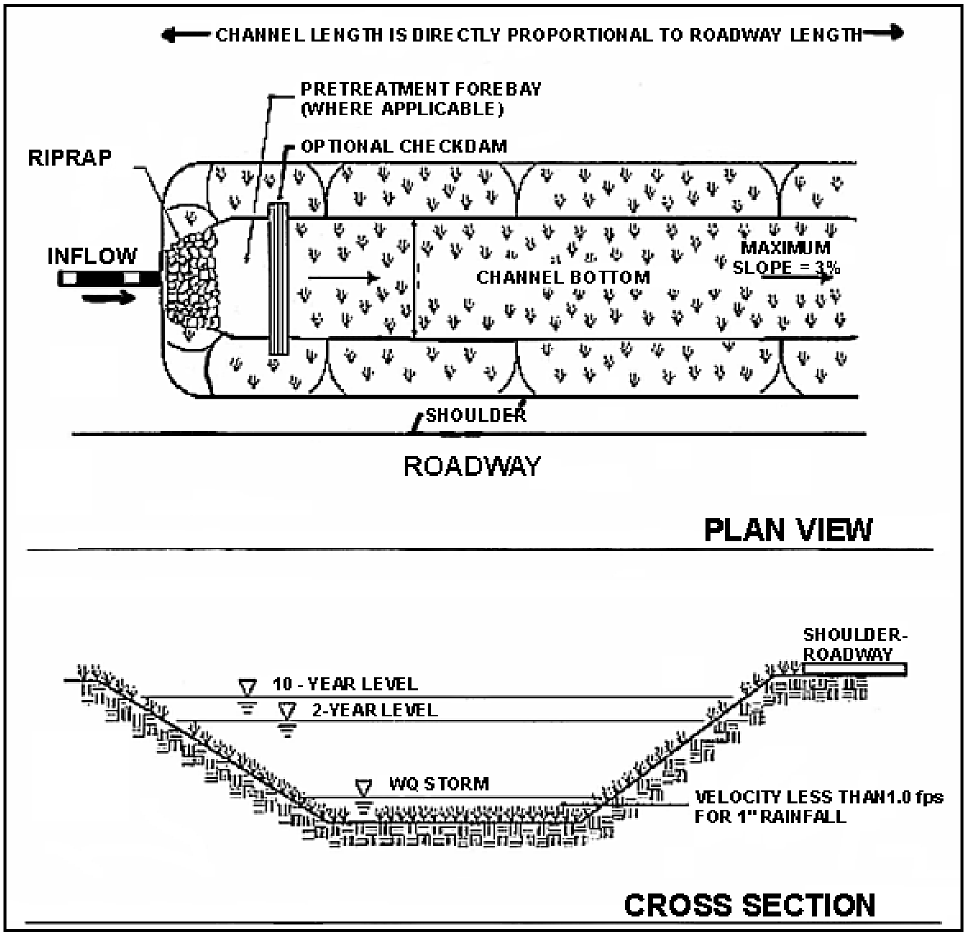



**Figure B.27.** Grassed drainage swale details (*Schueler, 1995*).

# 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

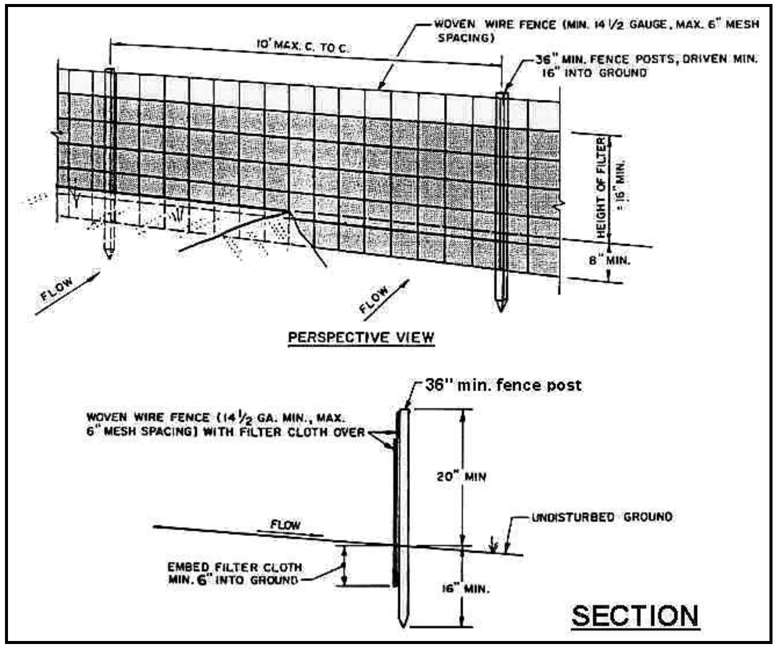



**Figure B.28.** Silt fence details (perspective and section views; *Empire State Chapter Soil & Water Conservation Society, 1997*).

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).

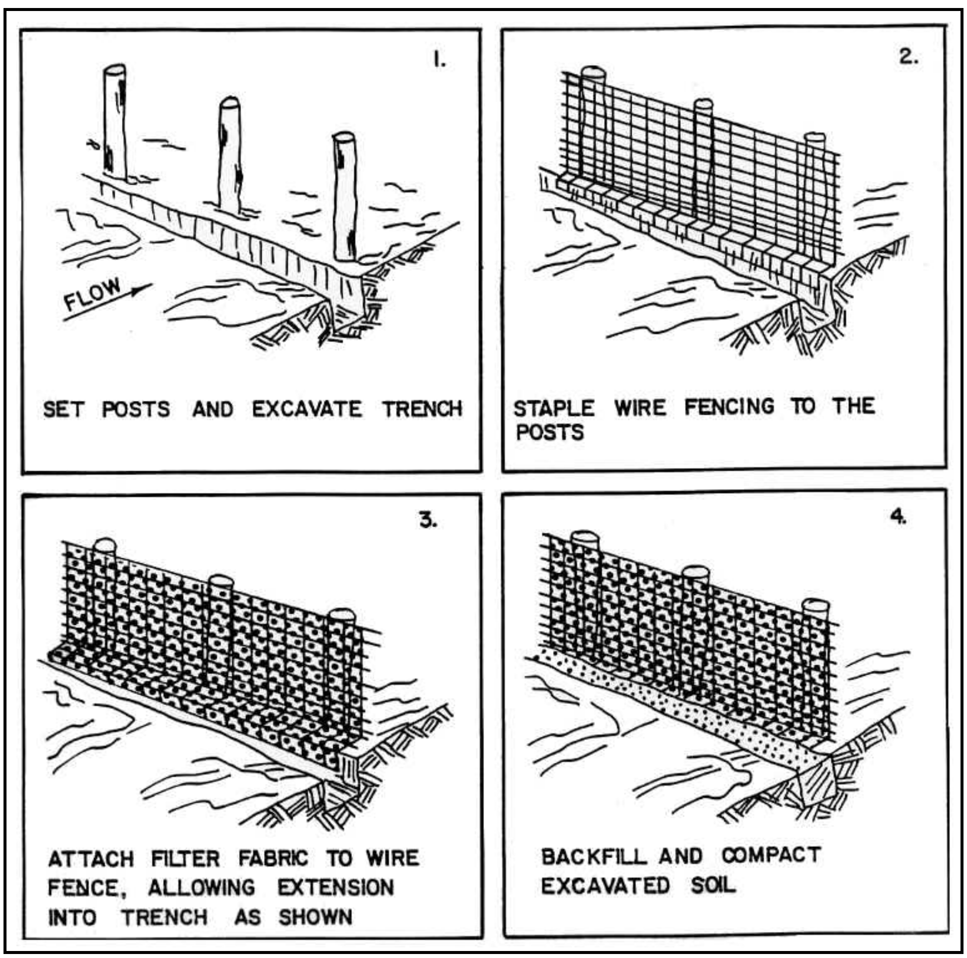



**Figure B.29.** A step-by-step procedure for building a silt fence (*USDA-SCS, 1993b*).

# Stabilized Construction Entrance

## Design Criteria and Construction Specifications

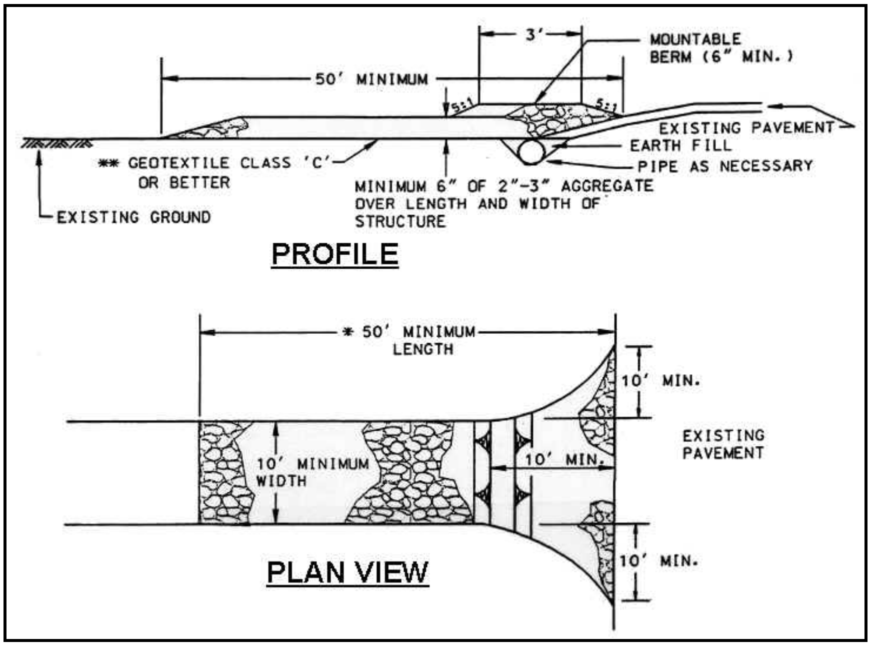



**Figure B.30.** Stabilized construction entrance details *(Maryland Department of the Environment, 1994)*.

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:

$$x = \frac{y}{S} \qquad \text{[EQ. B-1]}$$

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.

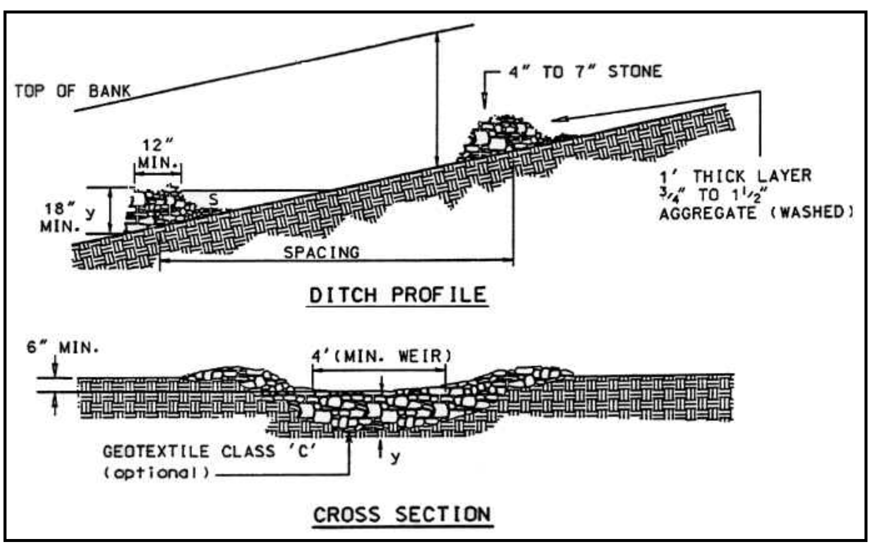



**Figure B.31.** Check dam details (*Maryland Department of the Environment, 1994*).

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.

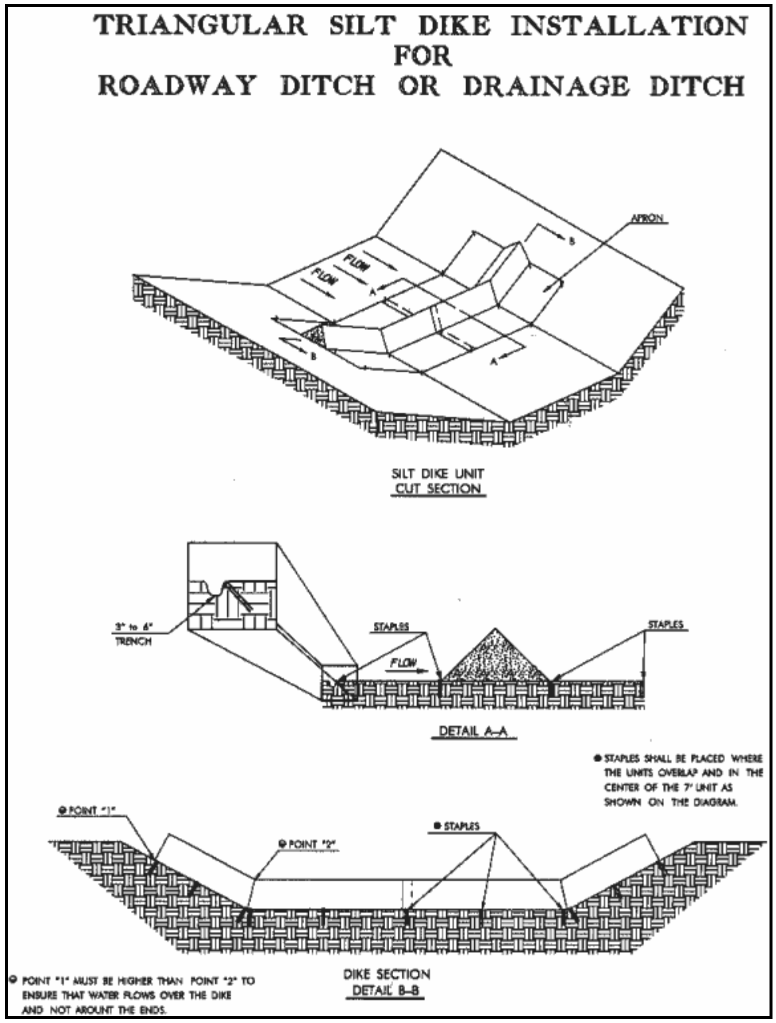



**Figure B.32.** Specifications for a triangular silt dike™ used as a check dam (*Triangular Silt Dike™, 2001*).

# 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.

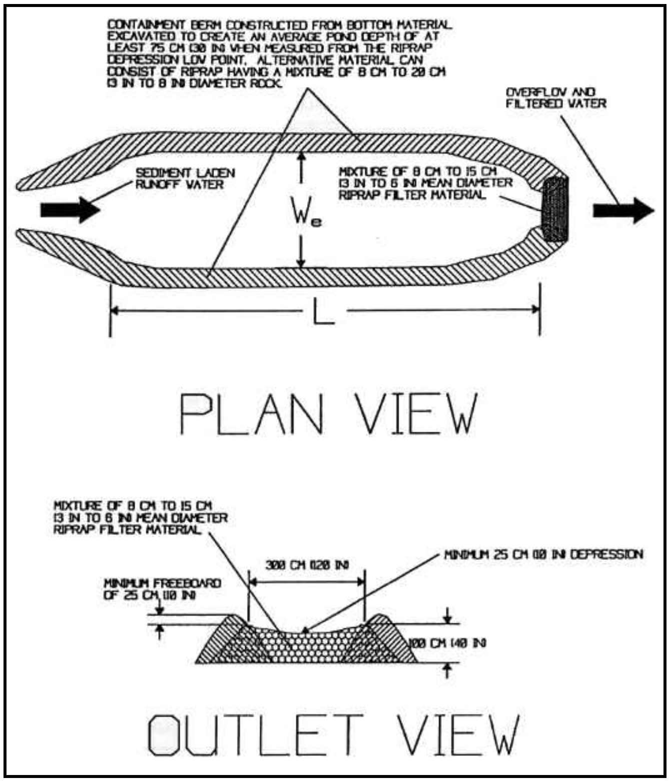


Figure B.33. Single chamber sediment trap (*Fifield, 1996*).

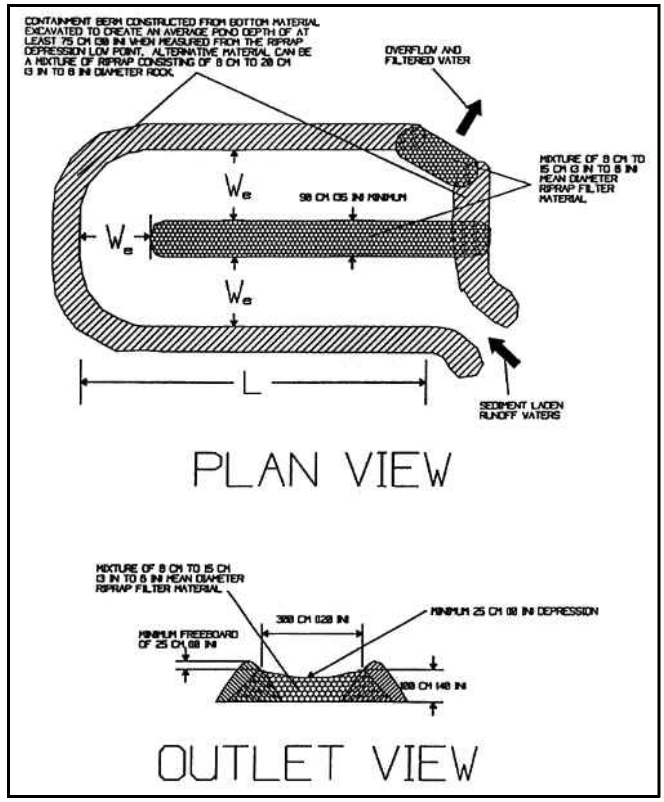


Figure B.34. Double chamber sediment trap (*Fifield, 1996*).

### *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.

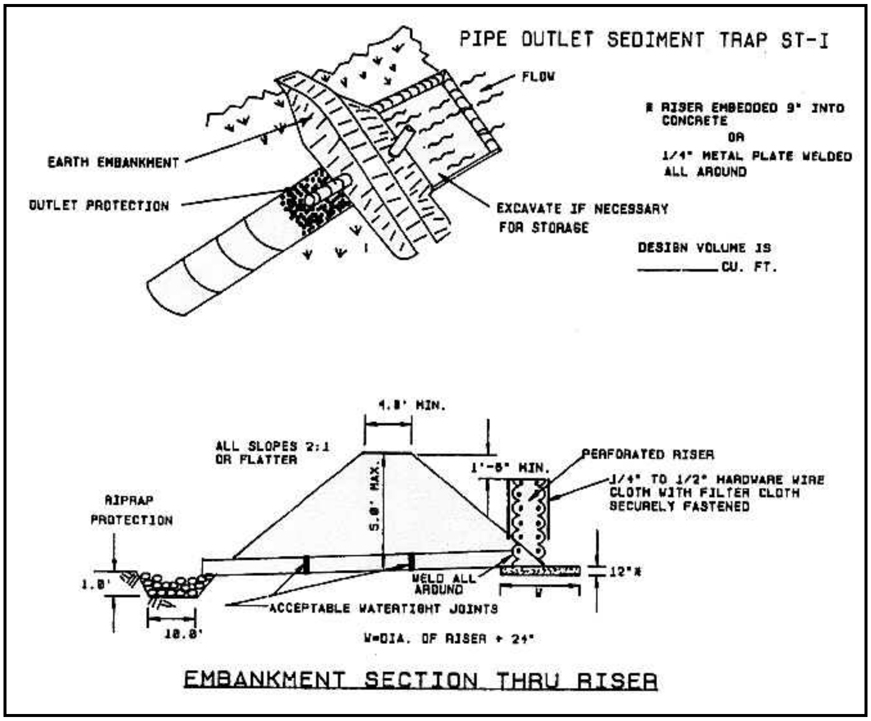



**Figure B.35.** Pipe outlet sediment trap details (construction specification should be attached to this detail to complete design; *Empire State Chapter Soil & Water Conservation Society, 1997*).

**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.
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.

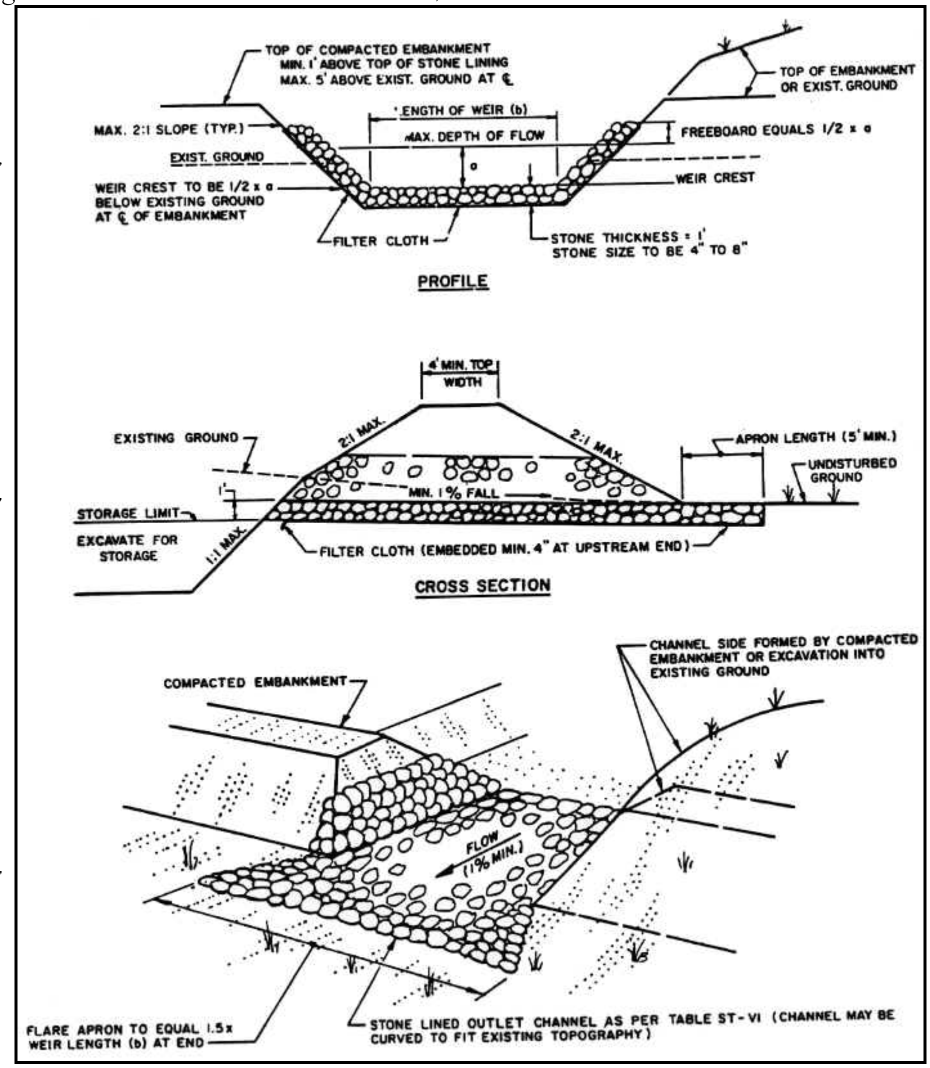



**Figure B.36.** Rip-rap outlet sediment trap details *(Empire State Chapter Soil & Water Conservation Society, 1997*).

**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.

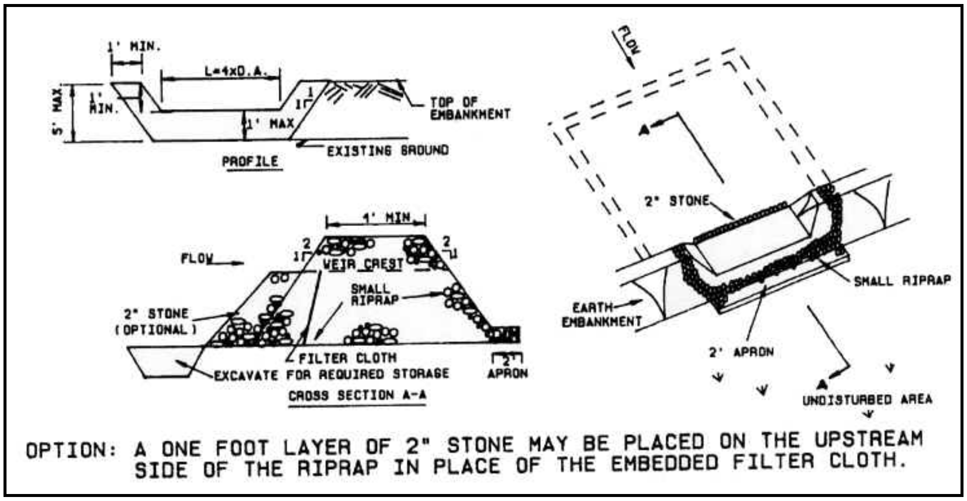



**Figure B.37.** Stone outlet sediment trap details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

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

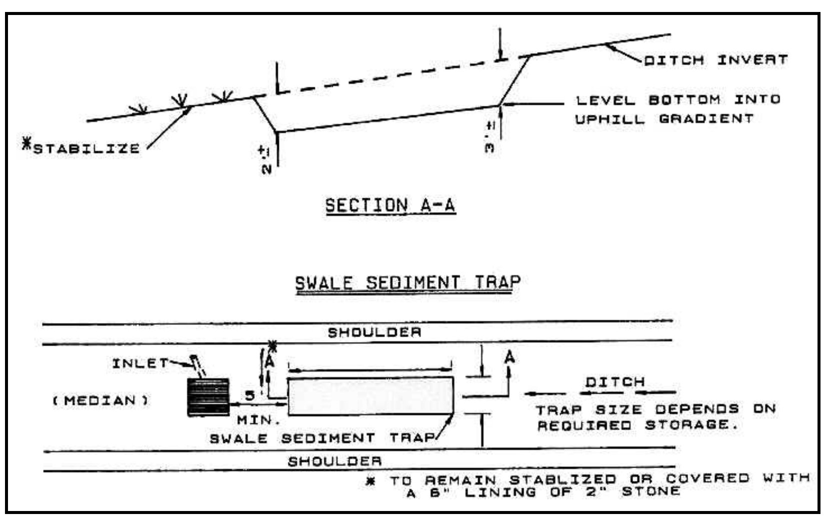



**Figure B.38.** Swale outlet sediment trap details *(Empire State Chapter Soil & Water Conservation Society, 1991*).

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).

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.

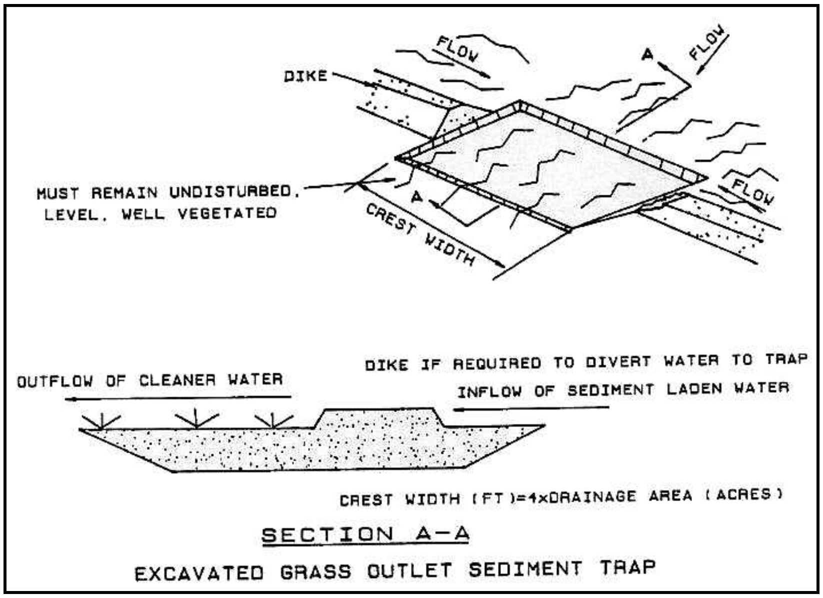



**Figure B.39.** Grass outlet sediment trap details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

### 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

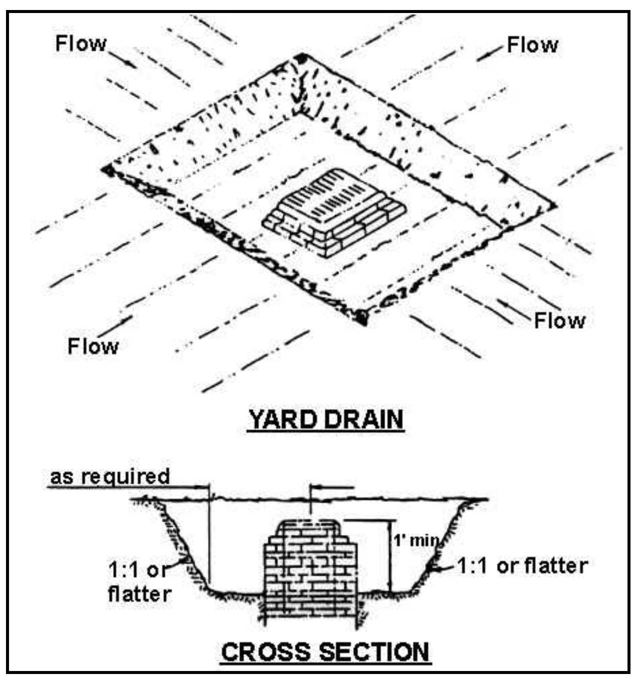



**Figure B.40.** Storm inlet sediment trap details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

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

**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.

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.

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).

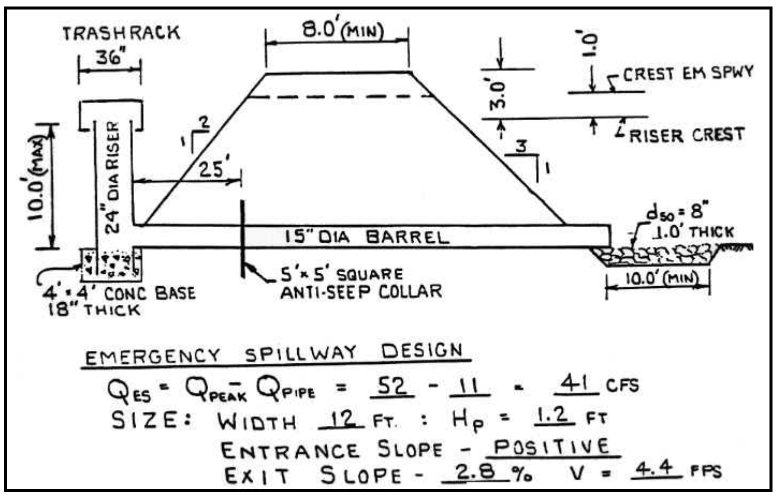



**Figure B.41.** Standard sediment basin I details (*Empire State Chapter Soil & Water Conservation Society, 1991*).

### *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 $ft^3$/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 $ft^3$/acre of drainage area.

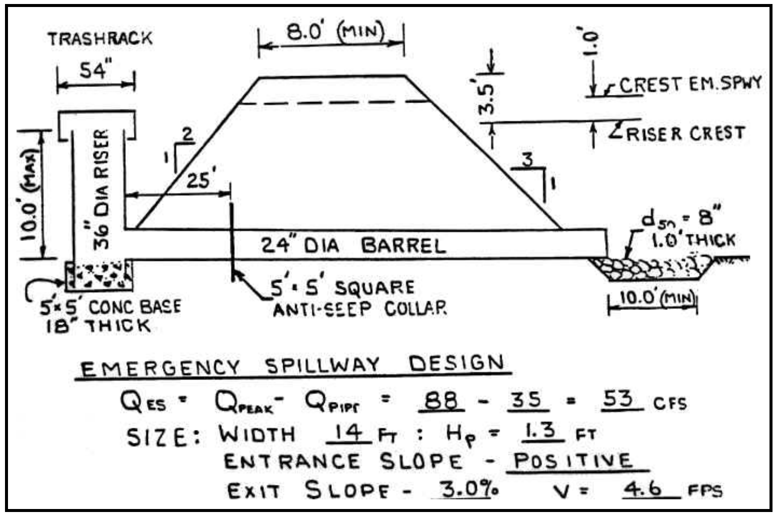



**Figure B.42.** Standard sediment basin II details (*Empire State Chapter Soil & Water Conservation Society, 1991*).

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. Crest elevation: 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.**

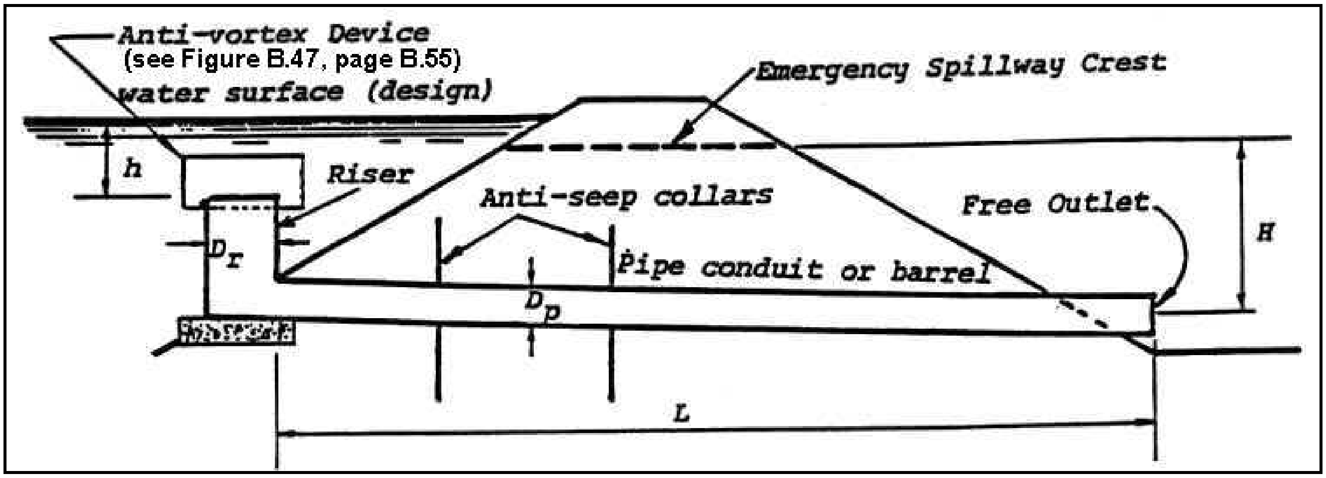



**Figure B.43.** Pipe spillway design (*Empire State Chapter Soil & Water Conservation Society, 1991*).

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)

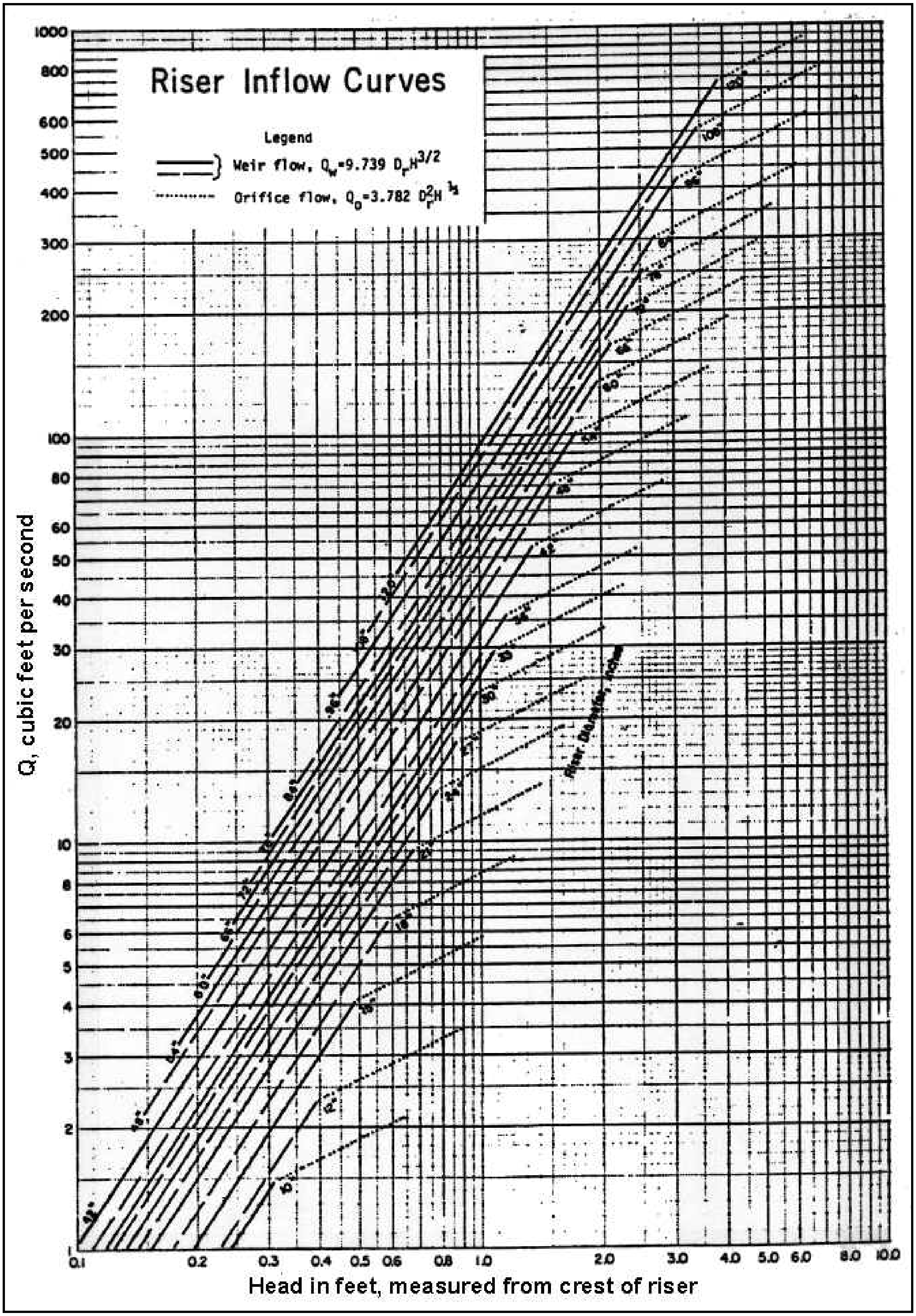



**Figure B.43.** Riser inflow chart (*Empire State Chapter Soil & Water Conservation Society, 1997*).

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 | 7.60 | 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 |

Correction Factors For Other Pipe Lengths

| L, in feet | 6" | 8" | 10" | 12" | 15" | 18" | 21" | 24" | 30" | 36" | 42" | 48" | 54" | 60" | 66" | 72" | 78" | 84" | 90" | 96" | 102" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 542 | 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*).

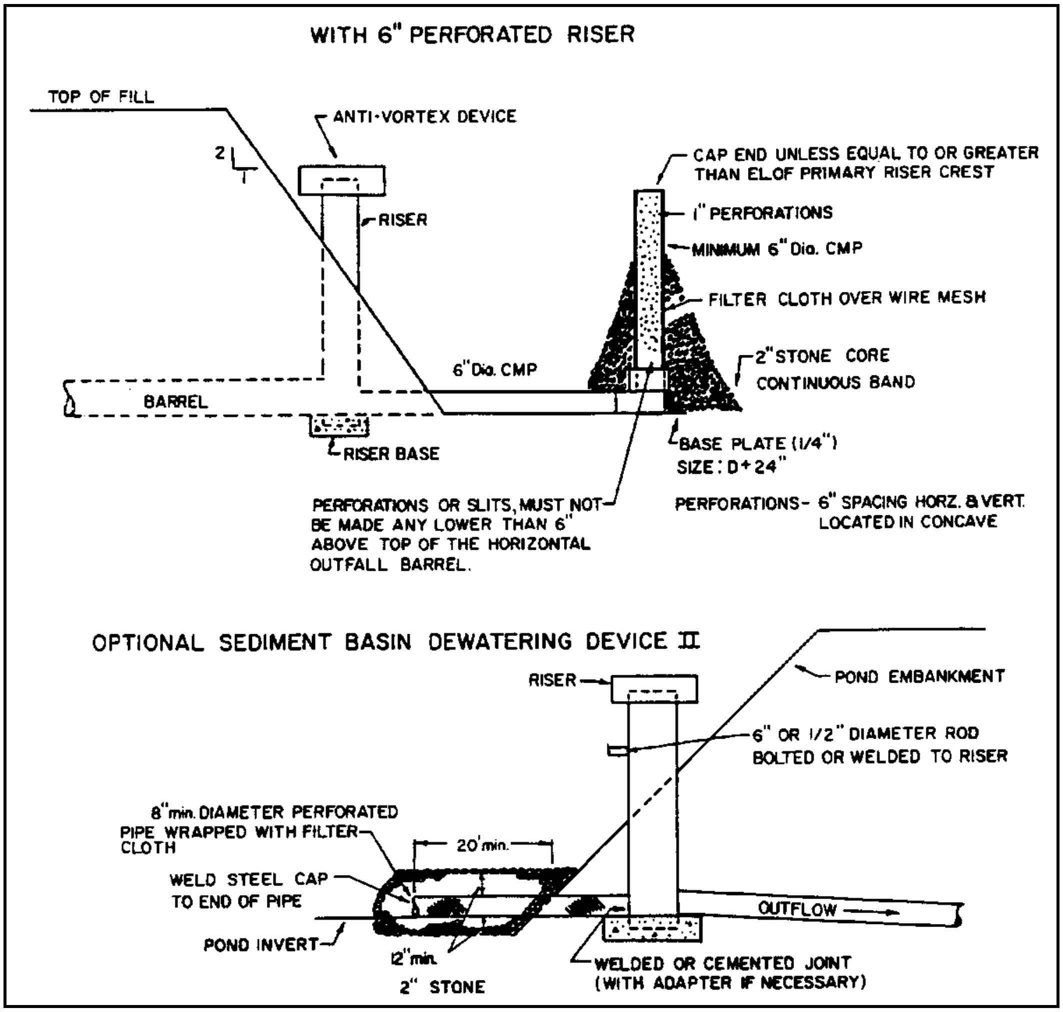



**Figure B.46.** Optional sediment basin de-watering methods (*Empire State Chapter Soil & Water Conservation Society, 1991*).

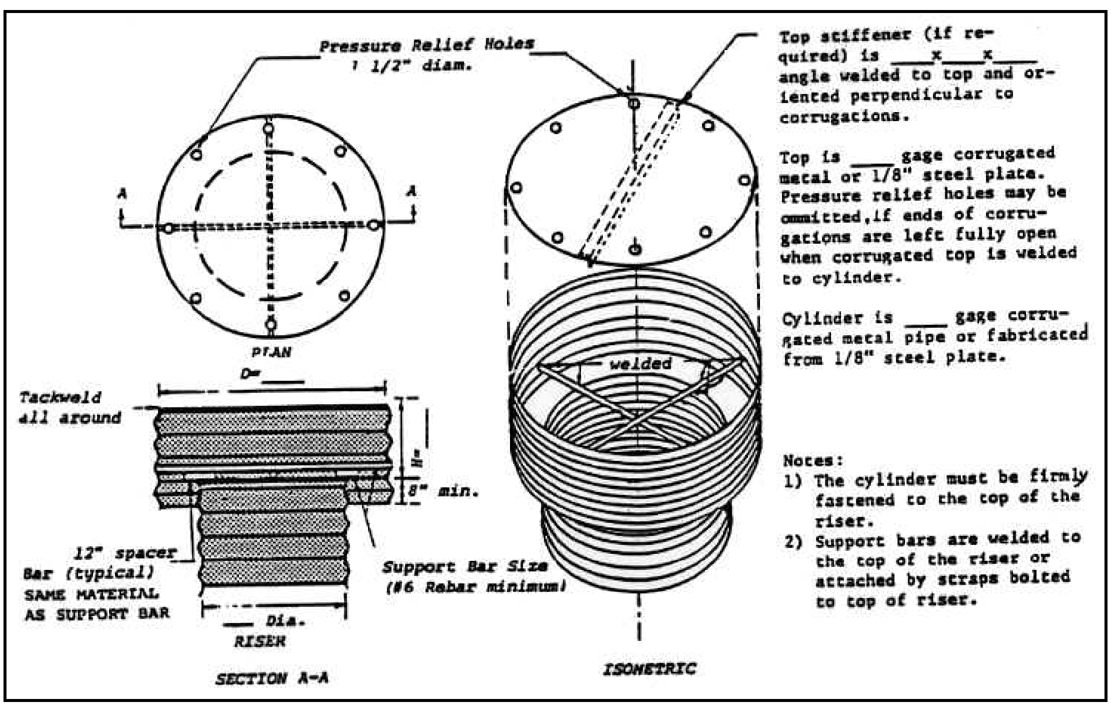
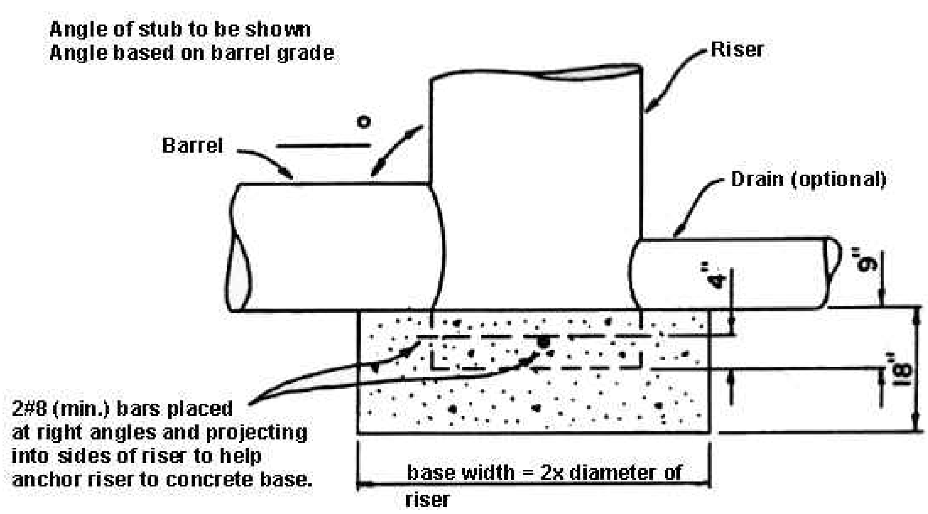



**Figure B.47.** Concentric trash rack and anti-vortex device *(Empire State Chapter Soil & Water Conservation Society, 1997*).

**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*).

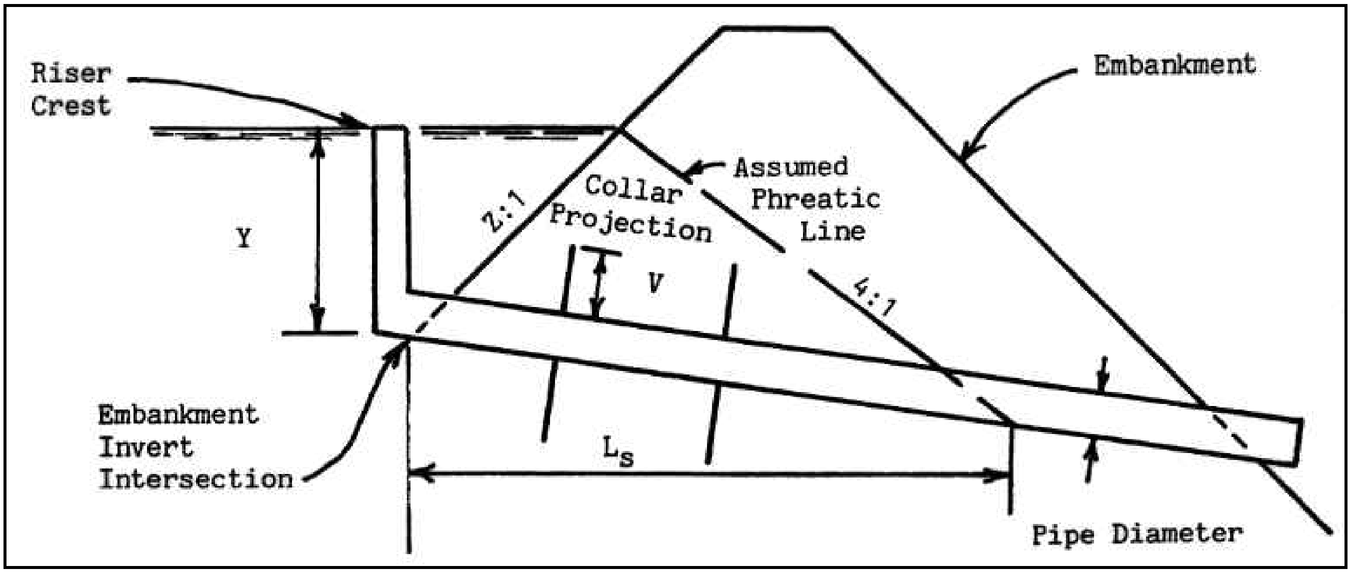



**Figure B.49.** Anti-seep collar design (see procedure detailed below; *Empire State Chapter Soil & Water Conservation Society, 1997*).

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).

$$L_s = y\,(z + 4)\left[1 + \frac{\text{pipe slope}}{0.25 - \text{pipe slope}}\right] \qquad \text{[EQ. B-4]}$$

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).

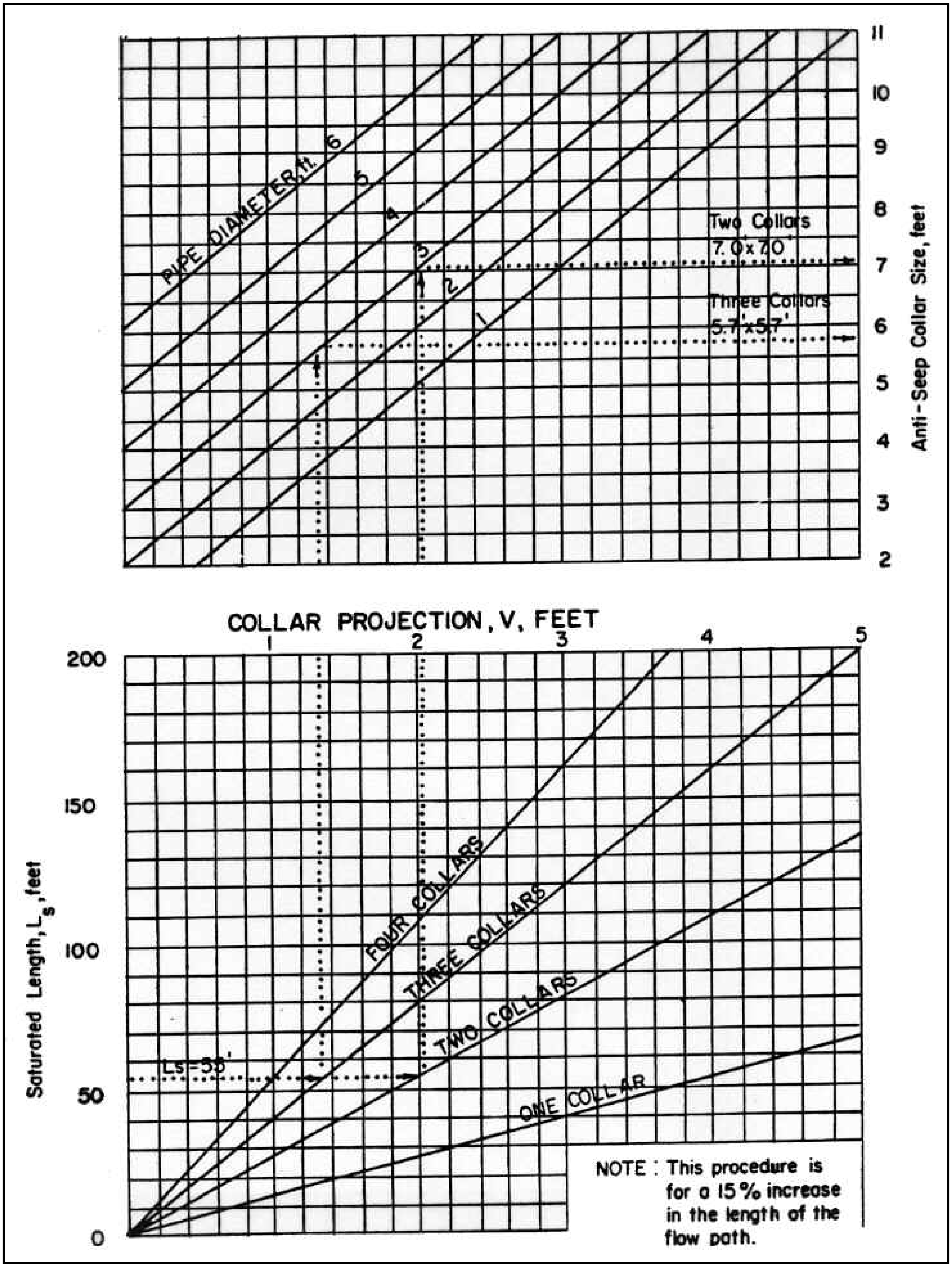



**Figure B.50.** Anti-seep collar design charts (*Empire State Chapter Soil & Water Conservation Society, 1997*).

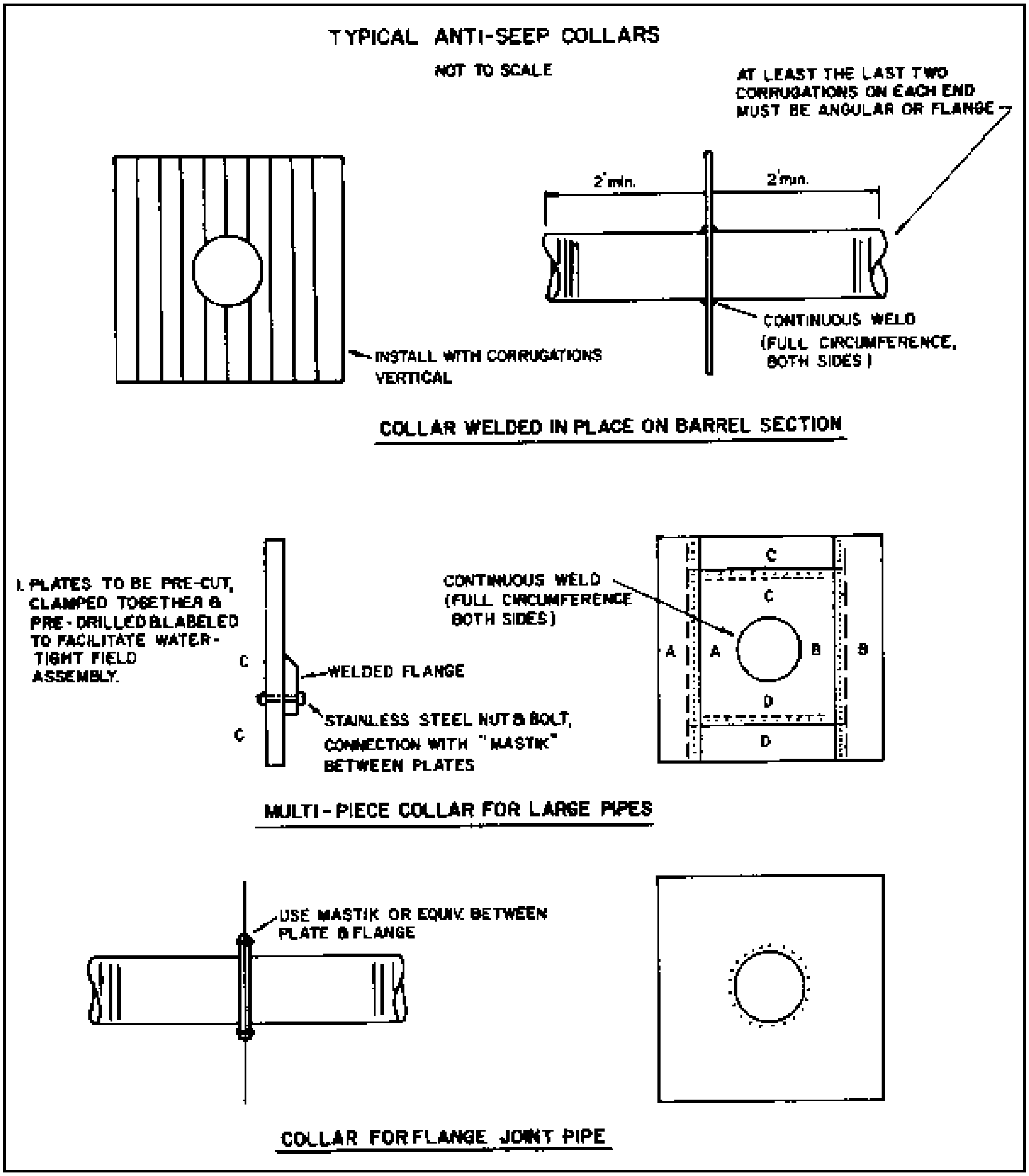



**Figure B.51.** Anti-seep collar construction details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

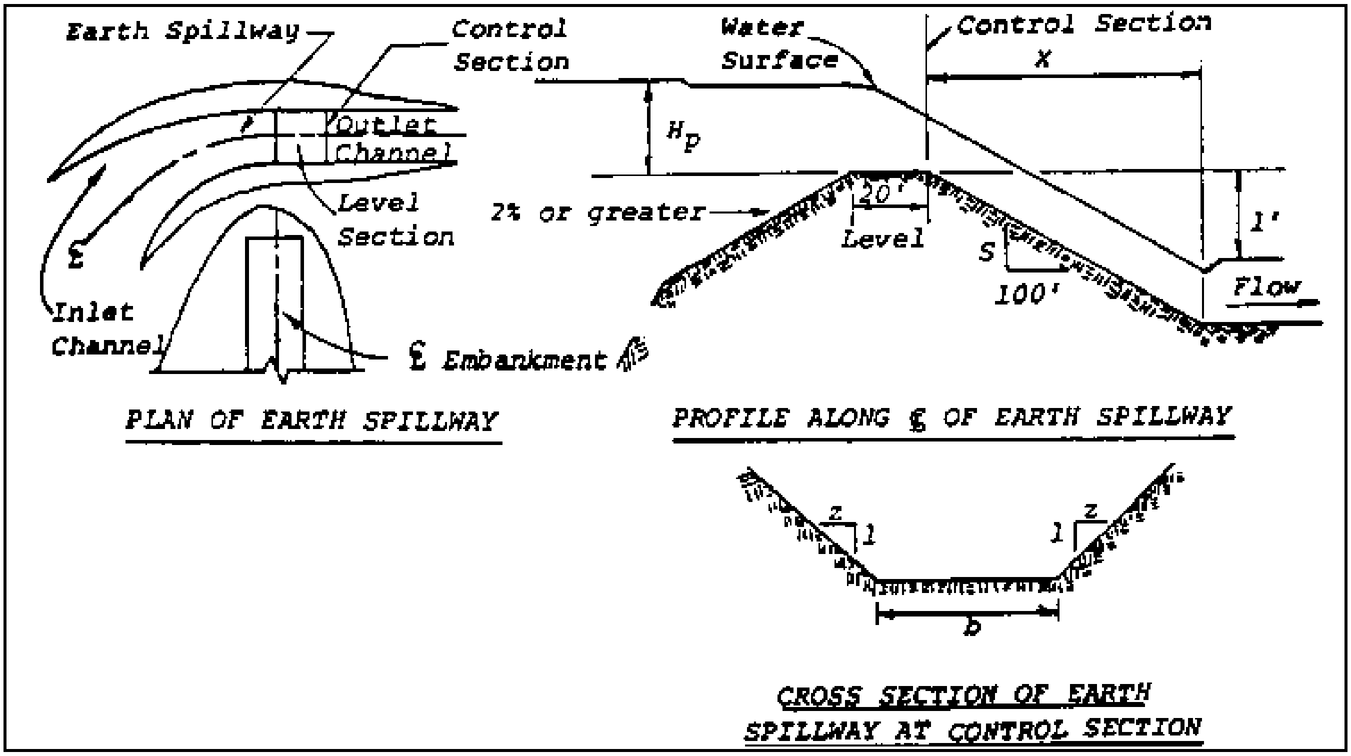



**Figure B.52.** Design data for earth spillways (*Empire State Chapter Soil & Water Conservation Society, 1991*).

***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:

$$V_e = V\left(\frac{S_e}{S}\right)^{0.3} \qquad \text{[EQ. B-5]}$$

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 |
| 0.5 | Q | 6 | 7 | 8 | 10 | 11 | 13 | 14 | 15 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 27 | 28 |
| | V | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| | S | 3.9 | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| | X | 32 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| 0.6 | Q | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 35 | 37 | 39 |
| | V | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| | S | 3.7 | 3.7 | 3.7 | 3.7 | 3.6 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |
| | X | 36 | 36 | 36 | 36 | 36 | 36 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 |
| 0.7 | Q | 11 | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 30 | 33 | 35 | 38 | 41 | 43 | 44 | 46 | 48 |
| | V | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| | S | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 |
| | X | 39 | 40 | 40 | 40 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 |
| 0.8 | Q | 13 | 16 | 19 | 22 | 26 | 29 | 32 | 35 | 38 | 42 | 45 | 46 | 48 | 51 | 54 | 57 | 60 |
| | V | 3.5 | 3.5 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |
| | S | 3.3 | 3.3 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| | X | 44 | 44 | 44 | 44 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| 0.9 | Q | 17 | 20 | 24 | 28 | 32 | 35 | 39 | 43 | 47 | 51 | 53 | 57 | 60 | 64 | 68 | 71 | 75 |
| | V | 3.7 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| | S | 3.2 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 |
| | X | 47 | 4[illegible] | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |
| 1.0 | Q | 20 | 24 | 29 | 33 | 38 | 42 | 47 | 51 | 56 | 61 | 63 | 68 | 72 | 77 | 81 | 86 | 90 |
| | V | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| | S | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| | X | 51 | 51 | 51 | 51 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| 1.1 | Q | 23 | 28 | 34 | 39 | 44 | 49 | 54 | 60 | 65 | 70 | 74 | 79 | 84 | 89 | 95 | 100 | 105 |
| | V | 4.2 | 4.2 | 4.2 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 |
| | S | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| | X | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| 1.2 | Q | 28 | 33 | 40 | 45 | 51 | 58 | 64 | 69 | 76 | 80 | 86 | 92 | 98 | 104 | 110 | 116 | 122 |
| | V | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| | S | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| | X | 58 | 58 | 59 | 59 | 59 | 59 | 59 | 59 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| 1.3 | Q | 32 | 38 | 46 | 53 | 58 | 65 | 73 | 80 | 86 | 91 | 99 | 106 | 112 | 119 | 125 | 133 | 140 |
| | V | 4.5 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 |
| | S | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| | X | 62 | 62 | 62 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 64 | 64 | 64 | 64 | 64 | 64 |
| 1.4 | Q | 37 | 44 | 51 | 59 | 66 | 74 | 82 | 90 | 96 | 103 | 111 | 119 | 127 | 134 | 142 | 150 | 158 |
| | V | 4.7 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 |
| | S | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| | X | 65 | 66 | 66 | 66 | 66 | 6[illegible] | 6[illegible] | 6[illegible] | 67 | 67 | 67 | 68 | 68 | 68 | 68 | 66 | 69 |
| 1.5 | Q | 41 | 50 | 58 | 66 | 75 | 85 | 92 | 10[illegible] | 108 | 116 | 125 | 133 | 142 | 150 | 160 | 169 | 178 |
| | V | 4.8 | 4.9 | 4.9 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.1 | 5.1 | 5.1 |
| | S | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 |
| | X | 69 | 69 | 70 | 70 | 71 | 7[illegible] | 7[illegible] | 71 | 7[illegible] | 71 | 7[illegible] | 72 | 72 | 72 | 72 | 72 | 72 |
| 1.6 | Q | 46 | 56 | 65 | 75 | 84 | 94 | 104 | 112 | 122 | 132 | 142 | 149 | 158 | 168 | 178 | 187 | 197 |
| | V | 5.0 | 5.1 | 5.1 | 5.1 | 5.1 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 |
| | S | 2.6 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| | X | 72 | 74 | 74 | 75 | 75 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| 1.7 | Q | 52 | 62 | 72 | 83 | 94 | 105 | 115 | 126 | 135 | 145 | 156 | 167 | 175 | 187 | 196 | 206 | 217 |
| | V | 5.2 | 5.2 | 5.2 | 5.3 | 5.3 | 5.3 | 5.3 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| | S | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| | X | 76 | 78 | 79 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| 1.8 | Q | 58 | 69 | 81 | 93 | 104 | 116 | 127 | 138 | 150 | 160 | 171 | 182 | 194 | 204 | 214 | 226 | 233 |
| | V | 5.3 | 5.4 | 5.4 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 |
| | S | 2.5 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| | X | 80 | 82 | 83 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 |
| 1.9 | Q | 64 | 76 | 88 | 102 | 114 | 127 | 140 | 152 | 164 | 175 | 188 | 201 | 213 | 225 | 235 | 248 | 260 |
| | V | 5.5 | 5.5 | 5.5 | 5.6 | 5.6 | 5.6 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 |
| | S | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| | X | 84 | 85 | 86 | 87 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| 2.0 | Q | 71 | 83 | 97 | 111 | 125 | 138 | 153 | 164 | 178 | 193 | 204 | 218 | 232 | 245 | 256 | 269 | 283 |
| | V | 5.6 | 5.7 | 5.7 | 5.7 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 |
| | S | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| | X | 88 | 90 | 91 | 91 | 91 | 9[illegible] | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 |
| 2.1 | Q | 77 | 9[illegible] | 107 | 122 | 135 | 149 | 162 | 177 | 192 | 207 | 220 | 234 | 250 | 267 | 276 | 291 | 305 |
| | V | 5.7 | 5.8 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| | S | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| | X | 92 | 93 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| 2.2 | Q | 84 | 100 | 116 | 131 | 146 | 163 | 177 | 194 | 210 | 224 | 238 | 253 | 269 | 288 | 301 | 314 | 330 |
| | V | 5.9 | 5.9 | 6.0 | 6.0 | 6.0 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.2 | 6.2 | 6.2 | 6.2 |
| | S | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| | X | 96 | 98 | 99 | 99 | 99 | 99 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2.3 | Q | 90 | 108 | 124 | 140 | 156 | 175 | 193 | 208 | 226 | 243 | 258 | 275 | 292 | 306 | 323 | 341 | 354 |
| | V | 6.0 | 6.1 | 6.1 | 6.1 | 6.2 | 6.2 | 6.2 | 6.2 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 |
| | S | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| | X | 100 | 102 | 102 | 103 | 103 | 103 | 104 | 104 | 104 | 105 | 105 | 105 | 105 | 105 | 105 | 105 | 105 |
| 2.4 | Q | 99 | 116 | 136 | 152 | 170 | 189 | 206 | 224 | 24[illegible] | 260 | 275 | 294 | 312 | 327 | 346 | 364 | 378 |
| | V | 6.1 | 6.2 | 6.2 | 6.3 | 6.3 | 6.3 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 |
| | S | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| | 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:

$$V = 0.4 \times A \times d \quad \text{[EQ. B-6]}$$

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.

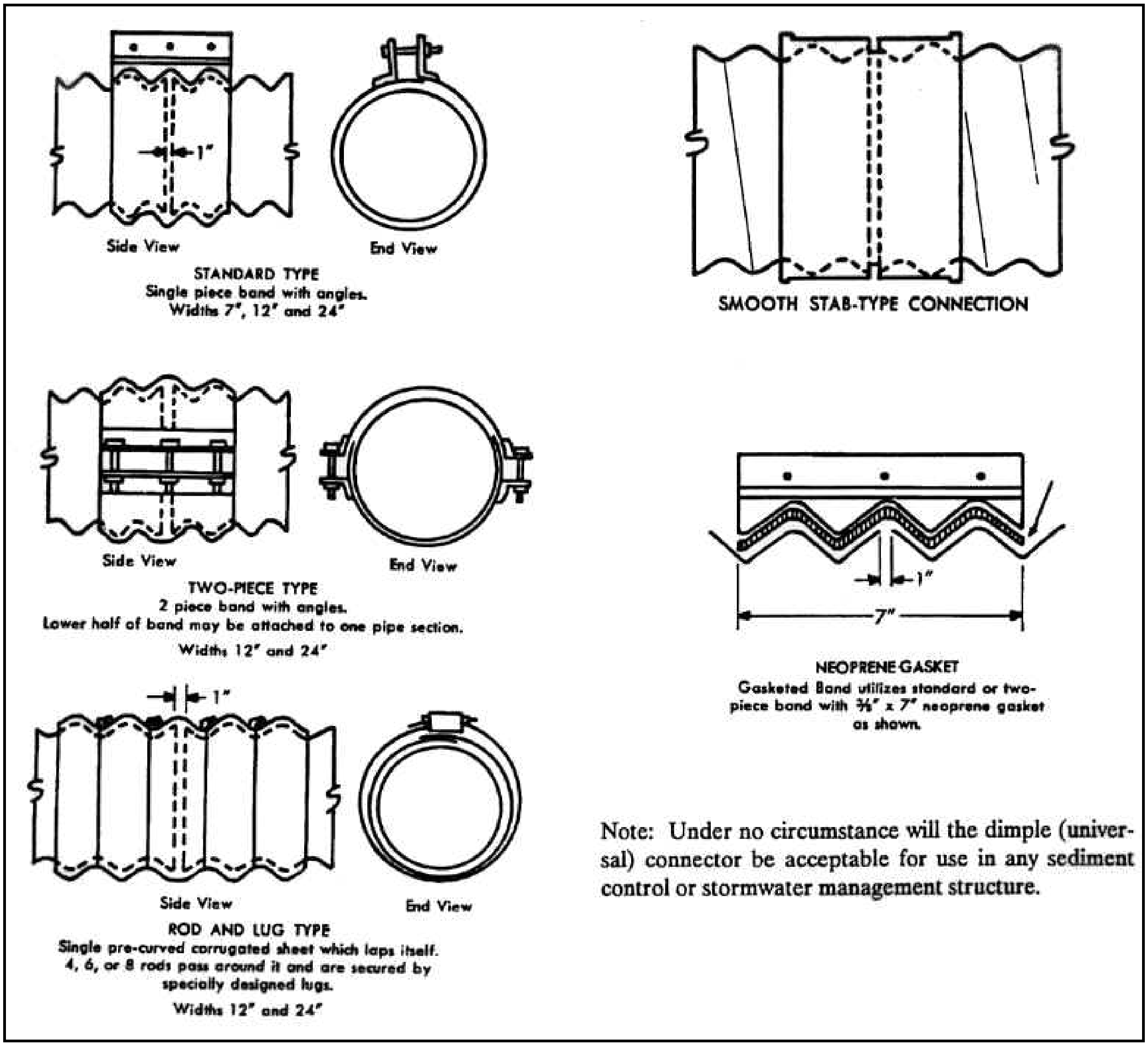



**Figure B.54.** Corrugated steel pipe couplers — all connector bands require neoprene gaskets *(Empire State Chapter Soil & Water Conservation Society, 1997*).

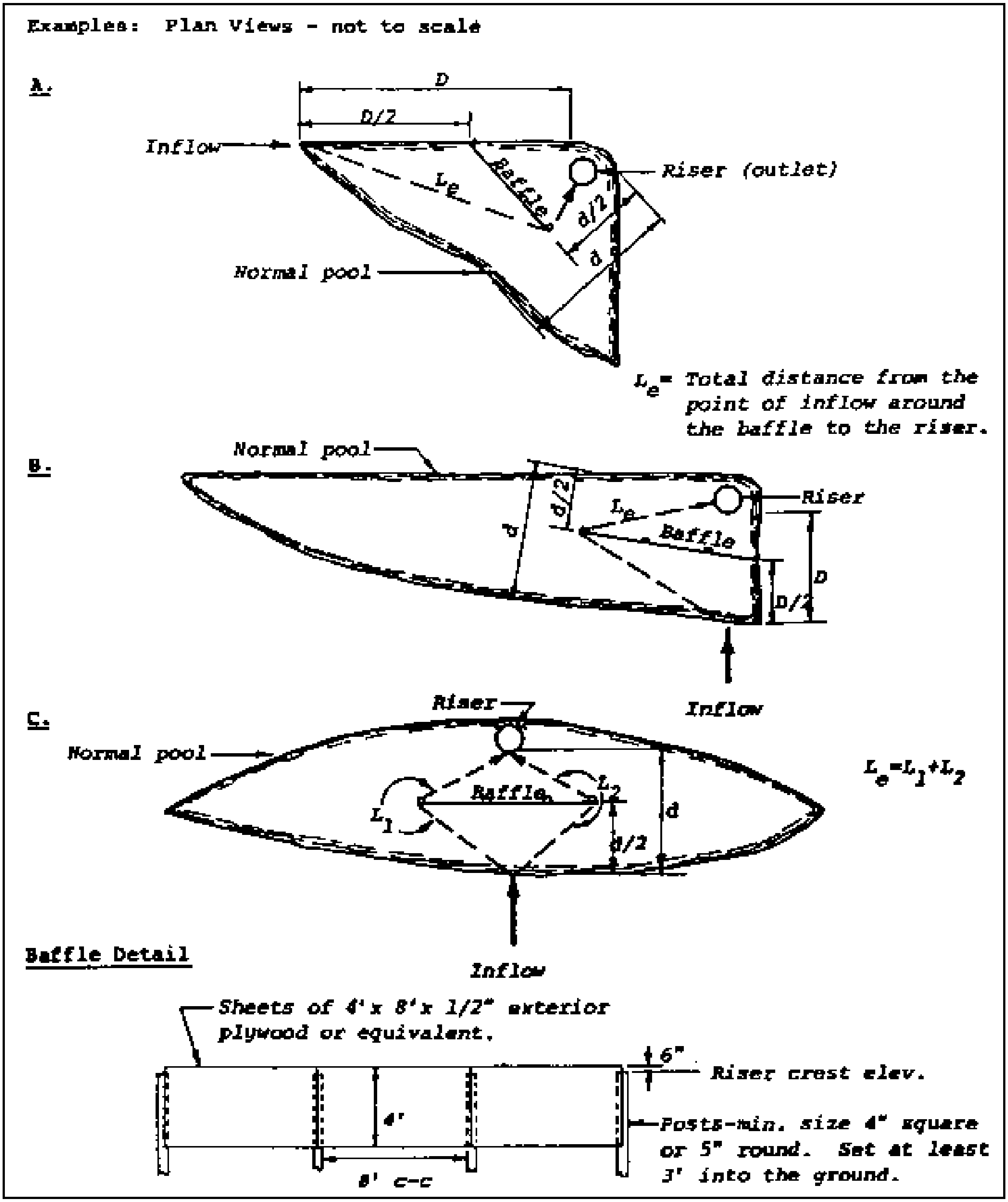



**Figure B.55.** Sediment basin baffle details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

# 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.

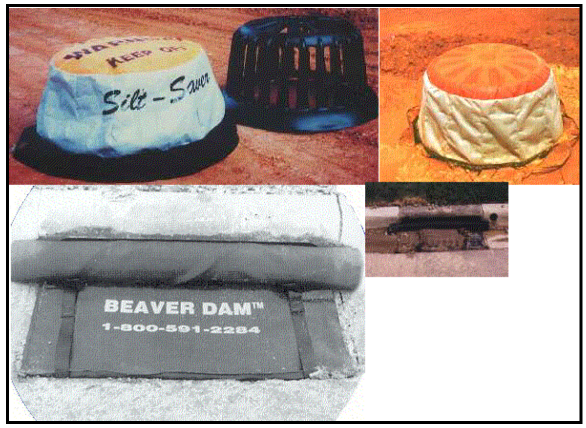



**Figure B.56.** Examples of manufactured inlet inserts (top: *SiltSaver Corp., 1999*, bottom: *Dandy Products, Inc., 2001*).

## ***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.

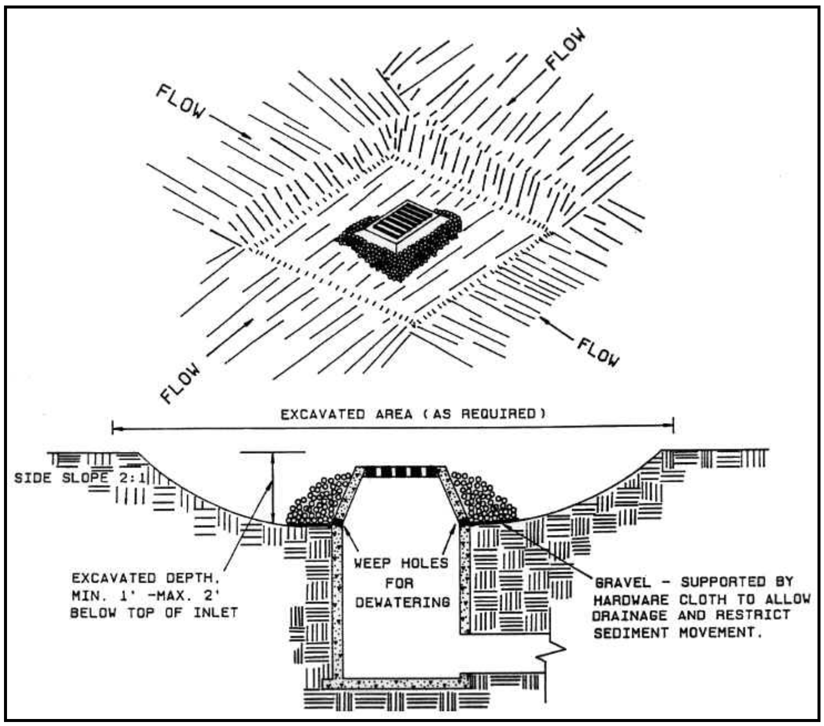



**Figure B.57.** Excavated drop inlet details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

### 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

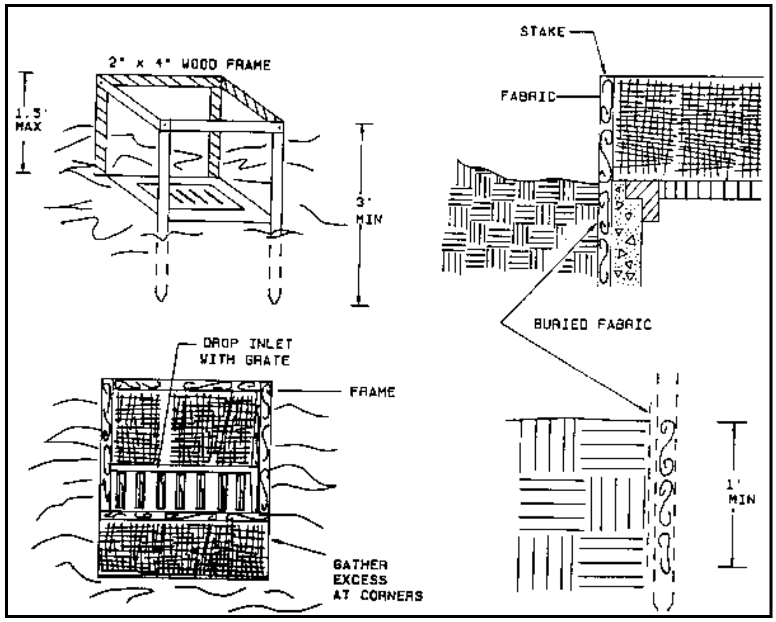



**Figure B.58.** Filter fabric drop inlet protection details (*Empire State Chapter Soil & Water Conservation Society, 1997*).

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)

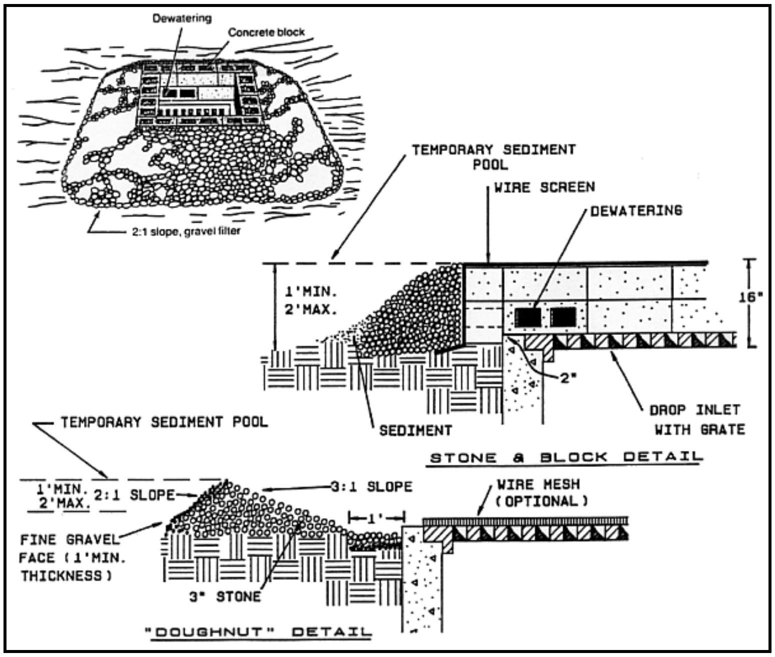



**Figure B.59.** Stone and block drop inlet protection details (*Empire State Chapter, 1997*).

### Design Criteria

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

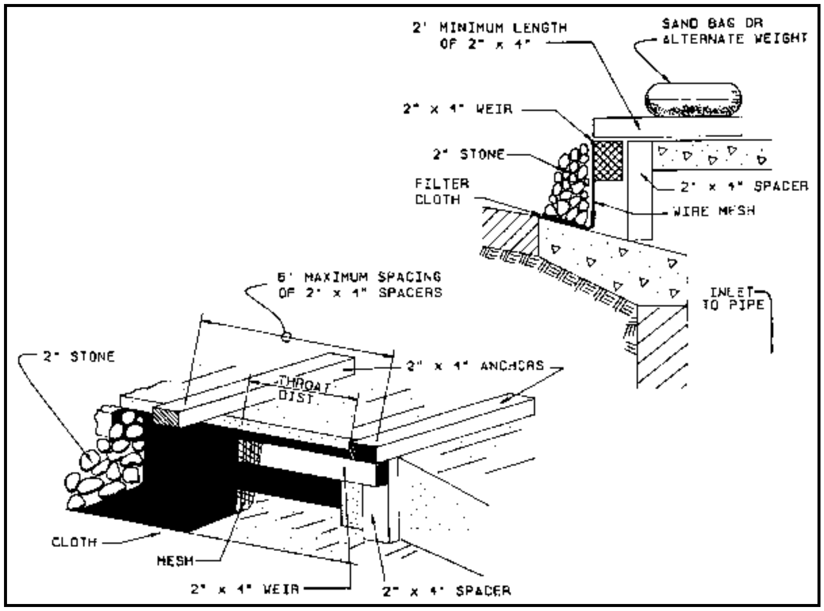



**Figure B.60.** Curb drop inlet protection details *(Empire State Chapter Soil & Water Conservation Society, 1997)*.

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.

### 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.

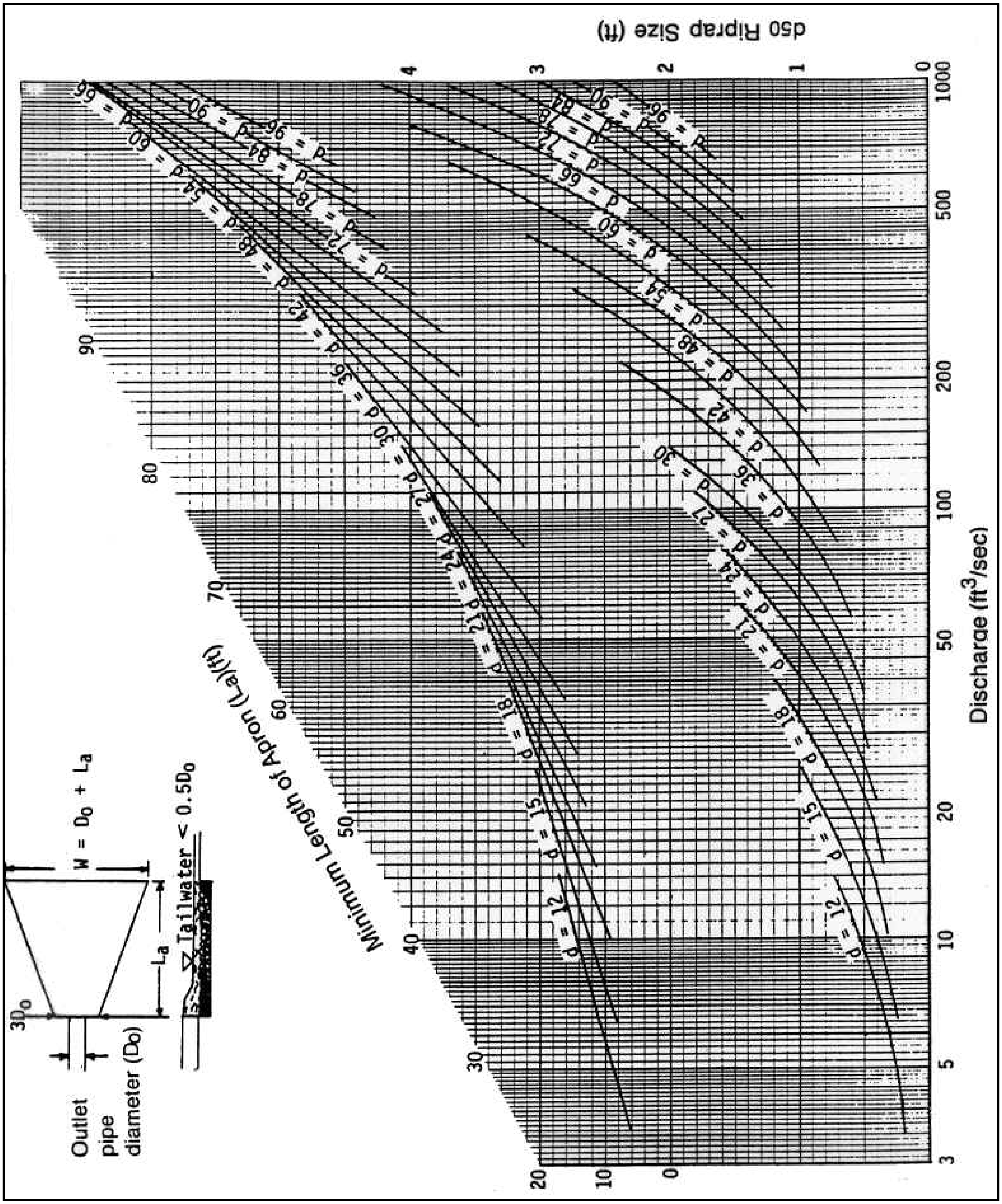



**Figure B.61.** Outlet protection design — Minimum Tailwater Condition (design of outlet protection from a round pipe flowing full, minimum tailwater condition: $T_w < 0.5D_o$; *Empire State Chapter Soil & Water Conservation Society, 1991*).

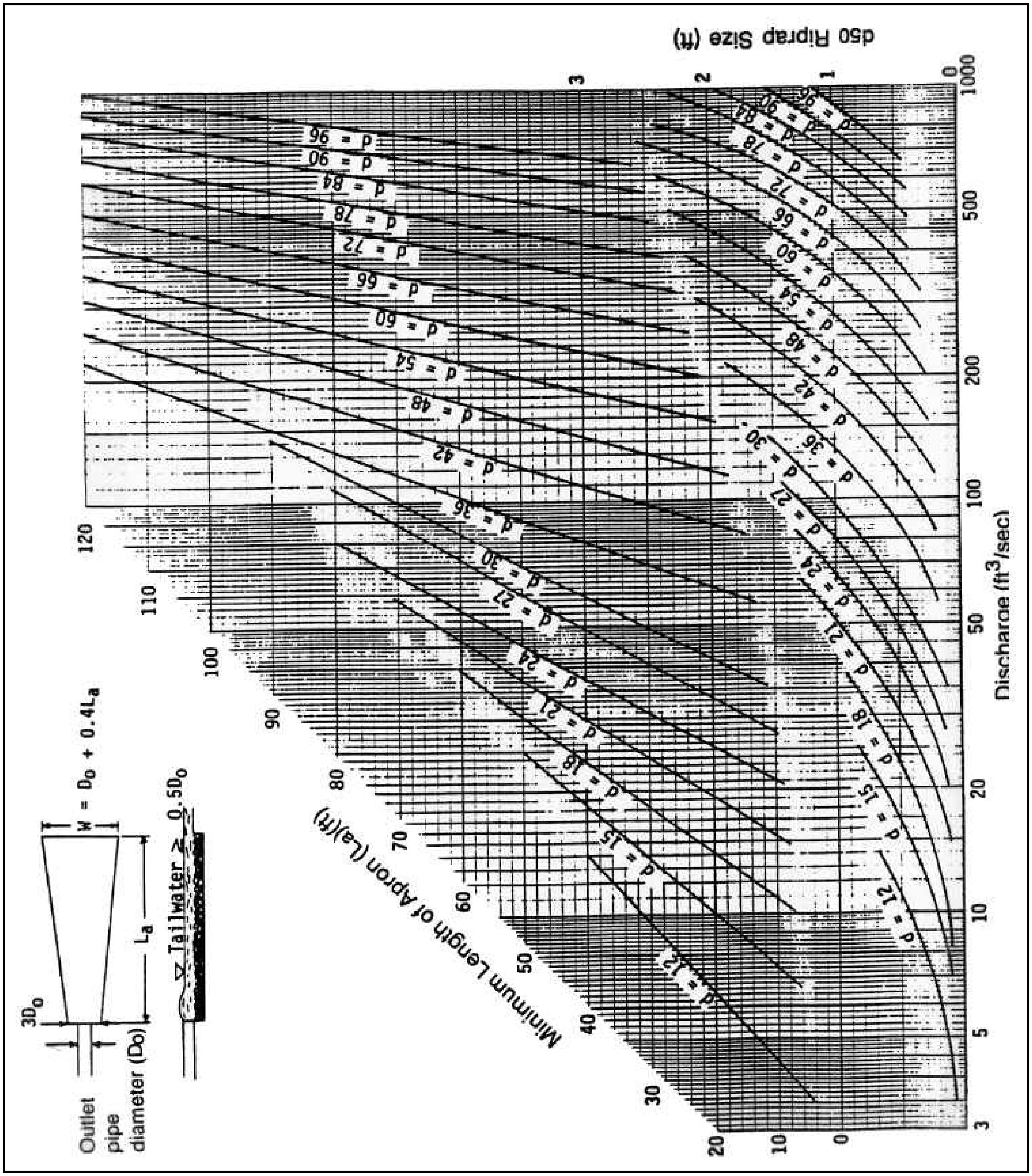



**Figure B.62.** Outlet protection design — Maximum Tailwater Condition (design of outlet protection from a round pipe flowing full, Maximum tailwater condition: $T_w > 0.5D_o$; *Empire State Chapter Soil & Water Conservation Society, 1991*).

### 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:

$$Q = \frac{\pi D^2}{4} \; x \; V = \frac{3.14 \; (5feet)^2}{4} \; x \; 12fps = 236fps$$

   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.

$$Q = \frac{\pi \; (2feet)^2}{4} \; x \; 10fps = 31.4fps$$

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.

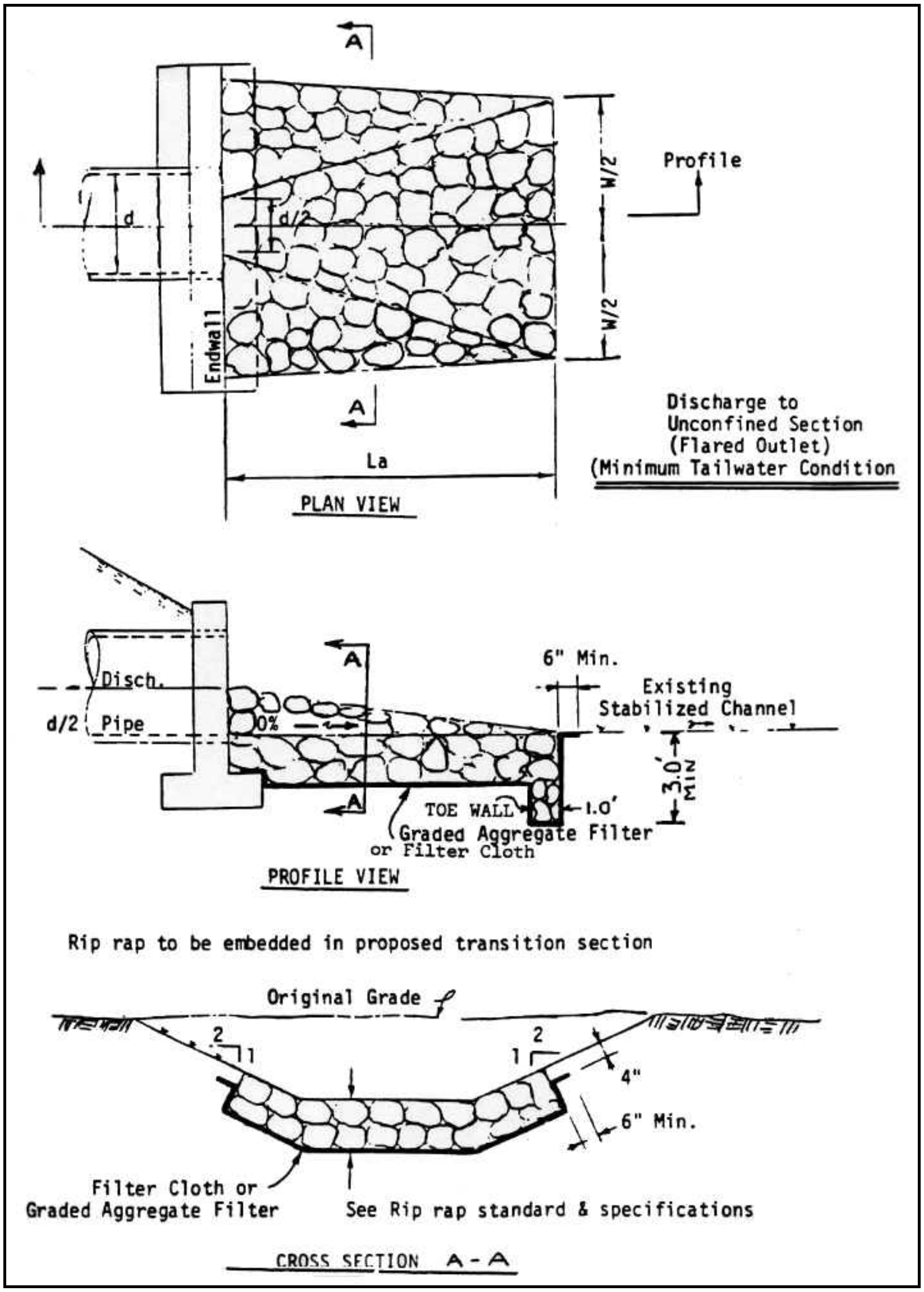



**Figure B.63.** Rip-rap outlet protection Example 1 *(Empire State Chapter Soil & Water Conservation Society, 1991)*.

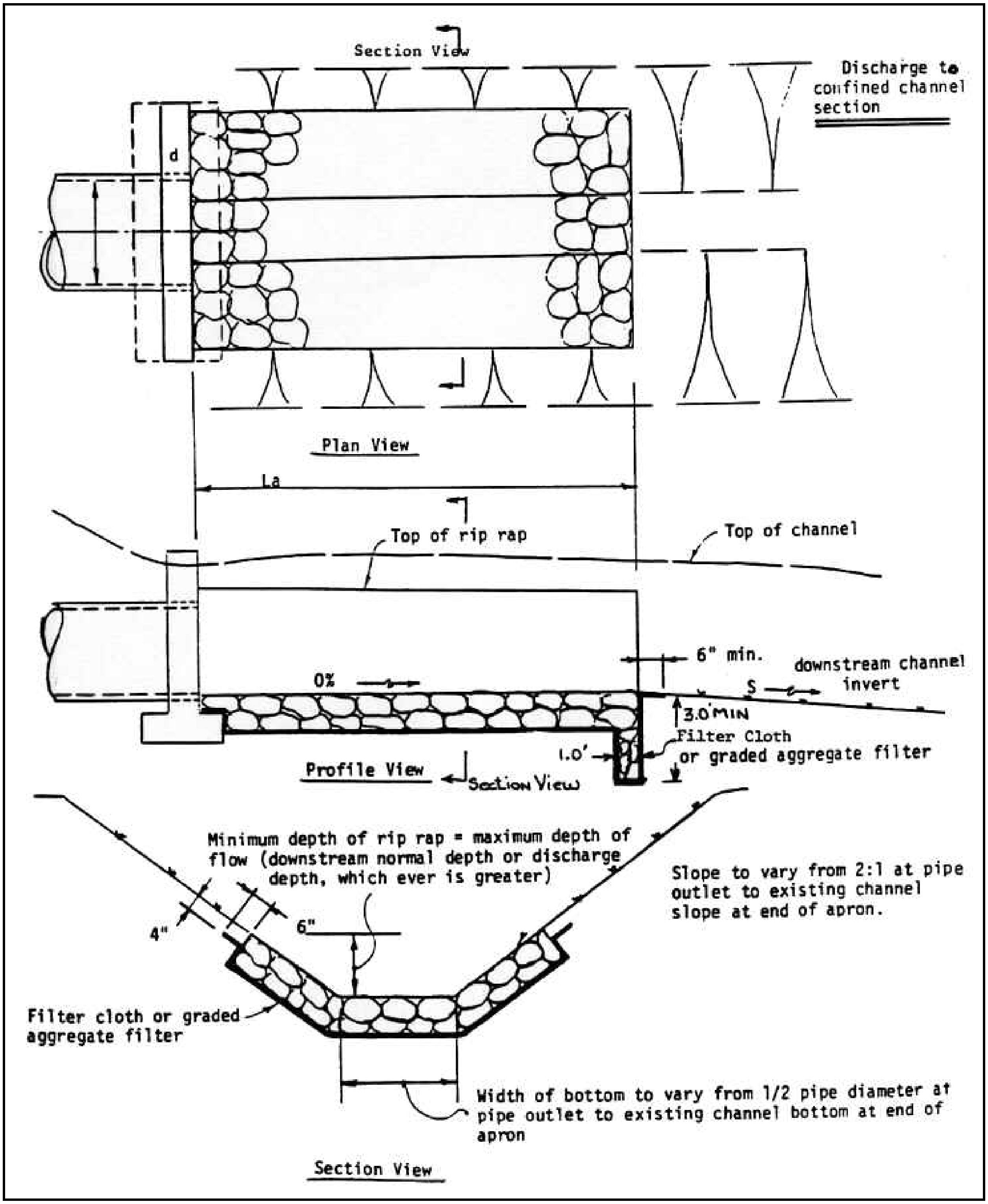



**Figure B.64.** Rip-rap outlet protection Example 2 (*Empire State Chapter Soil & Water Conservation Society, 1991*).

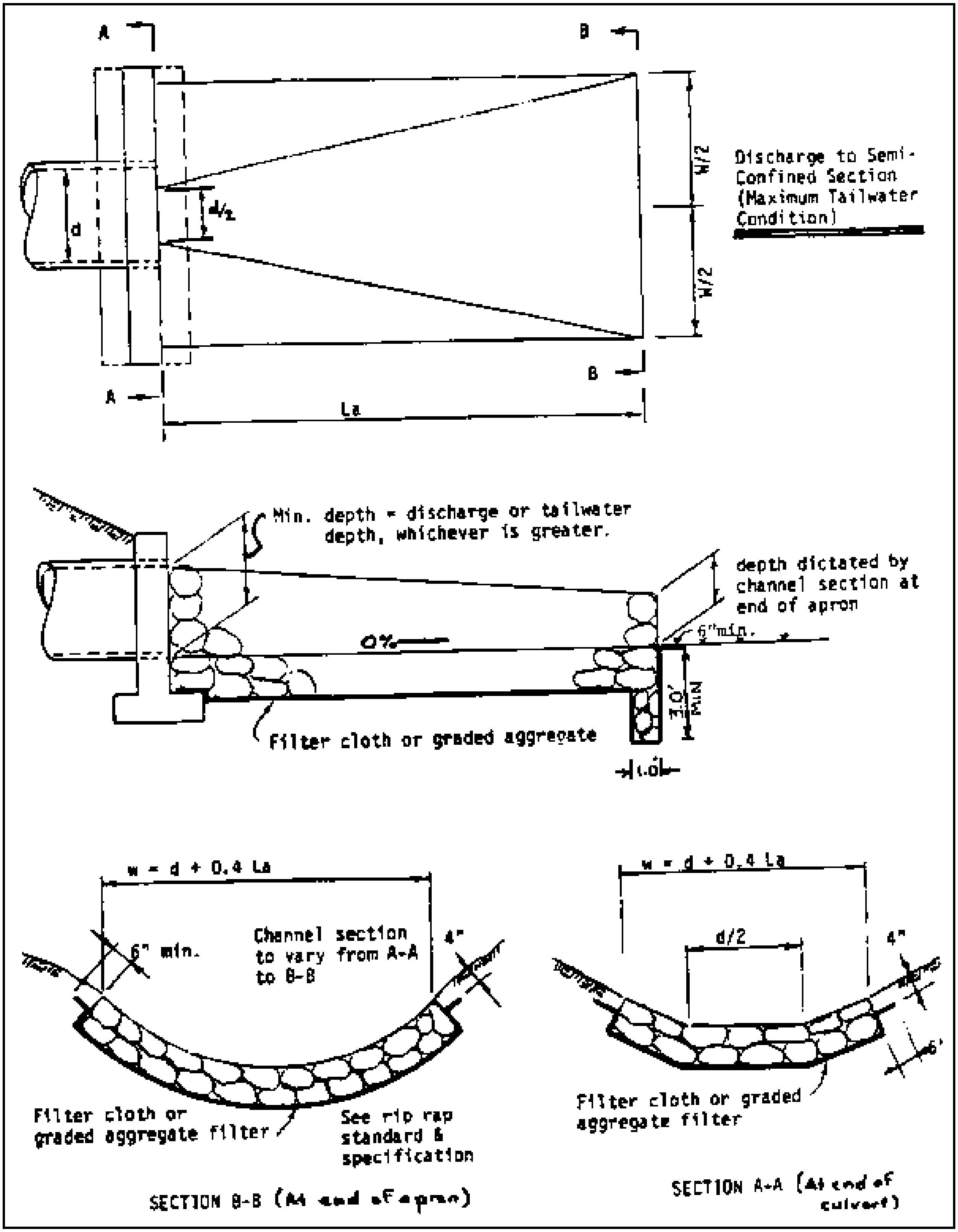



**Figure B.65.** Rip-rap outlet protection example (*Empire State Chapter Soil & Water Conservation Society, 1991*).

# 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.

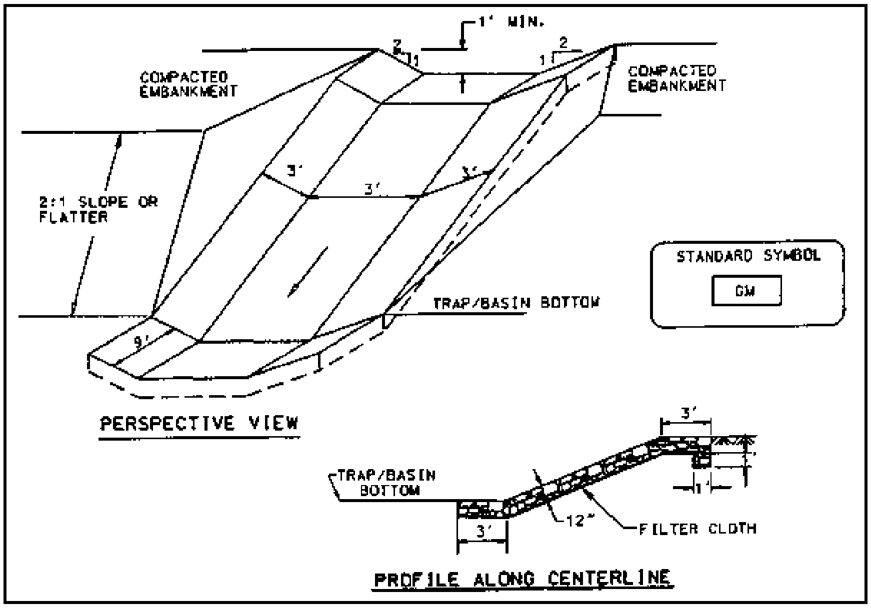



**Figure B.66.** Gabion inflow protection details *(Maryland Department of the Environment, 1994)*.

## 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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