SC DHEC South Carolina Department of Health and Environmental Control

D H E C

PROMOTE PROTECT PROSPER

Ocean and Coastal Resource Management

South Carolina DHEC
Storm Water Management
BMP Handbook

August 2005

Appendices

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AMD	Acrylamide Polymer
BFM	Bonded Fiber Matrix
BMP(s)	Best Management Practice(s)
CFS	Cubic Feet Per Second
CMP	Corrugated Metal Pipe
DHEC	South Carolina Department of Health and Environmental Control
ECB	Erosion Control Blanket
EPA	United Stated Environmental Protection Agency
EPSC	Erosion Prevention and Sedimentation Control
FDA	United States Food and Drug Administration
FGM	Flexible Growth Matrix
HDPE	High Density Polyethylene
MS4	Municipal Separate Storm Sewer System
MSDS	Material Safety Data Sheets
NPDES	National Pollutant Discharge Elimination System
PAM	Polyacrylamide or Polymer
RCP	Reinforced Concrete Pipe
SCS	Soil Conservation Service
SWPPP	Storm Water Pollution Prevention Program
TRM	Turf Reinforcement Mat
VFS	Vegetated Filter Strip

Erosion Prevention and Sediment BMP Basic Design Procedures

Control of sedimentation from construction sites is accomplished through the utilization of a variety of erosion and sediment control Best Management Practices (BMPs). The complexity of the erosion prevention and sediment control (EPSC) plan varies depending on the individual site conditions. The goal of implementing the erosion control plan is to limit the quantity of sediment being eroded from, and leaving a construction site. This is partially accomplished through the implementation of sediment control BMPs. However, these sediment trapping controls typically only remove a small portion of the clay particles eroded from the site. The best protection is provided by a combination of practices including temporary and permanent stabilization, flow diversions, and streambank protection, all which minimize the amount of soil that is eroded from the site.

Plan land development to control and limit erosion and sediment discharge from construction sites using, but not limited to, the BMPs listed in this Manual. The goal of these erosion and sediment control BMPs is to:

- Minimize the extent and duration of disturbed soil exposure.
- Protect off-site and downstream locations, drainage systems and natural waterways from the impacts of erosion and sedimentation.
- Limit the exit velocities of the flow leaving the site to non-erosive or pre-development conditions.
- Design and implement an ongoing inspection and maintenance plan.

SCDHEC regulations require that when runoff drains to a single outlet from land disturbing activities which disturb ten (10) acres or more then a sediment basin must be designed to meet a removal efficiency of 80 percent for suspended solids or 0.5 mL/L peak settleable concentration, which ever is less. The design storm event associated with this level of control is the **10-year 24-hour SCS Type II, or Type III (coastal zone) storm event**. Computer software packages and the Design Aids contained in this handbook may used to calculate trapping efficiencies and peak settleable concentrations.

Land disturbance activities that are greater than five (5) acres require the development of EPSC plans to achieve an 80 percent design removal efficiency goal. Simply applied, when a site is completely denuded of vegetation, structural and nonstructural EPSC measures are designed to trap 80 percent of the total suspended solids (TSS) generated on the site.

Use SCS (Soil conservation Service) procedures to determine runoff amounts. It is important to note that when a BMP is designed for the 10-year 24-hour storm event, the BMP will have a greater trapping efficiency for more frequent events such as the 2-year 24-hour storm event.

EPSC plans delineate the following elements:

- All sensitive features.
- Sources of sediment that may potentially leave the site.

- The location and depth of all structural and nonstructural BMPs necessary to achieve the 80 percent design removal efficiency goal to protect receiving water bodies, off-site areas and all sensitive features.

- Installation and maintenance of required BMPs.

- The sequencing of construction activities to be utilized on the project.

Utilize the following nonstructural site management practices on the design plans where applicable:

- Minimize site disturbance to preserve and maintain existing vegetative cover.

- Limit the number of temporary access points to the site for land disturbing activities.

- Phase and sequence construction activities to minimize the extent and duration of disturbed soil exposure.

- Locate temporary and permanent soil disposal areas, haul roads and construction staging areas to minimize erosion, sediment transport and disturbance to existing vegetation.

Detailed EPSC plans comply with the following specific standards and review criteria:

- Sediment Tracking Control. Locate and utilize stabilized construction entrances at all points of ingress and egress on the construction site to prevent the transfer of sediment onto public roads and right-of-ways by motor vehicles and runoff.

- Crossings. Minimize the crossing of waterways during construction. Crossings must be approved by the U.S. Army Corps of Engineers and SCDHEC. Avoid encroachment into stream buffers, riparian areas, and wetlands when possible.

- Topsoil. Stockpile and preserve topsoil from erosion or dispersal both during and after site grading operations when applicable.

- Temporary Stabilization Measures. Temporary stabilization is required within 14 days after construction activity is complete **unless construction activity is going to resume within 21 days**.

- Final Stabilization. Prevent soil from eroding after the construction is complete. Final Stabilization of the site is required within 14 calendar days of construction completion.

- Temporary Structural Controls. Design to accomplish maximum stabilization, prevent erosion and control sedimentation. Design temporary structural controls to control the peak runoff resulting from the design storm event. Install, maintain, and remove temporary controls according to the specifications set forth in this BMP Manual.

- Permanent Structural Controls. Design all permanent controls including channels, storm sewer inlets, detention basins, and water quality structures according to State Regulations and to the standards set forth in the BMP Manual.

Erosion Prevention Measures

Use erosion prevention measures during and after construction site preparation in order to safely convey clean water to storm drains or adequate watercourses. One or more measures should be utilized as appropriate during the project's construction phase. Such measures may include but are not limited to: phasing and construction sequencing, surface roughening, temporary seeding, mulching, erosion control blankets, and reinforcement matting. Each of these measures is discussed in the Sections below.

In addition to site-specific erosion control measures, the grading plan includes the following general measures as a minimum:

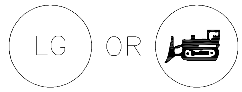
- Vegetated finished cut and fill slopes should not be steeper than 3H:1V, unless an erosion control blanket or turf reinforcement mat is used.
- Do not place cuts or fills close to property, endangering adjoining property without adequately protecting such properties against erosion, sedimentation, slippage, settlement, subsidence, or other damages.
- Provide subsurface drainage in areas having a high water table to intercept seepage that affects slope stability, bearing strength, and undesirable wetness.
- Do not place fill material where it can slide or wash onto another property.
- Do not place fill adjacent to channel banks where it can create bank failure, reduce the capacity of the stream, or result in downstream sediment deposition.
- Include all borrow and disposal areas as part of the grading plan.
- Provide adequate channels and floodways to safely convey increased runoff from the developed area to an adequate outlet without causing significant channel degradation, or increased off-site flooding.
- Grade the site to direct flows to appropriate controls.

The following Erosion Prevention Measures are discussed in this handbook:

- Surface Roughening
- Temporary Seeding
- Mulching
- Erosion Control Blankets (ECBs)
- Turf Reinforcement Mats (TRMs)
- Flexible Growth Matrix (FGM)
- Bonded Fiber Matrix (BFM)
- Permanent Seeding
- Sodding
- Riprap
- Outlet Protection
- Dust Control
- Polyacrylamide (PAM)

Surface Roughening

Plan Symbol



Description

Surface roughening is the creation of horizontal grooves, depressions, or steps that run parallel to the contour of the land. The following surface roughening measures are approved for use:

- Tracking (driving a crawler tractor up and down a slope, leaving the cleat imprints parallel to the slope contour).
- Stair-step grading.
- Grooving (using disks, spring harrows, or teeth on the bucket of a front-end loader).

Tracking

Description

Tracking is defined as driving tracked machinery up and down slopes, leaving the cleat imprints parallel to the slope contour.

When and Where to Use It

To slow erosion, perform tracking as soon as possible after the vegetation has been removed from the slope. Use tracking with temporary seeding and temporary mulching to stabilize an area.Perform tracking immediately after grading activities have ceased (temporarily or permanently) in an area.

Installation

Avoid excessive compacting of the soil surface when tracking since ~~because~~ soil compaction inhibits vegetation growth and causes higher runoff rates. As few passes as possible should be made with the machinery in order to minimize compaction

Seed and mulch surface roughened areas by the means of tracking within 14 days.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, re-grade and re-seed immediately.

Stair-Step Grading

Description

Stair-Step Grading is defined as cutting stair-steps into slopes with each step having a maximum horizontal distance of 4-feet and a maximum vertical distance of 4-feet.

When and Where to Use It

To slow erosion, perform stair step grading within 7 days after the removal of vegetation from the slope. Stair step grading is applicable on cut slopes with a gradient steeper than 3H:1V but less than 2H:1V. Stair-step grading is applicable on any material soft enough to be moved with a bulldozer. Stair-step grading works well with soils containing large amounts of small rock. Prepare stairs wide enough to work with standard earth moving equipment. Stair-step grading is used with seeding to stabilize an area.

Installation

The ratio of vertical cut distance to horizontal distance is steeper than 1V:1H and the horizontal portion of the "step" slopes towards the vertical wall.

Seed and stabilize areas graded in this manner within 14 days.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, re-grade and re-seed immediately.

Grooving

Description

Slope Grooving is defined as using machinery to create a series of ridges and depressions that run perpendicular to the slope on the contour.

When and Where to Use It

To slow erosion, perform slope grooving within 7 days after the removal of vegetation from the slope.

Groove cut and fill slopes with a gradient steeper than 3H:1V but less than 2H:1V. Grooving is done by any implement that is safely operated on the slope.

Slope Grooving is used with seeding and planting to stabilize an area.

Installation

Install slope grooving with any appropriate implement that is safely operated on the slope not causing undue compaction. Suggested implements include discs, chisel plows, and the teeth on a front-end loader bucket. Install grooves a minimum of three inches deep and no further than 15 inches apart.

Seed and stabilize areas that are graded in this manner within 14 days.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, re-grade and re-seed immediately.

Surface Roughening (Tracking)

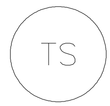
Surface Roughening (Tracking)

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Rills appear.	Re-grade and re-seed area immediately.

Temporary Seeding

Plan Symbol



Description

The purpose of temporary seeding is to reduce erosion and sedimentation by stabilizing disturbed areas that would otherwise lay bare for long periods of time before they are worked or stabilized. Temporary seeding is also used where permanent vegetation growth is not necessary or appropriate.

When and Where to Use It

Temporary seeding is used on exposed soil surfaces such as denuded areas, soil stockpiles, dikes, dams, banks of sediment basins, banks of sediment traps, and temporary road banks. Temporary seeding prevents and limits costly maintenance operations on other sediment control structures. Sediment clean-out requirements for sediment basins, sediment, traps, and silt fence is reduced if the drainage area is seeded when grading and construction operation are not taking place.

Temporary stabilization is required within 14 days after construction activity is complete **unless construction activity is going to resume within 21 days**. Cover seeded areas with an appropriate mulch to provide protection from the weather. When the temporary vegetation does not grow quickly or thick enough to prevent erosion, re-seed as soon as possible. Keep seeded areas adequately moist. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water wastes water and can cause erosion.

Seed Selection

Seed selection is based on geographical location, soil type and the season of the year in which the planting is to be done. Use the tables in Appendix C as a guide for conventional tillage methods (plowing, seedbed preparation, hydroseeding, etc). If a fast growing crop to nurse the permanent specie or species is required, then use the mix rate. Failure to carefully follow agronomic recommendations results in an inadequate stand of temporary vegetation that provides little or no erosion control.

Installation

Tillage

If the area has been recently plowed, no tillage is required other than raking or surface roughening to break any crust that has formed leaving a textured surface. Disk the soil for optimal germination when the soil is compacted less than 6-inches.

Soil Testing

Soil testing is available through Clemson University Cooperative Extension Service.

Lime

Lime is not required for temporary seeding unless a soil test shows that the soil pH is below 5.0. It may be desirable to apply lime during the temporary seeding operation to benefit the long-term permanent seeding. Apply a minimum of 1.5 tons of Lime/acre (70 pounds per 1000 square feet) if it is to be used.

Fertilizer

Apply a minimum of 500 pounds per acre of 10-10-10 fertilizer (11.5 pounds per 1000 square feet) or equivalent during temporary seeding unless a soil test indicates a different requirement. Incorporate fertilizer and lime (if used) into the top 4-6 inches of the soil by disking or other means where conditions allow.

Seeding

Loosen the soil surface before broadcasting the seed. Apply seed evenly by the most convenient method available for the type of seed used and the location of the temporary seeding. Typical application methods include but are not limited to cyclone seeders, rotary spreaders, drop spreaders, broadcast spreaders, hand spreaders, cultipacker seeder, and hydro-seeders. Cover applied seed by raking or dragging a chain, and then lightly firm the area with a roller or cultipacker.

Mulching

Use mulch with temporary seed applications to retain soil moisture and reduce erosion during the establishment of vegetation. Typical mulch applications include straw, wood fiber, hydromulches, BFM and FGM. Use hydromulches with a minimum blend of 70% wood fibers.

The most commonly accepted mulch used in conjunction with temporary seeding is small grain straw. This straw should be dry and free from mold damage and noxious weeds. The straw may need to be anchored with netting or emulsions to prevent it from being blown or washed away. Apply the straw mulch by hand or machine at the rate 1.5-2 tons per acre (90 pounds per 1000 square feet). Frequent inspections are necessary to check that conditions for growth are good.

Irrigation

Seeded areas should be kept adequately moist. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water wastes water and can cause erosion.

Re-seeding

Re-seed areas where seeding does not grow quickly, thick enough, or adequately to prevent erosion. Base seed selection should on the requirements of local Specifications.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Cover seeded with mulch to provide protection. Frequent inspections are necessary to check that conditions for growth are good.
- Supply temporary seeding with adequate moisture. Supply water as needed, especially in abnormally hot or dry weather or on adverse sites. Control water application rates to prevent runoff.

- Base seed selection on local Specifications.
- Re-seed areas where the plants do not grow quick enough, thick enough, or adequately enough to prevent erosion should be re-seeded.

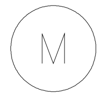
Temporary Seeding

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope was improperly dressed before application.	Roughen slopes. Furrow along the contour of areas to be seeded.
Coverage is inadequate.	Follow recommended application rates. Count the number of seedbags to ensure the correct amount of material is being applied. Reapply to thin areas.
Seeds fail to germinate.	Apply straw mulch to keep seeds in place and to moderate soil moisture and temperature. In arid areas, temporary irrigation may be necessary.
Seeded slope fails.	Fill in rills and re-seed; fertilize, and mulch slopes.
Seeding is washed off slope.	Allow at least 24-hours for the materials to dry before a rain event. Follow manufacturer's recommendations. Reapply where necessary.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow on stabilized area and to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Mulching

Plan Symbol



Description

Mulching is a temporary soil stabilization erosion control method where materials such as grass, hay, wood chips, wood fibers, or straw are placed on the soil surface. In addition to stabilizing soils, mulching enhancse the absorption of water by the soil, reduce evaporation losses, regulate soil temperatures, and reduce the speed of storm water runoff over an area.

When and Where to Use It

Use erosion control mulching on level areas or on slopes up to 50 percent. Where soil is highly erodible, nets should only be used in connection with organic mulch such as straw and wood fiber.

Mulch is an effective ground cover when the establishment of vegetation is improbable due to severe weather conditions (winter conditions), poor soil, or steep slopes.

Installation

Grading is not necessary before mulching but may be required if vegetation is expected to grow.

Anchor loose hay or straw by applying tackifier, stapling netting over the top, or crimping with a mulch-crimping tool.

Effective use of netting and matting material requires firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material.

Materials that are heavy enough to stay in place (for example, bark or wood chips on flat slopes) do not need anchoring.

Apply hydro-mulch in spring, summer, or fall to prevent deterioration of mulch before vegetation becomes established.

There must be adequate coverage to prevent erosion, washout, and poor plant establishment. If an appropriate tacking agent is not applied, or is applied in insufficient amounts, mulch is lost to wind and runoff.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Repair or replace damaged areas of mulch or tie-down material immediately.

Straw Mulch

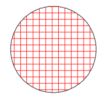
Straw Mulch with Tackifier

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Mulch blows away.	Anchor straw mulch in place by applying a tackifier, crimping, punching, or track walking. May need to use a different BMP.
Coverage is inadequate.	Follow recommended application rates. Ensure that the correct amount of material is implemented. Reapply as necessary.
Mulch has washed away.	Do not place mulch in concentrated flow areas. Reapply as necessary.
Area was improperly dressed before application.	Remove existing vegetation and roughen embankment and fill areas by rolling with a punch type roller or by track walking.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow onto stabilized area and/or to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Erosion Control Blankets (ECBs)

Plan Symbol



Description

Temporary erosion control blankets (ECBs) are products composed primarily of biologically, photochemically or otherwise degradable constituents such as wheat straw, coconut fiber, or aged curled excelsior wood product with longevity of approximately 1- to 3-years.

When and Where to Use It

ECBs are used for the temporary stabilization of soil immediately following seeding until the vegetative cover has grown and becomes established. ECBs provide temporary protection by degrading over time as the vegetation becomes established. Some products are effective for a few months while others degrade slowly and are effective for up to 3-years.

ECB Categories

- Class A (Slope Applications Only)
- Class B (Channel Applications Only).

Class A ECBs are for **slope applications only**.

- Applicable for slopes **2H:1V or flatter** only. Slopes greater than 2H:1V require Turf Reinforcement Matting (TRM).

Class B ECBs are for **channel applications**.

- Applicable for channels and concentrated flow areas with a maximum calculated shear stress **less than 1.75 lb/ft^2**. Channels and concentrated flow areas with design shear stresses greater than 1.75 lb/ft^2 require TRM

All acceptable Class A and Class B temporary erosion control blankets consisting of straw, coconut, or straw-coconut blends meet the following requirements:

- Utilize non-organic, photodegradable or biodegradable polypropylene netting.
- Consist of **double netted matting**, defined as matting with netting on both sides of the blanket. The top netting is degradable polypropylene with a maximum mesh opening of 0.75 inches by 0.75 inches. The bottom is degradable polypropylene with a maximum mesh opening of 0.5 inches by 0.5 inches.
- Be sewn on center a maximum of 2.0 inches

All acceptable Class A and Class B temporary erosion control blankets consisting of curled excelsior fibers meet the following requirements:

- Utilize non-organic, photodegradable or biodegradable polypropylene netting
- Consist of double netted matting. Double netted matting is matting with netting on both sides of the blanket. The degradable polypropylene top netting requires a maximum mesh opening of 1.0-inches by 1.0-inches, while the degradable polypropylene bottom netting requires a maximum mesh opening of 1.0-inches by 1.0-inches
- Consist of curled excelsior interlocking fibers with 80% of the fibers a minimum of 6-inches long
- Sewn on center a maximum of 4.0-inches.

Use Class A and Class B temporary erosion control blankets having the following Minimum Average Roll Values (MARV) for physical properties, as derived from quality control testing performed by a Geosynthetic Accreditation Institute – Laboratory Accreditation Program (GAI-LAP) accredited laboratory:

- Minimum mass per unit area (ASTM D6475) of 6 oz/yd^2 (203 g/m^2)
- Minimum thickness (ASTM D6525) of 0.25-inches (6 mm)
- Minimum initial grab tensile strength (ASTM D6818) of 75 x 75 lb/ft. (1 x 1 kN/m)
- Minimum roll width of 48-inches (1.22 m)
- For Class B channel applications, a minimum unvegetated shear stress of 1.0 lb/ft^2 (48 N/m^2) based on short-term peak flow duration of 0.5 hour is required.

Installation

Grade and compact areas to be protected with ECBs as indicated on the plans.

Remove large rocks, soil clods, vegetation, and other sharp objects that could keep the ECB from intimate contact with subgrade.

Prepare seedbed by loosening 2 to 3 inches of soil above final grade.

The proper installation of ECBs is different for each product, therefore the recommended installation procedure from the specific manufacturer should be followed.

When requested, a Manufacturer's Representative may be required to be on-site to oversee and approve the initial installation of the ECB. When requested, a letter from the Manufacturer approving the contractor installation may be required.

Inspection and Maintenance

- Inspect areas protected by ECBs for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Conduct regular inspections until grasses are firmly established.
- Adhere to the pinning or stapling pattern as shown on the Manufacturer's installation sheet. If there is evidence that the ECB is not securely fastened to the soil, require extra pins or staples to inhibit the ECB from becoming dislodged.
- If washout or breakage occurs, repair all damaged areas immediately by restoring the soil on slopes or channels to its finished grade, re-apply fertilizer and seed, and replacing the appropriate ECB material as needed.

ECB Channel Design Criteria

The design of a permanent conveyance with a grassed or vegetative lining should address the bare condition prior to vegetation being established. An ECB will protect the conveyance during this period. Use both the tractive force and the permissible velocity methods to determine the level of protection that is required.

The design of ECBs is based on the anticipated shear stresses and maximum flow velocities the fabric will encounter. Once the design shear stresses and maximum flow velocities are known, select a corresponding ECB that meets the conditions from the SCDOT approved product list.

- The governing equation for maximum channel shear stress is:

$$\tau = \gamma\, d_n\, S$$

Where:

τ = maximum shear stress (lbs/ft^2)
γ = unit weight of water = 62.4 lbs/ft^3
d_n = maximum normal channel flow depth (ft)
S = channel bed slope (ft/ft)

The following variables are required to determine the maximum velocity in a channel for a 10-year 24-hour storm event.

- Design peak flow rate value in cubic feet per second (cfs) for the 10-year 24-hour storm,
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape,
- Channel bed slope,
- Manning's channel roughness coefficient (n) of the ECB from the following conditions:
  - Bare ECB with no vegetation,
  - ECB with maintained vegetation, and
  - ECB with un-maintained vegetation, and
- Normal channel flow depth (d_n) based on peak flow rate, channel dimensions and Manning's n value.

The governing equation for maximum velocity is Manning's Equation:

$$V = (1.49 / n)\ R^{2/3}\ S^{1/2}$$

Where :

V = Maximum velocity (ft/sec)
n = Manning's channel roughness coefficient
R = Hydraulic radius of the flow based on d_n (ft)
S = Channel bed slope (ft/ft)

ECB Slope Application

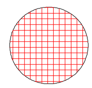
ECB Slope Application

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Undercutting occurs along the top of the slope.	Dig a 6-x 6-inch trench along the top of the slope and anchor blanket into trench by back filling and tamping the soil.
Blankets separate along the seams.	Overlap adjacent blanket 2- to 3-inch and staple every 3-feet.
Blankets separate where the rolls are attached end to end.	Shingle the blanket so the top blanket covers the bottom blanket by 6-inches and staple through the overlapped areas every 12-inches.
Blanket does not make complete contact with the soil surface.	Prepare the soil surface by removing rocks, clods, sticks and vegetation, fill in rill, and uneven areas.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow on stabilized area. Use other BMPs to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Turf Reinforcement Mats (TRMs)

Plan Symbol



Description

Turf Reinforcement Mats are products composed primarily of nondegradable products that enhance the ability of living plants to stabilize soils. They bind with roots to reinforce the soil matrix with longevity greater than 5-years.

When and Where to Use It

Use TRMs where vegetation alone will not hold a slope or streambank. TRMs enable the use of "green" solutions in areas where only "hard" solutions such as riprap or concrete linings were viable in the past.

TRM Categories

- Type 1, Type 2, Type 3, and Type 4.

Types 1 & 2 TRMs are a strong three-dimensional stable net structure. A degradable fiber matrix may be included to provide immediate coverage for bare soil.

- **Type 1** matting should be placed on slopes **2H:1V or flatter** or in channels where the calculated design shear stress is **4.0 lb/ft2 or less** and the design flow velocity is **up to 10 fps**.
- **Type 2** matting should be placed on slopes **1.5H:1V or flatter** or in channels where the calculated design shear stress is **6.0 lb/ft2 or less** and the design flow velocity is **up to 15 fps**.
- **Type 3** TRMs are a strong three-dimensional stable net structure providing sufficient thickness, strength, and void space to capture and retain soil and allow for the development of root growth and vegetation within the matrix. Matting of this type should be placed on slopes **1H:1V or flatter** or in channels where the calculated design shear stress is **8.0 lb/ft2 or less** and the design flow velocity is **up to 20 fps**
- **Type 4** (High Survivability) TRMs are specially designed geosynthetics for erosion control applications on steep slopes and vegetated waterways.

o All components of Type 4 TRMs should be 100% synthetic and resistant to biological, chemical, and ultraviolet degradation.

o Matting of this type should be placed on slopes **1H:1V or greater** or in channels where the calculated design shear stress is **up to 12 lb/ft2** and the design flow velocity is **up to 25 fps**.

o This category is used when field conditions exist with high loading and/or high survivability requirements such as maintenance, structural backfills protecting critical structures, utility cuts, potential traffic areas, abrasion, higher factors of safety and/or general durability concerns.

All primary TRM matrix materials are defined as long-term, non-degradable materials designed to reduce soil erosion and assist in the growth, establishment, and protection of vegetation for a period of time exceeding 5 years.
The major structural components of Type 1 and Type 2 TRMs are 100% synthetic and resistant to biological, chemical, and ultraviolet degradation. A degradable fiber matrix may be included to provide immediate coverage for bare soil. All components of Type 3 and Type 4 TRMs are 100% synthetic and resistant to biological, chemical, and ultraviolet degradation.

Installation

Grade and compact areas to be protected with TRMs as indicated on the plans.

Remove large rocks, soil clods, vegetation, and other sharp objects that could keep the TRM from intimate contact with subgrade.

Prepare seedbed by loosening 2 to 3 inches of soil above final grade.

The proper installation of TRMs is different for each product, therefore the recommended installation procedure from the specific manufacturer should be followed.

When requested, a Manufacturer's Representative may be required to be on-site to oversee and approve the initial installation of the TRM. When requested, a letter from the Manufacturer approving the contractor installation may be required.

Inspection and Maintenance

- Check areas protected by TRMs for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Conduct regular inspections until grasses are firmly established.
- Adhere to the pinning or stapling pattern as shown on the Manufacturer's installation sheet. If there is evidence that the TRM is not securely fastened to the soil, install extra pins or staples to inhibit the TRM from becoming dislodged.
- If washout or breakage occurs, repair all damaged areas immediately by restoring the soil on slopes or channels to its finished grade, re-apply fertilizer and seed, and replacing the appropriate TRM material as needed.

TRM Channel Design Criteria

When designing a permanent conveyance with a grassed or vegetative lining, the design should address the bare condition prior to vegetation being established. A geotextile lining may be applied to protect the conveyance during this period. It is important to use both the tractive force and the permissible velocity methods to determine the level of protection that is required.

The design of TRMs is based on the anticipated shear stresses and maximum flow velocities the fabric will encounter. Once the design shear stresses and maximum flow velocities are known, a corresponding TRM that meets the conditions may be selected from the SCDOT approved products list.

- The governing equation for maximum channel shear stress is:

$$\tau = \gamma\, d_n\, S$$

Where :

τ	=	maximum shear stress (lbs/ft^2)
γ	=	unit weight of water = 62.4 lbs/ft^3
d_n	=	maximum normal channel flow depth (ft)
S	=	channel bed slope (ft/ft)

The following variables are required to determine the maximum velocity in a channel for a 10-year 24-hour storm event.

- Design peak flow rate value in cubic feet per second (cfs) for the 10-year 24-hour storm,
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape,
- Channel bed slope,
- Manning's channel roughness coefficient (n) of the TRM based on the following,
  - Bare matting with no vegetation,
  - Matting with maintained vegetation, and
  - Matting with un-maintained vegetation, and
- Normal channel flow depth (d_n) based on peak flow rate, channel dimensions, and Manning's n value.

- The governing equation for maximum velocity is Manning's Equation:

$$V = (1.49 / n)\ R^{2/3}\ S^{1/2}$$

Where :

V	=	Maximum velocity (ft/sec)
n	=	Manning's channel roughness coefficient
R	=	Hydraulic radius of the flow based on d_n (ft)
S	=	Channel bed slope (ft/ft)

TRM Slope Application

TRM Channel Application

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Improper anchoring.	Dig trench along the top and bury the blankets. Use staples to anchor according to manufacturer's recommendations.
Undercutting due to inadequate preparation.	Prepare the soil surface. Remove rocks, clods, and other obstructions. Fill in rills in uneven areas to promote good contact between mat and soil.
Excessive water flows across stabilized slope surface.	Use other BMPs to limit flow on stabilized area. Use other BMPs to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Flexible Growth Media/Matrix

Plan Symbol

Description

A Flexible Growth Matrix (FGM) combines both chemical and mechanical bonding techniques to lock the matrix in place. FGM is composed of crimped, manmade fibers, organic fibers, and performance-enhancing additives that form a lofty, interlocking matrix. FGM has air spaces and water-absorbing cavities that improve seed germination, reduce the impact of raindrop energy, and minimize soil loss. Water insoluble tackifiers and flocculants chemically bond the matrix to the soil surface.

When and Where to Use It

FGM is applicable for the following situations:

- As a Type A Temporary Erosion Control Blanket
- Slopes up to 2H:1V
- As an infill for TRMs on slopes greater than 2H:1V
- Environmentally sensitive areas not compatible for netting
- When the required longevity of soil protection is up to 1 year
- When the site requires immediate erosion protection and there is a risk of impending weather
- When fast vegetation establishment is required
- When a high factor of design safety is required.

FGM is **not** applicable as a channel liner or for areas receiving concentrated flow. Applicable FGM may be selected from the SCDOT approved products list.

Installation

All FGM components are pre-packaged by the Manufacturer to assure material performance. Under no circumstances is field mixing of materials, additives or components accepted. Examine substrates and conditions where materials will be applied. Apply FGM to geotechnically stable slopes that have been designed and constructed to divert runoff away from the face of the slope. Do not proceed with installation until satisfactory conditions are established.

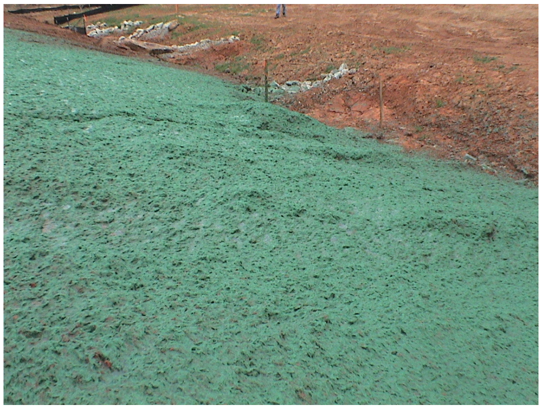
Install FGM with a contractor who is certified and trained by the Manufacturer in the proper procedures for mixing and applying the FGM. Strictly comply with the Manufacturer's mixing recommendations and installation instructions. Use approved hydraulic seeding/mulching machines with fan-type nozzle (50-degree tip) for FGM applications. Apply FGM from opposing directions to the soil surface in successive layers, reducing the “shadow effect” to achieve maximum coverage of all exposed soil. FGM does not require a cure time and is effective immediately such that FGM may be applied immediately before, during or after a rainfall event. Install FGM materials according to the Manufacturer’s application rates.

Inspection and Maintenance

- Check areas protected by FGM for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Reapply FGM to disturbed areas that require continued erosion control.

- Maintain equipment to provide uniform application rates. Rinse all mixing and application equipment thoroughly with water to avoid formation of residues and discharge rinse water appropriately.
- Degradation of FGM is expected to occur as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply FGM in accordance with the Manufacturer's instructions. Reapplication is not required unless FGM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

FGM Application



FGM

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope areas have eroded due to concentrated flows.	Make sure the upper end of the slope has a berm constructed to eliminate concentrated flows from flowing down the slope. Slope length may be too long and concentrated flows are occurring. Use sediment tubes or other practices to provide slope breaks. Re-apply FGM to the eroded areas once the concentration problem has been resolved.
Rain event is impending.	FGM does not require a cure time and is effective immediately such that FGM may be applied immediately before, during or after a rainfall event.
FGM has degraded.	FGM has a longevity of soil protection up to 1 year. In some instances degradation of FGM occurs as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply FGM in accordance with the Manufacturer's instructions. Reapplication is not required unless FGM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

Bonded Fiber Matrix (BFM)

Plan Symbol

Description

A Bonded Fiber Matrix (BFM) is a continuous layer of non-toxic, degradable, elongated fiber materials held together by water insoluble bonding agents. BFM eliminates direct raindrop impact on soil, allows no gaps between the product and the soil, and has a high water-holding capacity. BFMs do not form a water-insensitive crust that can inhibit plant growth. BFMs are completely photo- and biodegradable.

When and Where to Use It

BFMs are applicable when:

- Enhancement of temporary seeding operations to reduce erosion and expedite seed germination
- A high performance mulch is required for permanent seeding
- Seeding application will take place on highly erodible soil or slopes
- Slopes up to 1H:1V
- The required functional longevity of soil protection is 6 months or less
- The soil is dry and rain is not expected within 48 hours after application
- There is a high degree of certainty that heavy rains will not follow application.

BFMs are **not** applicable as Type A Temporary Erosion Control Blankets, channel liners or for areas receiving concentrated flow. Applicable BFM may be selected from the SCDHEC approved products list.

Installation

All BFM components are pre-packaged by the Manufacturer to assure material performance. Under no circumstances is field mixing of materials, additives or components accepted. Examine substrates and conditions where materials will be applied. Do not proceed with installation until unsatisfactory conditions are corrected. Apply BFM to geotechnically stable slopes that have been designed and built to divert runoff water away from the face of the slope, eliminating damage to the slope face caused by the surface flow from above the slope.

Install BFM with a contractor who is certified and trained by the Manufacturer in the proper procedures for mixing and applying the BFM. Strictly comply with the Manufacturer's mixing recommendations and installation instructions. Use approved hydraulic seeding/mulching machines with fan-type nozzle (50-degree tip) for BFM applications. Apply BFM from opposing directions to the soil surface in successive layers, reducing the "shadow effect" to achieve maximum coverage of all exposed soil. Do not apply the BFM immediately before, during or after rainfall. Allow the BFM a minimum of 24 hours to dry after installation. Do not exceed maximum slope length of 100 feet when slope gradients are steeper than 4H:1V. Install BFMs at a general application rate of 3500 pounds per acre.

Inspection and Maintenance

- Check areas protected by BFM for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Reapply BFM to disturbed areas that require continued erosion control.
- Maintain equipment to provide uniform application rates.

- Rinse all BFM mixing and application equipment thoroughly with water to avoid formation of residues and discharge rinse water appropriately.
- Degradation of BFM is expected to occur as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply BFM in accordance with the Manufacturer's instructions. Reapplication is not required unless BFM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

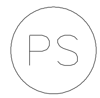
BFM Application

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope areas have eroded due to concentrated flows.	Make sure the upper end of the slope has a berm constructed to eliminate concentrated flows from flowing down the slope. Slope length may be too long and concentrated flows are occurring. Use sediment tubes or other practices to provide slope breaks. Re-apply BFM to the eroded areas once the concentration problem has been resolved.
Rain event is impending.	BFM requires a cure time. Do not apply the BFM immediately before, during or after rainfall. Allow the BFM a minimum of 24 hours to dry after installation.
BFM has degraded.	BFM has longevity of soil protection up to 6-months. In some instances degradation of BFM occurs as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply BFM in accordance with the Manufacturer's instructions. Reapplication is not required unless BFM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

Permanent Seeding

Plan Symbol



Description

Controlling runoff and preventing erosion by establishing a perennial vegetative cover with seed.

When and Where to Use It

A major consideration in the selection of the type of permanent grass to establish is the intended use of the land. Land use is separated in to two categories, high-maintenance and low-maintenance.

High-maintenance

High maintenance areas are mowed frequently, lime or fertilized on a regular basis, and require maintenance to an aesthetic standard. Land uses with high maintenance grasses include homes, industrial parks, schools, churches, and recreational areas such as parks, athletic fields, and golf courses.

Low-maintenance

Low maintenance areas are mowed infrequently, if at all, and lime and fertilizer may not be applied on a regular schedule. These areas are not subject to intense use and do not require a uniform appearance. The vegetation must be able to survive with little maintenance over long periods of time. Grass and legume mixtures are favored in these areas because legumes are capable of fixing nitrogen in the soil for their own use and the use of the grasses around them. Land uses requiring low-maintenance grasses include steep slopes, stream and channel banks, road banks, and commercial and industrial areas with limited access.

Seed Selection

The use of native species is preferred when selecting vegetation. Base plant seed selection on geographical location, the type of soil, the season of the year in which the planting is to be done, and the needs and desires of the permanent land user. Failure to carefully follow agronomic recommendations results in an inadequate stand of permanent vegetation that provides little or no erosion control.

Installation

Topsoil

Apply topsoil if the surface soil of the seedbed is not adequate for plant growth.

Tillage

If the area has been recently plowed, no tillage is required other than raking or surface roughening to break any crust that has formed leaving a textured surface. Disk the soil for optimal germination when the soil is compacted less than 6-inches. If the soil is compacted more than 6-inches, sub-soiled and disk the area.

Soil Testing

Soil testing is available through Clemson University Cooperative Extension Service.

Lime

Unless a specific soil test indicates otherwise, apply 1½ tons of ground course textured agricultural limestone per acre (70 pounds per 1000 square feet).

Fertilizer

Apply a minimum of 1000 pounds per acre of a complete 10-10-10 fertilizer (23 pounds per 1000 square feet) or equivalent during permanent seeding of grasses unless a soil test indicates a different requirement. Incorporate fertilizer and lime (if used) into the top 4-6 inches of the soil by disking or other means where conditions allow. Do not mix the lime and the fertilizer prior to the field application.

Seeding

Loosen the surface of the soil just before broadcasting the seed. Evenly apply seed by the most convenient method available for the type of seed applied and the location of the seeding. Typical application methods include but are not limited to cyclone seeders, rotary spreaders, drop spreaders, broadcast spreaders, hand spreaders, cultipacker seeder, and hydro-seeders. Cover applied seed by raking or dragging a chain or brush mat, and then lightly firm the area with a roller or cultipacker. Do not roll seed that is applied with a hydro-seeder and hydro-mulch.

Mulching

Cover all permanent seeded areas with mulch immediately upon completion of the seeding application to retain soil moisture and reduce erosion during establishment of vegetation. Apply the mulch evenly in such a manner that it provides a minimum of 75% coverage. Typical mulch applications include straw, wood fiber, hydromulches, BFM and FGM. Use hydromulches with a minimum blend of 70% wood fibers.

The most commonly accepted mulch used in conjunction with permanent seeding is small grain straw. Select straw that is dry and free from mold damage and noxious weeds. The straw may need to be anchored with netting or asphalt emulsions to prevent it from being blown or washed away. Apply straw mulch by hand or machine at the rate 2 tons per acre (90 pounds per 1000 square feet). Frequent inspections are necessary to check that conditions for growth are good.

Irrigation

Keep permanent seeded areas adequately moist, especially late in the specific growing season. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water wastes water and can cause erosion.

Re-seeding

Inspect permanently seeded areas for failure, make necessary repairs and re-seed or overseed within the same growing season if possible. If the grass cover is sparse or patchy, re-evaluate the choice of grass and quantities of lime and fertilizer applied. Final stabilization by permanent seeding of the site requires that it be covered by a 70% coverage rate.

Inspection and Maintenance

- Inspect seeded areas for failure and make necessary repairs and re-seed immediately. Conduct a follow-up survey after one year and replace failed plants where necessary.
- If vegetative cover is inadequate to prevent rill erosion, overseed and fertilize in accordance with soil test results.
- If a stand of permanent vegetation has less than 40 percent cover, re-evaluate choice of plant materials and quantities of lime and fertilizer.
- Re-establish the stand following seed bed preparation and seeding recommendations, omitting lime and fertilizer in the absence of soil test results.
- If the season prevents re-sowing, mulch is an effective temporary cover.
- Final stabilization of the site requires a 70 percent overall coverage rate. This does not mean that 30 percent of the site can remain bare. The coverage is defined as looking at a square yard of coverage, in which 70 percent of that square yard is covered with vegetation.

Permanent Seeding

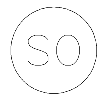
Permanent Seeding

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Areas have eroded.	Re-seed or replace eroded areas.
Vegetation cover is inadequate and rill erosion is occurring.	Overseed and fertilize in accordance with soil test results.
Stand of permanent vegetation has less than 40% cover.	Re-evaluate choice of plant materials and quantities of lime and fertilizer.
Vegetation show signs of wilting before noon.	Water vegetation by wetting soil to a depth of 4-inches.

Sodding

Plan Symbol



Description

Sodding is transplanting vegetative sections of plant materials to promptly stabilize areas that are subject to erosion. Use commercial sod which is a cultured product utilizing specific grass species.

When and Where to Use It

Sodding is appropriate for any graded or cleared area that may erode, and where a permanent, long-lived plant cover is immediately needed. Examples of where sodding is used are yards, buffer zones, streambanks, dikes, swales, slopes, outlets, level spreaders, and filter strips.

Installation

In general, do not use sod on slopes greater than 2H:1V or 3H:1V if it is to be mowed. If sod is placed on steep slopes, lay it with staggered joints and/or staple the sod down.

Clear the soil surface of trash, debris, roots, branches and soil clods in excess of 2-inches length or diameter. Rake soil surface to break crust just before laying sod or irrigate soil lightly if the soil is dry. Do not install sod on hot, dry or frozen soil, gravel, compacted clay, or pesticide treated soils.

Harvest, deliver and install sod within a period of 36-hours. Store rolls of sod in shade during installation. Sod should be free of weeds and be of uniform thickness, about 1-inch, and should have a dense root mat for mechanical strength.

Lay strips of sod beginning at the lowest area to be sodded with the longest dimension of the strip perpendicular to the slope, and stagger in a brick-like pattern. Wedge strips securely in place. Square the ends of each strip to provide for a close, tight fit. Match angled ends correctly to prevent voids.

Roll or compact immediately after installation to ensure firm contact with the underlying topsoil.

Irrigate the sod until the soil is wet to a depth of 2-inches, and keep moist until grass takes root.

Inspection and Maintenance

- Watering may be necessary after planting and during periods of intense heat and/or lack of rain (drought). Keep soil moist to a depth of 2-inches until sod is fully rooted.
- Mow to a height of 2 to 3 inches after sod is well-rooted (2-3 weeks). Do not remove more than 1/3 of the shoot in any one mowing.
- Permanent, fine turf areas require yearly applications of fertilizer and lime.
- Inspect the sod frequently after it is first installed, especially after large storm events, until it has established a permanent cover.

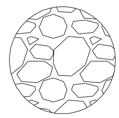
Sodding

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Drought	Keep soil moist to a depth of 2-inches until sod is fully rooted

Riprap

Plan Symbol



Description

Riprap is a permanent, erosion-resistant channel lining aggregate consisting of large, loose, angular stone with a filter fabric or granular underlining. The purpose of riprap is to:

- Protect the soil from the erosive force of concentrated runoff
- Slow runoff velocities while enhancing the potential for infiltration

The filter fabric or granular underlining prevents undermining of the riprap layer by the migration of soil particles under seepage forces through the riprap.

When and Where to Use It

The preferred method of slope and channel protection is the use of vegetation. If vegetation can not withstand the design flows, ECBs and TRMs are the preferred and suggested method of protection. When conditions are too severe for vegetation and TRMs, riprap may be used for erosion control and protection. Riprap is used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, drop structures, at the toe of slopes, and in transitions from concrete channels to vegetated channels. Riprap sizes are designed by the diameter or by the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be angular instead of spherical.

Installation

Place a lining of geotextile filter fabric or granular filter material between the riprap and the underlying soil surface to prevent soil movement into or through the riprap.

Inspection and Maintenance

- Once a riprap installation has been completed, it should require very little maintenance.
- It should, however, be inspected periodically to determine if high flows have caused scour beneath the riprap and filter fabric or dislodged any of the stone.
- Care must be taken to properly control sediment-laden construction runoff that may drain to the point of the new installation. If repairs are needed, they should be performed immediately.

Riprap Design Criteria

Riprap at Outlets

Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlet of drainage structure are given in the Outlet Protection section of this Manual.

Riprap for Channel Stabilization

Design of erosion protection within the channel can be accomplished using the FHWA Tangent Flow Method presented below. This method is applicable to both straight and curved channel sections where flows are tangent to channel bank. The Tangent Flow Method determines a stable rock size for straight and curved channel sections using known shape, flow depth, and channel slope dimensions. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3H:1V, the stone size must be modified. The final design size will be stable on both the sides and bottom of the channel.

Straight Channel Sections

1. Refer to the graph shown in Figures RR1 with the maximum flow depth (**d** in feet) and channel slope (ft/ft). Select the point where the maximum flow depth and channel slope intersect. Choose the $\mathbf{d_{50initial}}$ stone size based upon the location of the point of intersection.

2. This completes the design procedure for channels with side slopes 3H:1V and flatter. If the channel side slopes are steeper than 3H:1V, continue with step 3.

3. Refer to the graph shown in Figure RR2 with the side slope (**Z** in H:V) and the base width **(B)** to maximum depth **(d)** ratio **(B/d)**. Where the two lines intersect, move horizontally left to read $\mathbf{K_1}$.

4. Determine from the graph in Figure RR3 the angle of repose for the $\mathbf{d_{50initial}}$ stone size and the channel side slope **Z**. (Use an angle of 42^o for $\mathbf{d_{50initial}}$ >10-inches. Do not use riprap on slopes steeper than the angle of repose for the stone size.)

5. Refer to the graph shown in Figure RR4 with the side slope **(Z)** of the channel and the angle of repose for the $\mathbf{d_{50initial}}$ stone size. Where the two lines intersect, move vertically down to read $\mathbf{K_2}$.

6. Compute $\mathbf{d_{50initial} \times K_1/K_2 = d_{50design}}$ to determine the correct size stone for the bottom and side slopes of straight sections of channel.

Curved Channel Sections

1. Refer to steps 1-6 under Straight Channel Sections
2. Determine the radius of the curved section $(\mathbf{R_O})$ in feet.
3. Calculate the top width of the riprap at the design water surface $(\mathbf{B_S})$ in feet

B_S	=	$B_O + 2(Z*D)$
B_O	=	Bottom width of channel (feet)
Z	=	Channel sides slopes defined as ZH:1V
D	=	Depth of riprap (feet)

4. Calculate the Ratio $\mathbf{B_S / R_O}$
5. Knowing the value of the $\mathbf{B_S/R_O}$ ratio from step 4, use the graph in Figure RR5 and read the corresponding value of $\mathbf{K_3}$.
6. Compute $\mathbf{(d_{50design} \times K_3) = d_{50curve}}$ to determine the correct size stone for the bottom and side slopes of curved channel sections.

Straight Channel Design Example

Given: Trapezoidal channel depth (D) 3-feet, bottom width (B_o) 8-feet, side slopes (Z) 2H:1V, and a 2 percent slope.

Find: A stable riprap size for the bottom and side slopes of the channel.

Solution:

1. From Figure RR1, for a 3-foot-deep channel over a 2 percent grade,
   Read $d_{50initial}$ = 0.75-feet or 9-inches.

2. Since the side slopes are steeper than 3H:1V, continue with step 3
   **If side slopes were less than 3H:1V, the process would be complete.

3. From Figure RR2, B_O/d = 8/3 = 2.67, Side slopes Z = 2,
   Read K_1 = 0.82.

4. From Figure RR3, for $d_{50initial}$ = 9-inches,
   Read Angle of Repose = 41

5. From Figure RR4, side slopes Z = 2, and Angle of Repose = 41 ,
   Read K_2 = 0.73.

6. Stable Riprap = $d_{50design}$ x (K_1/K_2) = 0.75 x (0.82/0.73) = 0.84-feet or 10-inches

Curved Channel Design Example

Given: The preceding straight channel example has a curved section with a radius of 50-feet.

Find: A stable riprap size for the bottom and side slopes of the curved channel section.

Solution:

1. Stable Riprap = $d_{50design}$ 10-inches from straight channel calculations.

2. R_O = 50-feet.

3. Calculate Channel Top Width of Water Surface
   $B_S = B_O + 2(Z*D) = 8 + 2(2*3) = 20$-feet.

4. Calculate the Ratio B_S / R_O
   = 20/50 = 0.40

5. From Figure RR5, for B_S / R_O = 0.40
   Read K_3 = 1.1

6. $d_{50curve} = d_{50design} \times K_3$ = (0.84-ft. x 1.1) = 0.92-feet or 11-inches.

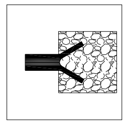
Riprap Lined Channel

Preventive Measures and Troubleshooting Guide

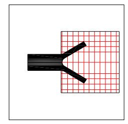
Field Condition	Common Solutions
High flows causing scour beneath riprap or filter fabric dislodging the stone.	Replace filter fabric and rearrange stone appropriately.
Riprap blocks channel, causing erosion along edges.	Make sure excavation is deep enough, rearrange riprap appropriately.
Piping or slumping occurs.	Make sure filter fabric was installed and make sure it isn't damaged.
Stones have moved and erosion of foundation has occurred.	Make sure riprap is properly graded.
Undercut riprap slope and slumping occurring.	Check to be sure that foundation toe is properly reinforced.
Stone displacement occurring.	Make sure fill slopes have been properly compacted, remove debris and make needed repairs.

Outlet Protection

Plan Symbol



RipRap



ECB or TRM

Description

Outlet protection dissipates the energy of concentrated storm water flows reducing erosion or scouring at storm water outlets. In addition, outlet protection lowers the potential for downstream erosion. Outlet protection is achieved through a variety of techniques, including turf reinforcement mats (TRMs), riprap, concrete aprons, paved sections and other structural measures.

The techniques outlined in this section are not the only techniques that may be used for outlet protection design. This section shows one method for outlet protection design as an example of the variables that need to be considered in the design. Other methods utilized that are not discussed in this Handbook should include all graphs, charts, and calculations verifying that the protection will handle the peak flow velocity, flow depths, and shear stress.

Outlet Protection Design Criteria

The design of outlets for pipes and channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous lining and protection of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10 percent should not be protected using just outlet protection. This causes re-concentration of the flow resulting in increased velocities when the flow leaves the protection area. Outlet protection may be designed according to the following criteria:

1. The design flow velocity exiting the outlet at design capacity **should not** exceed the permissible velocity of receiving area.

2. Tailwater Depth:
   Tailwater is the water depth at the downstream end or outfall of the culvert. The depth of tailwater immediately below the outlet protection must be determined for the design capacity of the pipe.

   Minimum Tailwater Condition is defined as a tailwater depth less than ½ the diameter of the outlet pipe. Pipes that outlet onto flat areas with no defined channel have a minimum tailwater condition.

   Maximum Tailwater Condition is defined as a tailwater depth greater than ½ the pipe diameter.

3. Protection Length:
   The required protection length, L_a, according to the tailwater condition, should be determined from Figure OP1(minimum tailwater condition) or Figure OP2 (maximum tailwater condition).

4. Protection Width: When the pipe discharges directly into a well-defined channel, the protection should 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).

- If the outlet discharges onto a flat area with no defined channel, the width of the protection should be determined with a Minimum Tailwater Condition:

  Design the upstream end of the protection, adjacent to the outlet, with a width three times the diameter of the outlet pipe (3D). Design the downstream end of the protection with a width equal to the pipe diameter plus the length of the apron ($D + L_a$).

- For a Maximum Tailwater Condition, design the downstream end of the protection with a width equal to the pipe diameter plus 0.4 times the length of the apron ($D + 0.4 * L_a$).

5. Bottom Grade: Construct the protection with no slope along its length (0 percent grade) where applicable. The downstream invert elevation of the protection is equal to the elevation of the invert of the receiving channel. There is no overfalling at the end of the protection.

6. Side Slopes: If the outlet discharges into a well-defined channel, the receiving side slopes of the channel should not be steeper than 3H: 1V.

7. Alignment: Locate the protection so there are no bends in the horizontal alignment.

8. Materials:

- The preferred protection lining is an appropriate permanent turf reinforcement matting (TRM). Calculate the shear stress and maximum velocity to determine the applicable TRM.
- When conditions are too severe for TRMs the protection may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median-sized stone for riprap may be determined from design figures according to the tailwater condition.
- In all cases, place a non-woven geotextile filter cloth between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the required physical properties for filter cloth.

Installation

- Do not protect pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% with only outlet protection. This causes re-concentration of the flow that results in large velocities when the flow leaves the protection area.
- Follow specific standards for installation of the selected materials used for outlet protection.
- Follow all Manufacturer’s installation procedures for TRMs and other manufactured products.
- A Manufacturer’s Representative may be required to oversee all installation procedures and officially approve the installation of manufactured products used for outlet protection.

Inspection and Maintenance

- Periodically check all outlet protection, aprons, plunge pools, and structural outlets for damage. Immediately make all needed repairs to prevent further damage.
- If any evidence of erosion or scouring is apparent, modify the design as needed to provide long term protection (keeping in mind fish passage requirements if applicable).
- Inspect outlet structures after heavy rains to see if any erosion has taken place around or below the structure.

Outlet Protection Design Example

Given: An 18-inch pipe discharges 24 cfs at design capacity onto a grassy slope (no defined channel).
Find: The required length, width, and median stone size (d_{50}) for riprap lined protection.
Solution:

1. The pipe discharges onto a grassy slope with no defined channel, a **Minimum Tailwater Condition**.

2. From Figure OP1, the intersection of a discharge of 24 cfs and a pipe diameter **(d)** of 18-inches, Gives a protection length (L_a) of 20-feet.

3. From Figure OP1, the intersection of a discharge of 24 cfs and a pipe diameter **(d)** of 18-inches. Gives a median stone size (d_{50}) of 0.8-ft.

4. The upstream protection width equals 3 times the pipe diameter ($3D_o$) = 3 x 1.5-feet = 4.5-feet

5. The downstream protection width equals apron length (L_a)+ pipe diameter **(d)** ; = 20-feet + 1.5-feet = **21.5-feet**

The table below provides general information for sizing rock and outlet aprons for various sized pipes

Pipe Size (inches)	Average Rock Diameter (inches)	Apron Width (feet)	Apron Length for Low Flow (feet)	Apron Length for High Flow (feet)
8	3	2-3	3-5	5-7
12	5	3-4	4-6	8-12
18	8	4-6	6-8	12-18
24	10	6-8	8-12	18-22
30	12	8-10	12-14	22-28
36	14	10-12	14-16	28-32
42	16	12-14	16-18	32-38
48	20	14-16	18-25	38-44

Riprap Outlet Protection

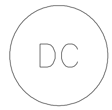
Riprap Outlet Protection

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Riprap washes away.	Replace riprap with a larger diameter stone based on the pipe diameter and discharge velocity.
Apron is displaced.	Align apron with receiving water and keep it straight throughout its length. Repair damaged fabric and/or replace riprap that has washed away.
Scour occurs around apron or riprap.	Remove damaged TRM or riprap, fill in scoured areas, and repair damage to slopes channels or underlying filter fabric. Reinstall outlet protection.
Outlet erodes.	Stabilize TRM outlets with vegetation, replace eroded riprap; grout riprap.

Dust Control

Plan Symbol



Description

Wind erosion occurs when the surface soil is loose and dry, vegetation is sparse or absent, the wind is sufficiently strong, and when construction traffic disturbs the soil. Wind erodes soils and transports the sediment off site in the form of fugitive dust, where it may be washed into receiving water bodies by the next rainfall event. Fugitive dust is a nuisance for neighbors. It settles on automobiles, structures and windows and finds its way into homes. It also makes breathing difficult for those with respiratory problems and becomes a safety problem when it blinds motorists, equipment operators, and laborers.

When and Where to Use It

Utilize dust control methods whenever there are offsite impacts, especially during periods of drought. Implemented dust control until final stabilization is reached.

Dust Control Design Criteria

There are many methods to control dust on construction sites. These methods include but are not limited to :

- Phasing the Project. Phasing is done to decrease the area of disturbed soil that is exposed to erosion. The smaller the amount of soil that is exposed at one time, the smaller the potential for dust generation. Phasing a project and utilizing temporary stabilization practices can significantly reduce dust emissions.
- Vegetative Cover. A vegetative cover helps reduce wind erosion. Vegetative Cover is for disturbed areas not subject to traffic. Vegetation provides the most practical method of dust control.
- Mulch. Mulching offers a temporary way to stabilize the soil and prevent erosion. Mulching offers a fast, effective means of controlling dust.
- Sprinkling Water. Sprinkling helps control the suspension of dust particles and promotes dust to settle out of the air. Sprinkling water is effective for dust control on haul roads and other traffic routes.
- Spray-on-Adhesive. Adhesives prevent soil from blowing away. Latex emulsions, or resin in water is sprayed onto mineral soils to prevent their blowing away and reduce dust caused by traffic.
- Calcium Chloride. Calcium chloride keeps the soil surface moist and prevents erosion. Calcium chloride is applied by mechanical spreaders as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.
- Barriers. Barriers are fences that prevent erosion by obstructing the wind near the ground stopping the soil from blowing offsite. Broad, wind, or sediment fences can control air currents and blowing soil. Barriers are not a substitute for permanent stabilization. Perennial grass and strands of existing trees may also serve as wind barriers.

Inspection and Maintenance

- Add additional dust control or re-spray area as necessary to keep dust to a minimum.
- Spray exposed soil areas only with approved dust control agents as indicated by the SCDHEC Standard Specifications.

Dust Control by Sprinkling Water

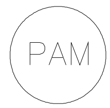
Dust Control by Sprinkling Water

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive dust leaves the site.	Increase frequency of dust control application. Consider using a palliative or binder on inactive areas.
Vehicles kick up dust.	Water more frequently. Limit vehicle speeds. Stabilize the roadway.
Watering for dust control causes erosion.	Reduce water pressure on the water truck. Check watering equipment to ensure that it has a positive shutoff. Water less frequently.
Sprayed areas are ineffective at limiting dust.	Re-spray areas and ensure that the application rate is proper. Try another product or method if current dust control is not effective.

Polyacrylamides (PAMs)

Plan Symbol



Description

Anionic polyacrylamides (PAM) are non-toxic chemical materials used for controlling soil erosion and sedimentation on construction and agricultural sites.

When and Where to Use It

Anionic PAM is available in emulsions, powders, gel bars, or logs. It is recommended that other BMPs be used in combination with anionic PAM. The use of seed and mulch for additional erosion protection beyond the life of the anionic PAM is required. Repeat application is recommended if disturbance occurs to target areas. The following are additional recommendations:

- Use setbacks when applying anionic PAM near natural waterbodies.
- Consider that decreased performance can occur due to ultra-violet light and time after mixing when applying anionic PAM.
- In concentration channels, the effectiveness of anionic PAM for stabilization decreases.
- If seed is applied with anionic PAM, mulch should be used to protect seed.
- Never add water to PAM, PAM must be slowly added to water.
- NOT ALL POLYMERS ARE PAM.

Installation

The manufacturer's guidelines for application should be followed.

- Only use the anionic form of PAM. Cationic PAM is toxic and should NOT be used.
- PAM and PAM mixtures have to be environmentally harmless, harmless to fish, wildlife, and plants.
- The pure form of anionic PAM should have less than or equal to 0.05 percent acrylamide monomer by weight, as established by FDA and EPA.
- In order to maintain less than or equal to 0.05 percent of acrylamide monomer, the maximum application rate of PAM, in pure form, should not exceed 200 pounds/acre/year. Do not over apply.
- Users of anionic PAM should obtain and follow all MSDS requirements and manufacturer's recommendations. The following criteria are generally included on the MSDS:
  - Ultra high molecular weight of 6 to 24 mg/mole (preferably 12-15 mg/mole)
  - Non-combustible
  - Does not change soil pH
  - Expiration date included
- Additives such as fertilizers, solubility promoters or inhibitors to PAM should be non-toxic.
- To prevent exceeding the acrylamide monomer limit in the event of a spill, the pure form of anionic PAM should not exceed 200 pounds/batch at 0.05 percent acrylamide monomer (AMD) or 400 pounds/batch at 0.025 percent AMD.

Inspection and Maintenance

- PAMs have been estimated to degrade approximately 10 percent per year. The effects are accelerated in highly exposed areas.
- If PAM treated soil is left undisturbed, reapplication may be necessary after 6-8 weeks.
- Further anionic PAM applications may be required for disturbed areas including highly silty and clayey soils, steep slopes, long grades, and high traffic or precipitation areas.
- All equipment should be maintained to provide the application rates recommended by the manufacturer.
- Rinse all equipment used to mix and apply anionic PAM thoroughly with water.

Liquid PAM

Solid/Block PAM

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope was improperly dressed before application.	Roughen slope and fill damaged areas.
Coverage is inadequate.	Follow recommended application rates. Reapply to thin areas.
Sprayed areas degrade or become ineffective.	Follow recommended application rates. Consider other or additional BMPs. Reapply as necessary.
Sprayed slope has spot failures.	Repair slopes, add jute netting and re-spray damaged areas.
Portions of the sprayed area have been disturbed.	Keep workers and equipment off sprayed areas. Repair and re-spray areas that have been damaged.
PAM is washed off slope.	Allow at least 24 hours for the materials to dry before a rain event. Follow manufacturer's recommendations. Reapply as necessary.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow on stabilized area. Use other BMPs to reduce slope lengths. Do not use to stabilize slopes with swift moving concentrated flows.

Sediment Control BMPs

Uncontrolled runoff from construction sites is a water quality concern because of the devastating effects that sedimentation has on local water bodies, particularly small streams. Numerous studies show that the amount of sediment transported by storm water runoff from construction sites with no controls is significantly greater than from sites with controls. In addition to sediment, construction activities yield pollutants such as pesticides, petroleum products, construction chemicals, solvents, asphalts, and acids that contaminate storm water runoff. During storm events, construction sites are a source of sediment-laden runoff, which can overwhelm a small stream channel's capacity, resulting in streambed scour, streambank erosion, and destruction of near stream vegetative cover. Where left uncontrolled, sediment-laden runoff causes the loss of in-stream habitats for fish and other aquatic species, an increased difficulty in filtering drinking water, the loss of drinking water reservoir storage capacity, and negative impacts on the navigational capacity of waterways.

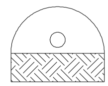
Polluted storm water runoff from construction sites often flows to Municipal Separate Storm Sewers (MS4s) and ultimately is discharged into local rivers and streams. Sediment is one of the main pollutant of concern. Sediment runoff rates from construction sites are typically 10 to 20 times greater than those of agricultural lands, and 1,000 to 2,000 times greater than those of forest lands. During a short period of time, construction sites have the potential to contribute more sediment to streams than is deposited naturally during several decades. The resulting siltation, and the contribution of other pollutants from construction sites, causes physical, chemical, and biological harm to our nation's waters. For example, excess sediment can quickly fill rivers and lakes, requiring dredging and destroying aquatic habitats.

There are numerous methods available to assist in the control of sediment. The following sediment control BMPs are discussed in this handbook:

- Temporary Sediment Basin
- Temporary Sediment Trap
- Silt Fence
- Rock Check Dams
- Sediment Tubes
- Stabilized Construction Entrances
- Storm Drain Inlet Protection
- Rock Sediment Dikes

Sediment Basin

Plan Symbol



Description

A Sediment Basin collects and traps sediment laden runoff from disturbed areas and slows down the flow so that soil particles fall from suspension and deposit in the basin. Drop inlet spillways, pipe spillways, rock fill outlets and weir spillways may be used for the design of the principal spillway.

When and Where to Use It

Temporary sediment basins are designed to have an 80 percent design removal efficiency goal for total suspended solids (TSS) or 0.5 mL/L peak settleable concentration, whichever is less. on sites where 10 or more acres are disturbed and drain to a single outlet point. A temporary sediment basin should not be built in wetlands, any active or live streams, ephemeral streams, or in Waters of State (defined to be all annual or perennial water bodies designated by a solid or dashed blue-line on USGS 7.5-minute quadrangle maps). Utilize temporary sediment basins until the contributing flow areas to the basin have undergone final stabilization.

Sediment Basin Design Criteria

Safety

Follow the design criteria such as those used by the USDA Soil Conservation Service (previously the Natural Resources Conservation Service), U.S. Army Corps of Engineers and the Dam Safety regulations.

Incorporate all possible safety precautions for ponds that are readily accessible to populated areas such as signs and fencing. The recommended inside pond slopes is 3H:1V with a 2H:1V maximum.

Design Aids

The Design Aids located in this section may be used to properly size sediment basins. Sedimot III, SEDCAD4 and other computer models that utilize eroded particle size distributions to calculate a corresponding trapping efficiency may also be utilized.

Riser Structure Design

Design the outlet riser to meet the discharge capacity of the 10-year 24-hour storm event.

General Design Requirements

a. Minimum drainage area - 5 acres
b. Maximum drainage area - 150 acres
c. 80 percent design removal efficiency goal for TSS.
d. The required draw down time of the basin is the time to detain flows to meet the 80 percent design removal goal. In many cases this will result in a draw down time longer than 36 hours. The maximum draw down time is 72 hours.

e. Basin Shape - Where applicable the effective flow length is at least twice the effective flow width . **(L = 2W minimum).**

f. Account for the sediment storage volume.

g. Outlet Riser and Barrel Requirements
1. Discharge capacity - 10-year 24-hour storm event.
2. Minimum outlet pipe diameter of 8-inches.
3. Required 6-inch low flow orifice at bottom of riser structure.
4. 2-year and 10-year 24-hour storm disturbed flow rates are ≤ to the pre-disturbance peak flow rates.
5. Anti-vortex device / trash rack required.
6. Minimum one-foot elevation difference from the top of riser to the crest of the emergency spillway.
7. Sediment volume storage accounted for in design volume.

h. Embankment Requirements
1. Maximum upstream slope – 2H:1V.
2. Maximum downstream slope – 2H:1V.
3. Freeboard - 12 inch minimum.
4. Antiseep collars are required on all penetrations through the dam.

Inspection and Maintenance

The key to a functional sediment basin is continual monitoring, regular maintenance and regular sediment removal. Attention to sediment accumulations within the pond is extremely important. Continually monitor sediment deposition in the basin. Owners and maintenance authorities should be aware that significant concentrations of heavy metals (e.g., lead, zinc, and cadmium) as well as some organics such as pesticides, may be expected to accumulate at the bottom of these treatment facilities.

- Remove sediment when it reaches 50 percent of storage volume or reaches the top of the designed cleanout stake where applicable.
- Remove all temporary sediment basins within 30 days after final site stabilization is achieved or after it is no longer needed.
- Remove trapped sediment from the site , or stabilize on site.
- Permanently stabilize disturbed areas resulting from the removal of the sediment basin.

Sediment Basin Design Aids

Each soil type has an eroded particle diameter. See Appendix E. This data is required to determine the settling velocity of the particle, V_{15}. Figure SV-1 plots eroded particle diameter, d_{15}, versus settling velocity. Use this figure to determine the value of V_{15}. Use the basin ratio shown in the formula below to determine trapping efficiency. Figures SB-1 and SB-2 plot trapping efficiency versus the basin ratio. The basin ratio should be less than or equal to the curve value at any given trapping efficiency. The figures depicting trapping efficiency values are for the following two separate conditions:

- SB -1,basins **not** located in low lying areas and/or not having a high water table, and
- SB-2, basins located in low lying areas and/or having a high water table.

$$\text{Basin Ratio} = \frac{q_{po}}{A\,V_{15}}$$

Where:

q_{po} = Peak outflow rate from the basin for the 10-year 24-hour storm event (cfs),
A = Surface area of the pond at riser crest (acres),
V_{15} = Characteristic settling velocity (fps) of the characteristic D_{15} eroded particle (mm).

D_{15} is read from the tables in Appendix E, or is determined from a site specific soil eroded particle size distribution analysis. Never use the primary particle size distribution.

V_{15} is calculated or read from Figure SV1.

Constraints for use of Sediment Basin Design Aids:

- Watershed area less than or equal to 30 acres
- Overland slope less than or equal to 20 percent
- Outlet diameter less than or equal to 6-feet
- Basin Ratios above the design curves are not recommended for any application of the design aids. If the basin ratio q_{po}/AV_{15} intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

- A basin **not** located in a low lying area and not having a high water table, has a basin ratio equal to 2.20 E5 at 80 percent trapping efficiency as shown in Figure SB1.

- A basin that **is** located in a low lying area or in an area that has a high water table, has a basin ratio equal to 4.70 E3 at 80 percent trapping efficiency as shown in Figure SB2.

Sediment Basin Design Example

Given: Construct a sediment basin on a 14-acre (0.0219 mi^2) disturbed site.
The site is not located in a low lying area and does not have a high water table.
Peak discharge is limited to that of the current land use, established grass.
A pond site is available with an area at the riser crest of 0.75 ac.
Soil in the area is an Edisto with a Hydrologic Soil Group Type C.

Find: Trapping efficiency for a 10-year, 24-hour Type II storm if time of concentration is 20 minutes.

Solution:

1. Estimate the peak runoff allowed. The SCS curve number is found for a hydrologic soil group C with established grass as 74. Using a 10-year, 24-hour design storm of 6.0-inches, with this curve number yields a runoff volume of 3.2-inches using the SCS curve number method.

2. Using the SCS graphical method to estimate peak flow, the I_a/P ratio computes to approximately 0.12. Combining this and an estimated time of concentration equal to 0.33 hrs yields a q_u = 650 csm/in for a Type II storm distribution.

3. The peak discharge allowed is calculated by multiplying q_u times the runoff volume times the disturbed area in mi^2 and is approximately 46 cfs.

4. D_{15} for an Edisto sub-soil 0.0128. Using this diameter, V_{15} is estimated from Figure SV-1 as 3.7E-4 ft/sec.

5. The sediment basin ratio can now be calculated by calculating

$$q_{po} / (AV_{15}) = 46 / [(0.75)(3.7E\text{-}4)] = 1.70\ E5$$

6. Using Sediment Basin Design Aid (Figure SB-1) with this sediment basin ratio, read across to the curve and then turn down to the x-axis. The trapping efficiency is estimated to be 81%.

7. If the desired trapping efficiency was not obtained, the process would need to be repeated with a larger basin or decreased discharge until the desired trapping efficiency was found.

Temporary Sediment Basin

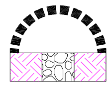
Temporary Sediment Basin Perforated Riser

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Outlet pipe is clogged with the debris.	Clean outlet pipe. Install a trash rack around pipe to hold back larger debris particles.
Spillway erodes due to high velocity flows.	Stabilize outlet with an ECB, TRM or riprap.
Side Slope eroding.	Stabilize slopes with vegetation, ECB, TRM, riprap or equivalent method.
Excessive accumulated sediment buildup.	Remove sediment to maintain the sediment storage capacity.
The upstream drainage area is too large.	Limit the contributing drainage area or expand basin. Ensure drainage area does not exceed recommended acreage. If the drainage area does exceed this limit, install diversion ditches and add additional BMPs to accommodate the diverted flow.

Sediment Trap

Plan Symbol



Description

A sediment trap is formed by excavating a pond or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is constructed using stones or aggregate to slow the release of runoff. The trap retains the runoff long enough to allow most of the silt to settle out. Design sediment traps to have an 80 percent design removal efficiency goal of the total suspended solids (TSS) in the inflow.

When and Where to Use It

A sediment trap may be formed completely by excavation or by construction of a compacted embankment. The outlet should be a rock fill weir/spillway section, with the area below the weir acting as a filter for sediment and the upper area as the overflow spillway depth. Temporary sediment traps should not be placed in Waters of the State or USGS blue-line streams (unless approved by SCDHEC, State, or Federal authorities).

Sediment Trap Design Criteria

To complete the design of the temporary sediment trap:

- Determine the required sediment storage volume.
- Determine the bottom and top surface area of the sediment storage volume using 3H:1V side slope from the bottom of the trap.
- Determine the total trap dimensions by adding the depth required for the 10-year, 24-hour design storm above the surface of the sediment storage volume, while not exceeding 2H:1V side slopes. Side slopes of 3H:1V are recommended, with a maximum of 2H:1V.
- Design temporary sediment traps with a minimum storage capacity of 1800 cubic feet of storage for each acre draining to them, regardless of the calculated trapping efficiency.

Design Aids

The Design Aids located in this section may be used to properly size sediment traps. Sedimot III, SEDCAD4, and other computer models that utilize eroded particle size distributions and calculates a corresponding trapping efficiency may also be utilized.

General Design Requirements

a. Maximum Drainage Area - 5 acres
b. Maximum Design Life - 18 months
c. 80 percent design removal efficiency goal for TSS
d. Basin Shape - The flow length is 2 times the flow width.
e. Embankment Requirements:
   1. Maximum dam height: 5-feet.
   2. Maximum stone height: 3.5-feet.
   3. Minimum rock bottom width: 3-feet.
   4. Discharge and treatment capacity for the 10-year 24-hour storm event.

Installation

Install a non-woven geotextile filter fabric before installing the stone for the outlet structure. Allow the stone to extend downstream past the toe of the embankment. Mark the sediment cleanout level of trap with a stake in the field. Seed and mulch all disturbed areas.

Inspection and Maintenance

The key to a functional sediment trap is continual monitoring, regular maintenance and regular sediment removal.

- Remove sediment when it reaches 50 percent of storage volume or top of cleanout stake.
- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Remove all temporary sediment traps within 30 days after final site stabilization is achieved or after it is no longer needed.
- Remove trapped sediment from the site, or stabilized on site.
- Permanently stabilized disturbed areas resulting from the removal of sediment traps.

Sediment Trap Design Aids

The sediment trap design aid is a single line grouping all soil textures together. For the sediment trap, the ratio is:

$$\text{Sediment Trap Ratio} = \frac{q_{po}}{A\,V_{15}}$$

Where

q_{po} = Peak outflow for the 10-year 24-hour storm event (cfs)

A = Surface area at the elevation equal to the bottom of the rock fill outlet (acres)

V_{15} = Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Read D_{15} is read Figure ST-1, or determine from a site specific soil eroded particle size distribution analysis. Never use the primary particle size distribution.

Read V_{15} from Figure SV1.

Constraints for the use of Sediment Trap Design Aids are:

- Watershed area less than or equal to 5 acres
- Overland slope less than or equal to 20 percent
- Rock fill diameter greater than 0.2-feet and less than 0.6-feet
- Rock fill height less than 5-feet
- Top width of rock fill between 2- and 4-feet
- Maximum Side slopes 1:1 to 1.5:1.

Sediment Trap Ratios above the design curves are not recommended for any application of the design aids. If the sediment trap ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A sediment trap ratio equal to 9.0 E4 has an 80 percent trapping efficiency

Route storm flows through sediment traps to calculate the required depth and storage volume of the trap.

Calculate a sediment storage volume and provide this volume below the bottom of the rock fill outlet structure.

Sediment trap Design Example

Given: A sediment trap designed for a 10-year, 24-hour storm is to be constructed on a development site as a temporary sediment control measure for a 3-acre drainage area that is totally disturbed.

The outlet is to be a rock fill constructed of rock with a mean diameter of 0.5-feet.

The soil is a Cecil sandy loam, the slope of the watershed is 5 percent, and the time of concentration is 6 minutes.

Find: If the desired trapping efficiency is 80 percent, what is the required peak discharge for trap areas of 0.10, 0.25, and 0.50 acres.

Solution:

1. Determine the Sediment Trap Ratio. From the Sediment Trap Design Aid (Figure ST1), the ratio for a design trapping efficiency of 80 percent is 9.0E4 ft^2/acre.

2. Determine the ratio of qpo/A required from the Sediment Trap Ratio,

$$\textit{Sediment Trap Ratio} = 9.0x10^4 = qpo/A*V_{15}$$

3. The D_{15} for a Cecil soil is 0.0066 mm, and the corresponding V_{15} for a Cecil sandy loam soil is 1.2E-4 ft/sec. Hence,

$$9.0x10^4\ V_{15} = qpo/A = (9.0x10^4)(1.2x10^{-4}) = 11\ cfs\ /acre\ of\ pond.$$

4. Determine qpo/A values. The following results are tabulated for the acreage shown:

Sediment Trap Bottom Area (acres)	qpo Through Rock Fill (cfs)
0.10	1.1
0.25	2.8
0.50	5.5

Each of these combinations will give the desired resulting 80 percent trapping efficiency.

The rock fill outlet structure must be designed to convey a peak flow of that shown in column two of the table above. See Section 6.4 for design details. If the check rock fill overtops, the trapping efficiency is assumed to be zero.

Sediment Trap

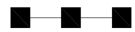
Sediment Trap

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Outlet spillway is clogged with the debris.	Remove debris by lightly raking debris from upstream side of spillway. If debris is excessive, remove smaller filter stone on upstream side of spillway and replace with new clean stone.
Spillway erodes due to high velocity flows.	Stabilize outlet with larger riprap on downstream side of spillway.
Side Slope eroding.	Stabilize slopes with vegetation, ECB, TRM, riprap or equivalent method.
Excessive accumulated sediment buildup.	Remove sediment to maintain sediment storage capacity.
Drainage area is too large.	Limit the contributing drainage area by installing diversion ditches and adding additional BMPs to accommodate the diverted flow.

Silt Fence

Plan Symbol



Description

Silt fence is used as a temporary perimeter control around sites where there will be soil disturbance due to construction activities. Silt fence consists of geotextile fabric stretched across steel posts. The lower edge of the fence is vertically trenched into the ground and covered by compacted backfill.

When and Where to Use It

Silt fence is applicable in areas:

- Where the maximum sheet or overland flow path length to the fence is 100-feet.
- Where the maximum slope steepness (normal [perpendicular] to fence line) is 2H:1V.
- That do not receive concentrated flows greater than 0.5 cfs.
- ¼ acre drainage per 100 linear feet

Do not place silt fence across channels or use it as a velocity control BMP.

Materials

Steel Posts

Use 48-inch long steel posts that meet the following minimum physical requirements:

- Composed of high strength steel with minimum yield strength of 50,000 psi.
- Have a standard "T" section with a nominal face width of 1.38-inches and nominal "T" length of 1.48-inches.
- Weigh 1.25 pounds per foot (± 8%).
- Have a soil stabilization plate with a minimum cross section area of 17-square inches attached to the steel posts.
- Painted with a water based baked enamel paint.

Use steel posts with a minimum length of 4-feet, weighing 1.25 pounds per linear foot (± 8%) with projections to aid in fastening the fabric. Except when heavy clay soils are present on site, steel posts will have a metal soil stabilization plate welded near the bottom such that when the post is driven to the proper depth, the plate will be below the ground level for added stability. The soil plates should have the following characteristics:

- Be composed of minimum 15 gauge steel.
- Have a minimum cross section area of 17-square inches.

Geotextile Filter Fabric

Filter fabric is:

- Composed of fibers consisting of long chain synthetic polymers composed of at least 85% by weight of polyolefins, polyesters, or polyamides.
- Formed into a network such that the filaments or yarns retain dimensional stability relative to each other.
- Free of any treatment or coating which might adversely alter its physical properties after installation.
- Free of defects or flaws that significantly affect its physical and/or filtering properties.
- Cut to a minimum width of 36 inches.

Use only fabric appearing on SCDOT Approval Sheet #34 meeting the requirements of the most current edition of the SCDOT Standard Specifications for Highway Construction.

Silt Fence Design Criteria

Design Aids

The Design Aids located in this section may be used to properly size silt fence. Sedimot III, SEDCAD4, and other computer models that utilize eroded particle size distributions and calculates a corresponding trapping efficiency may also be utilized. See Figure SF-1 for silt fence trapping efficiency.

General Design Requirements

a. 80 percent design removal efficiency goal for TSS
b. Maximum Slope Length - 100-feet
c. Maximum Slope Gradient – 2H:1V
d. Minimum Installed Fence Fabric Height – 18-inches
e. Maximum Installed Fence Fabric Height – 24-inches (exception for tidal areas)
f. Minimum Post Bury Depth – 18-inches
g. Maximum Post Spacing – 6-feet

Installation

Leave 10 feet between silt fence and creek or wetland.

Excavate a trench approximately 6-inches wide and 6-inches deep when placing fabric by hand. Place 12-inches of geotextile fabric into the 6-inch deep trench, extending the remaining 6-inches towards the upslope side of the trench. Backfill the trench with soil or gravel and compact.

Bury 12-inches of fabric into the ground when pneumatically installing silt fence with a slicing method.

Purchase fabric in continuous rolls and cut to the length of the barrier to avoid joints. When joints are necessary, wrap the fabric together at a support post with both ends fastened to the post, with a 6-inch minimum overlap.

Install steel posts to a minimum depth of 24-inches. Install steel posts a minimum of 1- to 2- inches above the fabric, with no more than 3-feet of the post above the ground. Space posts to maximum 6-feet centers.

Attach fabric to the steel posts using heavy-duty plastic ties that are evenly spaced and placed in a manner to prevent sagging or tearing of the fabric. In call cases, ties should be affixed in no less than 4 places.

Install the fabric a minimum of 24-inches above the ground. When necessary, the height of the fence above ground may be greater than 24-inches. In tidal areas, extra silt fence height may be required. The post height will be twice the exposed post height. Post spacing will remain the same and extra height fabric will be 4-, 5-, or 6-feet tall.

Locate silt fence checks every 100 feet maximum and at low points.

Install the fence perpendicular to the direction of flow and place the fence the proper distance from the toe of steep slopes to provide sediment storage and access for maintenance and cleanout.

Height of Fill (ft)	Fill Slope	Minimum Silt Fence Offset from Toe of Slope (ft)	Minimum right of Way Offset From Toe of Slope (ft)
< 6	2:1 4:1 6:1	2	3
6-10	2:1	12*	13*
	4:1 6:1	3	4
>10	2:1	12*	13*
	4:1 6:1	4	5

*These minimum offsets may be reduced when curb and gutter or some other feature reduces the flow of water down the slope. The smaller offsets of each group of height of fill can not be reduced.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation. Check for sediment buildup and fence integrity. Check where runoff has eroded a channel beneath the fence, or where the fence has sagged or collapsed by fence overtopping.
- If the fence fabric tears, begins to decompose, or in any way becomes ineffective, replace the section of fence immediately.
- Remove sediment accumulated along the fence when it reaches 1/3 the height of the fence, especially if heavy rains are expected.
- Remove trapped sediment from the site or stabilize it on site.
- Remove silt fence within 30 days after final stabilization is achieved or after temporary best management practices (BMPs) are no longer needed.
- Permanently stabilize disturbed areas resulting from fence removal.

Silt Fence Design Aids

This design aid for applies to silt fences placed in areas down slope from disturbed areas where it serves to retard flow and cause settling. Two conditions must be met for satisfactory design:

- Trapping efficiency must meet the desired level of control, and
- Overtopping of the fence must not occur.

The silt fence design aid is a single line grouping all soil textures together. A similar procedure was used for development of the ratio as used for the ponds and rock checks. For the silt fence, the ratio is:

$$\text{Silt Fence Ratio} = \frac{q_{po}}{V_{15} P_{area}}$$

Where:

q_{po} = Peak outflow through the fence for the 10-year 24-hour storm event (cfs),
V_{15} = Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm),
P_{area} = Potential ponding area up slope of the fence (ft^2).

Estimate the ponding area by using the height of the fence available for flow through and extending a horizontal line from the fence to an intersection with the ground surface upslope of the fence. Calculate the unit available area by multiplying the fence height by the ground slope. Obtain the potential ponding area by multiplying this unit area by the available fence length.

Using the calculated ponding area, calculate the ratio and enter the value in Figure SF-1 to determine the trapping efficiency. Perform an overtopping calculation using the slurry flow rate through the fence. Check this rate against the incoming flow to determine if enough storage exists behind the fence preventing overtopping.

Constraints for the use of Silt Fence Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 6 percent
- Slurry flow rate through the fence is less than or equal to 10 gpm/ft
- Maximum height of the silt fence is less than or equal to 3-feet

Silt Fence Ratios above the design curves are not recommended for any application of the design aids. If the silt fence ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A silt fence ratio equal to 0.23 has an 80 percent trapping efficiency as shown in Figure SF-1.

Silt Fence Design Examples

Given: Design a silt fence 1.5 ft-tall at the toe of a 2.0 percent slope draining a linear construction site.

Topography will cause runoff to drain through 400-feet of total fabric length.
Peak flow from the 1.0-acre upslope area is estimated at 2.5 cfs using the rational equation with "C" equal to 0.25 and intensity equal to 10.0 iph.

Slurry flow rate for the filter fabric is 10 gpm/ft^2 of fabric according to manufacturer specifications or other source.

Find: **(A)** The trapping efficiency if the soil is Lakeland Sand with an eroded size distribution having a D_{15} equal to 0.0463 mm.

(B) The trapping efficiency if the soil is Cecil with an eroded size distribution having a D_{15} equal to 0.0066 mm.

Solution:

A:

1. The settling velocity V_{15} of the D_{15} particle (0.0463 mm) is read from Figure SV-1 as 5.1 E-3 ft/sec.

2. Estimate the ponded area using the geometry of the installation. With a fence length of 400 ft, maximum depth equal to 1.5 ft, and upstream slope of 2.0 percent, there will be ponded area of 75 ft^2/linear ft of fabric for a total ponded area of:

$$P_{area} = (75\ ft^2/ft)\ (400\ ft) = 30{,}000\ ft^2$$

   The geometry calculates a required tie back of 75-feet to provide an adequate ponding area.

3. The silt fence ratio is calculated as:

$$\text{Silt Fence Ratio} = q_{po} / (V_{15}\ P_{area}) = 2.5/[(5.1E\text{-}3)(30{,}000)] = 0.017$$

4. Reading the trapping efficiency from the Silt Fence Design Aid (Figure SF-1) with the ratio equal to 0.017, the trapping efficiency is approximately **94 percent**.

- Check the fence for its ability to pass the design flow without overtopping.

5. Convert the peak flow from cfs to gpm:

$$q_{po} = (2.5\ ft^3/sec)(7.48\ gal/ft^3)(60\ sec/min) = 1122\ gpm$$

6. Divide the peak flow rate by the effective height (1.5-ft) and the slurry flow rate of 10 gpm/ft^2 of fabric to calculate the required fence length.

$$L = (1122) / (1.5)\ (10) = 75\ ft$$

7. 75 ft is less than the 400 ft available, so the fence will not overtop if it is properly maintained. Note: This analysis does not account for concentration of flows or strength of the posts, or fabric.

B.

1. A Cecil D_{15} topsoil is 0.0066 mm, and the settling velocity is found to be V_{15} = 1.2 E-4 fps.

2. The filter fence ratio is calculated as:

   $\text{Silt Fence Ratio} = q_{po} / (V_{15}\ P_{area}) = 2.5/[(1.2E\text{-}4)(30{,}000)] = 0.70$

3. Reading the trapping efficiency from the Silt Fence Design Aid (Figure SF1) with the ratio equal to 0.70, the trapping efficiency is approximately **70 percent.**

Silt Fence

Silt Fence

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive sediment accumulation.	Remove sediment. Apply hydraulic mulch or straw mulch or other BMPs upstream to reduce eroded sediment.
Bottom of fence is not properly keyed in.	Dig trench, place fabric, and backfill.
Length of slope draining to silt fence is too long.	Shorten slope length using diversion ditches, additional silt fence runs, or other BMPs.
Storage capacity is inadequate due to sediment buildup.	Remove accumulated sediment when it reaches 1/3 the height of the barrier.
Lack of sufficient ponding area.	Install fence with at least a 5-feet setback from the toe of the slope where possible. Divert flow at top of slope with diversion ditches.
Erosion occurs around ends.	Turn ends into the up-slope area every 100 feet.
Silt fence is not installed along level contour.	Reinstall silt fence so that change in elevation does not exceed 1/3 the fabric height along the reach.
Slope draining to fence is too steep.	Shorten slope length using fiber rolls or equivalent. Increase setback of silt fence from the toe of slope.
Fence is installed in concentrated flow area.	Replace fence with proper BMP such as check dams, if appropriate.
Tie backs or j-hooks not installed or installed incorrectly.	Place Tie backs or j-hooks at a maximum separation of 100-feet.
Posts are too far apart.	Add stakes a maximum of 6-feet apart.
Concentrated flows causing erosion.	Place cross barrier check dams behind the silt fence.

Rock Check Dam

Plan Symbol

Description

A rock check dam is a small, temporary or permanent rock fill dam constructed across a drainage ditch, swale, or channel to lower the speed of concentrated flows. Design rock check dams to have an 80 percent design removal efficiency goal of the total suspended solids (TSS) in the inflow.

When and Where to Use It

Install rock check dams in steeply sloped swales, or in swales where adequate vegetation can not be established. Use rock check dams in small open channels. Do not place check dams in Waters of the State or USGS blue-line streams (unless approved by SCDHEC, State, or Federal authorities).

Rock Check Dam Design Criteria

Design Aids

The Design Aids located in this section (RC-C, RC-M, RC-F) may be used to properly size rock check dams. Sedimot III, SEDCAD4, and other computer models that utilize eroded particle size distributions and calculates a corresponding trapping efficiency may also be utilized.

General Design Requirements

a. 80 percent design removal efficiency goal for TSS
b. Maximum Drainage Area – 5 acres
c. Maximum Height – 2-feet
d. Spacing varies with the bed slope of the ditch. Space rock checks such that the toe of the upstream check is at the same elevation as the top of the downstream check.
e. If the rock check dam is not properly sized, the flow will overtop the structure and the Trapping Efficiency is assumed to be 0 percent when this failure takes place.

Installation

Install the center section of the rock check lower than the edges.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Inspect for sediment and debris accumulation.
- Inspect rock check dam edges for erosion and repair promptly as required.
- Remove sediment when it reaches 1/3 the original check height.
- In the case of grass-lined ditches and swales, remove rock check dams when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent.
- After construction is complete, remove stone if vegetation is used for permanent stabilization.
- Seed and mulch the area beneath the rock ditch checks immediately after dam removal.

Rock Check Dam Design Aids

Design aids for rock check dams were developed similarly to those for ponds. Again, the D_{15} eroded particle size is used for the calculation of the characteristic settling velocity. The ratio for ditch checks is defined by:

The Rock Check Dam Design Aids have been designed for the following soil classifications:

- Coarse (sandy loam)
- Medium (silt loam)
- Fine (clay loam).

The design ratio should be less than or equal to the curve value at any given trapping efficiency.

$$\text{Rock Check Ratio} = \frac{Sq^{(1-b)}}{aV_{15}}$$

Where:

S = Channel slope (%),
q = Unit width flow through the check for the 10-year 24-hour storm event (cfs/ft),
V_{15} = Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).
Coefficients *a* and Exponent *b* is interpolated from tables

Constraints for the use of Rock Check Dam Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 15 percent
- Maximum depth of the ditch is less than or equal to 6-feet

Rock Check Ratios above the design curves are not recommended for any application of the design aids. If the Rock Check Ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A rock check dam located on coarse soils has a ditch check ratio equal to 1.10 E3 at 80 percent trapping efficiency as shown in Figure RC-C.

A rock check dam located on medium soils has a ditch check ratio equal to 5.80 E3 at 80 percent trapping efficiency as shown in Figure RC-M.

A rock check dam located on fine soils has a ditch check ratio equal to 1.20 E4 at 80 percent trapping efficiency as shown in Figure RC-F.

Rock Check Dam Design Examples

Given: Install a rock check dam with a channel slope of 1.0 percent in the Piedmont on an area having Cecil sandy loam soils with an eroded size distribution of medium texture.

The runoff coefficient "C" for the rational method is estimated as 0.4 with an intensity of 6.75 in/hr for the design storm.

Drainage area to the ditch check is 4.4 ac.

Average rock diameter of the ditch check is 0.10 m (4 in.).

Average width (perpendicular to flow) is 6.7 ft and ditch check length is 3.3 feet.

Find: The trapping efficiency for the rock ditch check.

Solution:

1. A Cecil D_{15} topsoil is 0.0066 mm, and the settling velocity is found to be V_{15} = 1.2 E-4 fps.

2. Peak flow is estimated from the given information by substituting into the rational formula so that:

$$q_p = C\ i\ A = 0.4\ (6.75)(4.4) = 11.9\ \text{cfs}$$

3. The flow rate should be converted to flow per unit width by dividing the peak flow by the check width to obtain the design q as

$$q = 11.9\ \text{cfs}/6.7\ \text{ft} = 1.78\ \text{cfs/ft}$$

4. Appropriate values of the coefficients a and b are interpolated from the table provided in the Design Aids Section of this Handbook.

- Rock diameter of 0.10 m
- Flow length of 1.0 m

a = 4.13
b = 0.6651

Substitute all values and calculate the ditch check ratio

$$Sq^{(1-b)}/a\ V_{15} = (1.0)(1.78^{(1-0.6651)})/(4.13)(1.2E\text{-}4) = 2448$$

5. Enter the Rock Check Dam Design Aids for medium texture soil (Figure RC-M) on the y-axis with Rock Check Ratio = 2.5E3, go to line and turn to the x-axis to read trapping efficiency.

6. Trapping efficiency equals 86 percent.

Note: The rock check dam must also be checked for overtopping since this is a common occurrence and results in total failure of the check. If the check overtops, the trapping efficiency is assumed to be zero.

Rock Check Dam

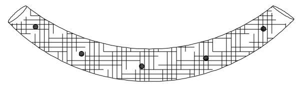
Rock Check Dam

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Too much sediment has accumulated.	Remove accumulated sediment to recover holding capacity.
There is insufficient ponding area.	Space check dams farther apart. Increase height of dam.
The check dam is higher than the drainage channel.	Lower check dam so that it is 6 inches lower than the channel side.
Check dams wash away.	Use larger stone for the body of the check dam. Decrease check dam spacing by adding more dams.
Wrong type of materials is used to construct check dam.	Use larger stones. Do not use straw bales or silt fence for checks.

Sediment Tubes

Plan Symbol



Description

Sediment tubes are elongated tubes of compacted geotextiles, curled excelsior wood, natural coconut fiber or hardwood mulch. Straw, pine needle, and leaf mulch-filled sediment tubes are not permitted.

When and Where to Use It

Install sediment tubes along contours, in drainage conveyance swales, and around inlets to help reduce the effects of soil erosion by energy dissipation and retaining sediment.

Materials

Sediment tubes for ditch checks and Type A Inlet Structure Filters exhibit the following properties:

- Produced by a Manufacturer experienced in sediment tube manufacturing.
- Composed of compacted geotextiles, curled excelsior wood, natural coconut fibers, hardwood mulch or a mix of these materials enclosed by a flexible netting material.
- Straw, straw fiber, straw bales, pine needles, and leaf mulch are not allowed under this specification.
- Utilizes outer netting that consists of seamless, high-density polyethylene photodegradable materials treated with ultraviolet stabilizers or a seamless, high-density polyethylene non-degradable materials.
- Diameter ranging from 18-inches to 24-inches.
- Curled excelsior wood, or natural coconut rolled erosion control products (RECPs) that are rolled up to create a sediment tube are **not** allowed under this specification.
- Select applicable Sediment Tubes from the SCDOT approved products list.

Installation

Proper site preparation is essential to ensure sediment tubes are in complete contact with the underlying soil or underlying surface. Remove all rocks, clods, vegetation or other obstructions so installed sediment tubes have direct contact with the underlying soil or surface.

Install sediment tubes by laying them flat on the ground. Construct a small trench to a depth that is 20% of the sediment tube diameter. Lay the sediment tube in the trench and compact the upstream sediment tube soil interface. Do not completely bury sediment tubes during installation. Review all project specifications for special installation requirements. Install sediment tubes so no gaps exist between the soil and the bottom of the sediment tube. Lap the ends of adjacent sediment tubes a minimum of 6-inches to prevent flow and sediment from passing through the field joint. Never stack sediment tubes on top of one another.

Avoid damage to sediment tubes during installation. Should the sediment tube become damaged during installation, place a stake on both sides of the damaged area terminating the tube segment and install a new tube segment. Perform field monitoring to verify that installation procedures do not damage sediment tubes. Replace all damaged sediment tubes damaged during installation as directed by the Inspector or Manufacturer's Representative at the contractor's expense.

Install sediment tubes in swales or drainage ditches perpendicular to the water flow and extend them up the side slopes a minimum of 1-foot above the design flow depth. Space sediment tubes according to the following table.

Slope	Maximum Sediment Tube Spacing
Less than 2%	150-feet
2%	100-feet
3%	75-feet
4%	50-feet
5%	40-feet
6%	30-feet
Greater than 6%	25-feet

Install sediment tubes using wooden stakes (2-inch x 2-inch) or steel posts (standard “U” or “T” sections with a minimum weight of 1.25 pounds per foot) a minimum of 48-inches in length placed on 2-foot centers. Intertwine the stakes with the outer mesh on the downstream side, and drive the stakes in the ground to a minimum depth of 24-inches leaving less than 12-inches of stake above the exposed sediment tube.

An acceptable alternative installation is driving stakes on 2-foot centers on each side of the sediment tube and connecting them with natural fiber twine or steel wire to inhibit the non-weighted sediment tube from moving vertically. Sediment tubes can also be secured by installing the stakes on 2-foot centers in a crossing manner ensuring direct soil contact at all times.

Select the sediment tube check length to minimize the number of sediment tubes needed to span the width of the drainage conveyance. If the required length (perpendicular to the water flow) is 15-feet, then one 15-foot sediment tube is preferred compared to two overlapping 10-foot sediment tubes.

Install sediment tubes for ditch checks over bare soil, mulched areas, or erosion control blankets. Keep sediment tubes for ditch checks in place until fully established vegetation and root systems have completely developed and can survive on their own.

Inspection and Maintenance

- Inspect sediment tubes after installation for gaps under the sediment tubes and for gaps between the joints of adjacent ends of sediment tubes.
- Inspect every 7-days and within 24-hours of a rainfall event of 0.5-inches or greater.
- Repair all rills, gullies, and undercutting near sediment tubes.
- Remove all sediment deposits that impair the filtration capability of sediment tubes when the sediment reaches 1/3 the height of the exposed sediment tube.
- Remove and/or replace installed sediment tubes as required to adapt to changing construction site conditions.
- Remove sediment tubes from the site when the functional longevity is exceeded as determined by the Engineer, Inspector or Manufacturer’s Representative. Gather sediment tubes and dispose of them in regular means as non-hazardous, inert material.
- Prior to final stabilization, backfill all trenches, depressions and other ground disturbances caused by the removal of sediment tubes.

Sediment Tube Check Dam

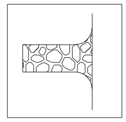
Sediment Tube Check Dam

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Too much sediment has accumulated.	Remove accumulated sediment to recover holding capacity. Remove accumulated sediment from the upstream side of the sediment tube when the sediment has reached a height of approximately one-third the original height of the tube (measured at the center).
There is insufficient ponding area.	Space sediment tubes farther apart or increase the sediment tube diameter.
Sediment tube washes away.	Use larger sediment tubes. Decrease post spacing, and add more posts. Install posts on both the upstream and downstream sides of the sediment tube. Decrease sediment tube spacing by adding more sediment tube check dams.
Other application used instead of sediment tubes	Do not use straw bales or silt fence as sediment tube check alternatives. In some situation rock check dams may be used as a sediment tube alternative.
Wrong type of materials or wrong type of sediment tube utilized.	Straw, pine needle and leaf mulch-filled sediment tubes are not permitted. Curled excelsior wood, or natural coconut rolled erosion control products (RECPs) that are rolled up to create a sediment tube are **not** permitted. Do not use straw bales or silt fence for checks.

Stabilized Construction Entrance

Plan Symbol



Description

A stabilized construction entrance is a temporary stone-stabilized pad located at all points of vehicular ingress and egress on a construction site to reduce the amount of mud, dirt, and rocks transported onto public roads by motor vehicles equipment and runoff.

When and Where to Use It

Use stabilized construction entrances whenever repetitive traffic will be leaving a construction site and moving directly onto a public road. Construction entrances provide an area where mud is removed from vehicle tires before entering a public road.

General Design Requirements

a. Minimum Entrance Dimensions
   1. Thickness = 6-inches
   2. Width of entrance area = 24-feet
   3. Length = 100-feet or required length for 10 tire revolutions
b. Material consisst of stone with a D_{50} diameter ranging from 2 to 3 inches.
c. Non-woven geotextile fabric is required to underlie the stone.

Installation

Remove all vegetation and any objectionable material from the foundation area.

Divert all surface runoff and drainage from stones to a sediment trap or basin.

Install a non-woven geotextile fabric prior to placing any stone.

Install a culvert pipe across the entrance when needed to provide positive drainage.

The entrance consists of 2 to 3 inch D_{50} aggregate with a minimum thickness of 6-inches.

Minimum dimensions of the entrance are 24-feet wide by 100-feet long, and may be modified as necessary to accommodate site constraints.

Taper the edges of the entrance out towards the road to prevent tracking of mud at the edge of the entrance.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation, or after heavy use.
- Check for mud and sediment buildup and pad integrity.
- Make daily inspections during periods of wet weather. Maintenance is required more frequently in wet weather conditions. Reshape the stone pad as needed for drainage and runoff control.
- Wash or replace stones as needed.

- Wash or replace he stone in the entrance whenever the entrance fails to reduce mud being carried off site by vehicles. Frequent washing will extend the useful life of stone.
- Immediately remove mud and sediment tracked or washed onto public roads by brushing or sweeping.
- Only use flushing when the water is discharged to a sediment trap or basin.
- Repair any broken pavement immediately.
- Inspect and clean sediment traps immediately following each rainfall.
- Dispose of sediment in a suitable area in such a manner that it will not erode.
- Remove as soon as they are no longer needed to provide access to the site. Bring the disturbed area to grade, and stabilize it using appropriate permanent stabilization methods.

Construction Entrance

Construction Entrance

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Access points require constant maintenance.	Select proper stabilization material or consider alternate methods for longevity, performance and site conditions.
Stone is tracked onto roadway.	Limit larger vehicles from construction exit or use larger diameter material.
Aggregate material is being incorporated into the soil.	Use geotextile fabric under base material.
Excessive sediment is tracked onto roadway.	Increase length of stabilized exit. Regularly maintain access area to remove sediment buildup.
Sediment-laden water is leaving the construction site.	Properly grade access points to prevent runoff from leaving site. Route runoff through a sediment-trapping device.
Sediment is being tracked from numerous locations.	Limit the number of access points and require their use. Stabilize designated access points.

Storm Drain Inlet Protection

Description

Storm drain inlet protection is achieved by placing a temporary filtering device around any inlet to trap sediment. This mechanism prevents sediment from entering inlet structures. Additionally, it serves to prevent the silting-in of inlets, storm drainage systems, or receiving channels.

There are six (6) types of inlet structure filters, including:

- Type A-Low Flow
- Type B-Medium Flow, Low Velocity
- Type C-Medium Flow, Medium Velocity
- Type D-High Flow, High Velocity
- Type E-Surface Course Curb Inlet
- Type F-Inlet Tubes

When and Where to Use It

Inlet protection may be installed prior to the construction of roads however, once the sub base is placed, a different type of inlet protection may be required. Inlet protection is required on all inlets that have outfalls that bypass sediment trapping structures and directly discharge off site. Use inlet protection as a last resort for sediment control when no other means are practical and do not use as the only means of protection.

General Design Requirements

Type A-Low Flow Inlet Filters include filter fabric inlet protection and 18-inch diameter sediment tubes

- Applicable for inlets with peak flow rates **less than 1 cfs** where the inlet drain area has grades less than 5%. The immediate drainage area (5-foot radius around the inlet) has grades less than 1%. Areas receiving concentrated flows **are not** acceptable.

Type B-Medium Flow, Low Velocity Inlet Filters include hardware fabric and stone inlet protection.

- Applicable for inlets with peak flow rates **less than 3 cfs** where the inlet drain area has grades **less than 5%.** Flow velocities to the inlet may **not exceed 3 feet per second**. Applicable where an overflow capacity is **not** required to prevent excessive ponding around the structure.

Type C-Medium Flow, Medium Velocity Inlet Filters include block and gravel inlet protection.

- Applicable for inlets with peak flow rates **less than 3 cfs** where the inlet drain has grades **less than 5%.** Flow velocities to the inlet may **not exceed 5 feet per second**. Applicable where an overflow capacity is required to prevent excessive ponding around the structure. **Not applicable in areas exposed to traffic**, such as median drains

Type D-Rigid Inlet Filters include prefabricated inlet filters composed of a geotextile fabric connected to a rigid structure

- Applicable for drainage areas up to **2 acres** with peak flow rates **greater than 3 cfs** where the inlet drain area has grades **greater than 5%**. Flow velocities to the inlet may **exceed 3 feet per second**.
- These filters are used for median applications (Type D1) and for sump applications (Type D2). Applicable where an overflow capacity **is** required to prevent excessive ponding around the structure. Capable of protecting inlet structures not associated with curb inlets. The inlets may include, but are not limited to yard inlets, DI 24-inches by 24-inches, DI 24-inches by 36-inches and manholes.

Type E-Surface Course Curb Inlet Filters include prefabricated inlet filters composed of a synthetic material that has aggregate compartments for stone, sand, or other weighted mechanisms to hold the unit in place.

- Applicable for roadway catch basins after the road surface course is placed

Type F-Inlet Tubes are classified in two categories: weighted inlet tubes and non-weighted inlet tubes.

- Weighted inlet tubes are applicable for inlets with drainage areas less than 1 acre. Weighted inlet tubes are used for placement on gravel, concrete, asphalt or other hard surfaces around drainage inlets where stakes cannot be driven. Weighted inlet tubes are applicable where construction traffic may occur around the inlet. All weighted Type F Inlet Structure Filters are applicable as Type E Inlet Structure Filters.

- Non-weighted inlet tubes are inlet tubes applicable for Catch Basins with drainage areas less than 1 acre where stakes or posts are driven to hold the tube in place. For non-weighted inlet tube applications, an inlet tube is placed on subgrade and is applicable until the road base course is placed.

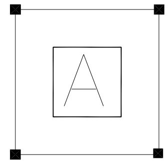
- Both weighted and non-weighted inlet tubes are applicable as weep hole inlet filters, although non-weighted inlet tubes can only be used in situations where stakes is driven into the ground or subgrade to secure the tube.

General Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each storm that produces ½-inches or more of rain. Handle any damage or needed repairs immediately.
- Inspect after installation for gaps that may permit sediment to enter the storm drainage system.
- Remove accumulated sediment and debris from the surface and vicinity of Inlet Filters after each rain event or as directed by the Engineer, Inspector or Manufacturer's Representative.
- Remove sediment when it reaches approximately 1/3 the height of the Inlet Filter. If a sump is used, remove sediment when it fills approximately 1/3 the depth of the hole. Maintain the pool area, always providing adequate sediment storage volume for the next storm event.
- Remove, move, and/or replace as required to adapt to changing construction site conditions.
- Remove Inlet Filters from the site when the functional longevity is exceeded as determined by the Engineer, Inspector or Manufacturer's Representative.
- Dispose of Inlet Filters no longer in use at an appropriate recycling or solid waste facility.
- Prior to final stabilization, backfill and repair all trenches, depressions, and other ground disturbances caused by the removal of Inlet Filters.
- Remove all construction material and sediment and dispose of them properly. Grade the disturbed areas to the elevation of the inlet structure crest. Stabilize all bare areas immediately.

Type A – Filter Fabric Inlet Protection

Plan Symbol



Design filter fabric inlet protection to have an 80 percent design removal efficiency goal of the total suspended solids (TSS) in the inflow. The Design Aids located in the Silt Fence section of this Handbook may be used to properly design filter fabric inlet protection.

Materials

Use filter fabric that conforms to SCDOT standard specifications for highway construction (latest edition). Refer to the silt fence geotextile fabrics SCDOT Approval Sheet #34.

Use 48-inch long wood posts that meet the following requirements.

- 2-inch by 2-inch size.
- Heavy-duty wire staples at least 1½-inch long, spaced a maximum of 6-inches apart to attach the filter fabric to wooden stakes.

Use 48-inch long steel posts that meet the following minimum physical requirements:

- Be composed of high strength steel with minimum yield strength of 50,000 psi.
- Have a standard "T" section with a nominal face width of 1.38-inches and nominal "T" length of 1.48-inches.
- Weigh 1.25 pounds per foot (± 8%).
- Be painted with a water based baked enamel paint.

Installation

Excavate a trench 6-inches wide and 6-inches deep around the outside perimeter of the inlet.

Extend the filter fabric a minimum of 12-inches into the trench. Backfill the trench with soil or crushed stone and compact over the filter fabric unless the fabric is pneumatically installed.

Install the filter fabric to a minimum height of 18-inches and maximum height of 24-inches above grade. Space the posts around the perimeter of the inlet a maximum of 3-feet apart and drive them into the ground a minimum of 24-inches.

Cut the filter fabric from a continuous roll to the length of the protected area to avoid the use of joints. When joints are necessary, wrap filter fabric together only at a support post with both ends securely fastened to the post, with a minimum 6-inch overlap.

Attach fabric to wood posts using heavy-duty wire staples at least 1½-inch long, spaced a maximum of 6-inches apart.

Attach fabric to steel posts with heavy-duty plastic ties. Attach at least four (4) evenly spaced ties in a manner to prevent sagging or tearing of the fabric. In all cases, affix ties in no less than four (4) places.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation. Replace the fabric if it becomes clogged.
- Remove the sediment when it reaches 1/3 the height of the fabric. Take care not to damage or undercut fabric when removing sediment.
- If a sump is used, remove sediment when it fills 1/3 the depth of the hole.
- Maintain the pool area, always providing adequate sediment storage volume for the next storm.
- Remove storm drain inlet protection only after the disturbed areas are permanently stabilized.
- Remove all construction material and sediment, and dispose of them properly.
- Grade the disturbed area to the elevation of the drop inlet structure crest. Use appropriate permanent stabilization methods to stabilize bare areas around the inlet.

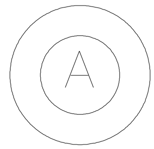
Filter Fabric Inlet Protection

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive sediment entering inlet.	Ensure that soil stabilization and sediment control devices are installed upstream of inlets. Ensure that the barriers around the inlet are installed correctly. Filter fence needs to be keyed in so that water goes through filter fabric and not under it. Use a different type of inlet protection if concentrated flows are observed.
Filter fabric clogged by sediment or other debris.	Replace filter fabric.
Sediment reaches 1/3 the height of fabric.	Remove sediment.
Ponded water causes a traffic concern.	Use alternate BMPs upstream. Remove inlet protection if necessary.

Type A – Sediment Tube Inlet Protection

Plan Symbol



Materials

Sediment tubes for Type A Inlet Structure Filters exhibit the following properties:

- Produced by a Manufacturer experienced in sediment tube manufacturing.
- Composed of compacted geotextiles, curled excelsior wood, natural coconut fibers, hardwood mulch or a mix of these materials enclosed by a flexible netting material.
- Straw, straw fiber, straw bales, pine needles, and leaf mulch are not allowed under this specification.
- Utilizes outer netting that consists of seamless, high-density polyethylene photodegradable materials treated with ultraviolet stabilizers or a seamless, high-density polyethylene non-degradable materials.
- Diameter ranging from 18-inches to 24-inches.
- Curled excelsior wood, or natural coconut rolled erosion control products (RECPs) that are rolled up to create a sediment tube are **not** allowed under this specification.
- Select applicable Sediment Tubes from the SCDOT approved products list.

Use 48-inch long wood posts that meet the following requirements.

- 2-inch by 2-inch size.
- Heavy-duty wire staples at least 1½-inch long, spaced a maximum of 6-inches apart to attach the filter fabric to wooden stakes.

Use 48-inch long steel posts that meet the following minimum physical requirements:

- Be composed of high strength steel with minimum yield strength of 50,000 psi.
- Have a standard "T" section with a nominal face width of 1.38-inches and nominal "T" length of 1.48-inches.
- Weigh 1.25 pounds per foot (± 8%).
- Be painted with a water based baked enamel paint.

Installation:

Remove all rocks, clods, vegetation or other obstructions so installed sediment tubes have direct contact with the underlying soil or surface.

Install sediment tubes by laying them flat on the ground. Construct a small trench to a depth that is 20% of the sediment tube diameter. Lay the sediment tube in the trench and compact the upstream sediment tube soil interface. Do not completely bury sediment tubes during installation. Lap the ends of adjacent sediment tubes a minimum of 6-inches to prevent flow and sediment from passing through the field joint. Never stack sediment tubes on top of one another.

Install sediment tubes using wooden stakes (2-inch x 2-inch) or steel posts (standard "U" or "T" sections with a minimum weight of 1.25 pounds per foot) a minimum of 48-inches in length placed on 2-foot centers. Intertwine the stakes with the outer mesh on the downstream side, and drive the stakes in the ground to a minimum depth of 24-incest leaving less than 12-inches of stake above the exposed sediment tube.

Inspection and Maintenance:

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Inspect sediment tubes after installation for gaps under the tubes and for gaps between joints of adjacent ends of sediment tubes. Repair rills, gullies, and all undercutting near sediment tubes.
- Remove and/or replace installed sediment tubes as required to adapt to changing construction site conditions.
- Remove all sediment tubes from the site when the functional longevity is exceeded as determined by the Engineer, Inspector or Manufacturer's Representative.
- Dispose of sediment tubes in regular means as non-hazardous, inert material.

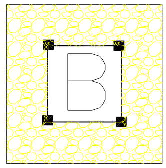
Sediment Tube Inlet Protection

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Too much sediment has accumulated.	Remove accumulated sediment to recover holding capacity. Remove accumulated sediment from the upstream side of the sediment tube when the sediment has reached a height of approximately one-third the original height of the tube (measured at the center).
Sediment tube washes away.	Use larger sediment tubes. Decrease post spacing, and add more posts. Install posts on both the upstream and downstream sides of the sediment tube.
Other application used instead of sediment tubes	Do not use straw bales as sediment tube alternatives.
Wrong type of materials or wrong type of sediment tube utilized.	Straw, pine needle and leaf mulch-filled sediment tubes are not permitted. Curled excelsior wood, or natural coconut rolled erosion control products (RECPs) that are rolled up to create a sediment tube are **not** permitted. Do not use straw bales.

Type B - Hardware Fabric and Stone Inlet Protection

Plan Symbol



Design hardware fabric and stone inlet protection to have an 80 percent design removal efficiency goal of the total suspended solids (TSS) in the inflow. The Design Aids located in the Rock Check Dam section of this Handbook may be used to properly design hardware fabric inlet protection.

Materials

Use hardware fabric or comparable wire mesh with maximum openings of 0.5-inches x 0.5-inches as the supporting material.

Use48-inch steel posts that meet the following minimum physical requirements:

- Be composed of high strength steel with minimum yield strength of 50,000 psi.
- Have a standard "T" section with a nominal face width of 1.38-inches and nominal "T" length of 1.48-inches.
- Weigh 1.25 pounds per foot (± 8%).
- Be painted with a water based baked enamel paint.

Use heavy-duty wire ties to attach the wire mesh material to the steel posts.

Place Aggregate No. 5 washed stone against the hardware fabric on all sides.

Installation

Excavate a trench 6-inches deep around the outside perimeter of the inlet.

Use hardware fabric or comparable wire mesh with maximum openings of 0.5-inches by 0.5-inches as the supporting material. Extended the fabric a minimum of 6-inches into the ground. Backfill the trench with soil or crushed stone and compact over the fabric.

Use steel posts with a minimum post length of 48-inches consisting of standard "T" sections with a weight of 1.25 pounds per foot (±8%). Install the wire mesh fabric above grade a minimum of 18-inches without exceeding 24-inches.

Space the steel posts a maximum of 3-feet apart around the perimeter of the inlet and drive them into the ground a minimum of 24-inches.

Use heavy-duty wire ties spaced a maximum of 6-inches apart to attach the wire mesh material to the steel posts.

Place Aggregate No. 5 washed stone to a minimum height of 12-inches, and a maximum height of 24-inches against the hardware fabric on all sides.

Inspection and Maintenance

- If the stone becomes clogged with sediment, pull the stones away from the inlet and clean or replace them.
- Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.

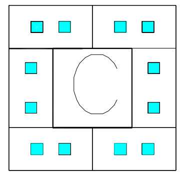
Hardware Fabric and Stone Inlet Protection

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive sediment is entering the inlet.	Ensure that soil stabilization and sediment control devices are installed upstream of inlets. Ensure that the barriers around the inlet are installed correctly.
Sediment reaches 1/3 the height of the structure.	Remove sediment.
Stone filter material becomes clogged with sediment.	Pull stones away from inlet and clean them, or replace them with new stones.
Ponded water causes a traffic concern.	Use alternate BMPs upstream. Remove drain inlet protection if necessary.

Type C - Block and Gravel Inlet Protection

Plan Symbol



Block and gravel filters are used where heavy flows and higher velocities are expected and where an overflow capacity is necessary to prevent excessive ponding around the structure.

Materials

Use masonry blocks ranging from 8 to 12 inches wide.

Use hardware fabric or comparable wire mesh with maximum openings of ½-inches x ½-inches as the supporting material.

Use 1-inch D_{50} washed stone gravel.

Installation

Place the bottom row of the concrete blocks lengthwise on their side so that the open end faces outward, not upward.

The height of the barrier is varied, depending upon design needs by stacking a combination of blocks that are 8- and 12-inches wide.

Place wire mesh over the outside vertical face of the concrete blocks to prevent stones from being washed through the holes in the blocks. Use hardware cloth or comparable wire mesh with ½-inch x ½-inch openings.

Install 1-inch D_{50} washed stone to a height equal to the elevation of the top of the blocks.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each storm that produces ½-inches or more of rain. Any needed repairs should be handled immediately.
- Remove sediment when it reaches 1/3 the height of the blocks. If a sump is used, remove sediment when it fills 1/3 the depth of the hole.
- If the stone filter becomes clogged with sediment, the stones must be pulled away from the inlet and cleaned or replaced. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.
- Remove inlet protection structures after the disturbed areas are permanently stabilized. Remove all construction material and sediment, and dispose of them properly.
- Grade the disturbed area to the elevation of the drop inlet structure crest.
- Stabilize all bare areas immediately.

Block and Gravel Inlet Protection

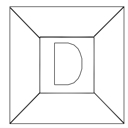
Block and Gravel Inlet Protection

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive sediment is entering the inlet.	Ensure that soil stabilization and sediment control devices are installed upstream of inlets. Ensure that the block and gravel inlet protection is installed correctly.
Sediment reaches 1/3 the height of the blocks.	Remove sediment.
Stone filter material becomes clogged with sediment.	Pull stones away from inlet and clean them, or replace them with new stones.
Ponded water causes a traffic concern.	Use alternate BMPs upstream. Remove inlet protection if necessary.

Type D – Rigid Inlet Filters

Plan Symbol



There are two uses for rigid inlet filters: median applications (Type D1) and sump applications (Type D2). Type D1 filters have more overflow capacity and less filtration area than Type D2 to prevent ponding in medians. These filters are capable of protecting inlet structures not associated with curb inlets

Materials

Rigid inlet filters exhibit the following properties:

- Composed of a geotextile fabric connected to a rigid structure. The geotextile fabric is non-biodegradable and resistant to degradation by ultraviolet exposure and resistant to contaminants commonly encountered in storm water.
- Use a rigid structure composed of high molecular weight, high-density polyethylene copolymer with a UV inhibitor. Do not use structures that are not reusable and recyclable.
- Use a filter fabric constructed of 100% continuous polyester non-woven engineering fabric. The filter fabric is fabricated to provide a direct fit adjacent to the associated rigid structure.
- Rigid inlet filters have a two-stage design. The first stage conveys normal flows at a minimum clean water flow rate of 100 gallons per minute per square foot. The second stage conveys high flow rates, with a minimum apparent opening of 0.5-inch per square inch (No. 12 standard sieve opening).
- Type D1 inlet filters have a first stage minimum height of 9-inches and a maximum height of 12-inches in order to allow greater overflow capacity and prevent ponding in the median.
- Rigid inlet filters completely surround the inlet.
- Rigid inlet filters have lifting devices or structures to assist in the installation and to allow inspection of the storm water system.
- The filter fabric is capable of reducing effluent sediment concentrations by no less than 80% under typical sediment migration conditions.
- Select applicable Type D inlet filters from the SCDOT approved products list.

Installation

Install rigid inlet filters in accordance with the Manufacturer’s written installation instructions. Properly install rigid inlet protection so the inlet is completely enclosed.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each storm that produces ½-inches or more of rain. Any needed repairs should be handled immediately.
- Inspect after installation to insure that no gaps exist that may permit sediment to enter the storm drain system.
- Remove and/or replace rigid inlet filters to adapt to changing construction site conditions.
- Clean the rigid inlet protection filter material when it becomes covered or clogged with deposited sediment.
- Replace the rigid inlet protection filter material as directed by the Engineer.

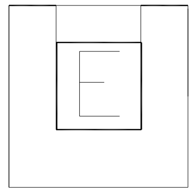
Rigid Inlet Filters

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive sediment is entering the inlet.	Ensure that soil stabilization and sediment control devices are installed upstream of inlets. Ensure that the rigid inlet filters are installed correctly.
Sediment reaches 1/3 the height of the structure.	Remove sediment.
Rigid inlet filter material becomes clogged with sediment.	Pull rigid inlet filters from inlet and clean them, or replace rigid inlet filters with new filter material.
Ponded water causes a traffic concern.	Use alternate BMPs upstream. Remove rigid inlet filter if necessary.

Type E - Surface Course Curb Inlet Filters

Plan Symbol



Materials

Use surface course inlet filters that have a minimum height or diameter of 9-inches and have a minimum length that is 2-feet longer than the length of the curb opening. Surface course inlet filters are not designed to completely block the inlet opening.

Use surface course inlet filters constructed with a synthetic material that will allow storm water to freely flow through while trapping sediment and debris. Use a material that is non-biodegradable and resistant to degradation by ultraviolet exposure and resistant to contaminants commonly encountered in storm water. Straw, straw fiber, straw bales, pine needles, and leaf mulch are not permissible filter materials.

Surface course inlet filters have aggregate compartments for stone, sand or other weighted materials or mechanisms to hold the unit in place.

Use filter fabric that is capable of reducing effluent sediment concentrations by no less than 80% under typical sediment migration conditions.

Select Type E inlet filters from the SCDOT approved products list.

Installation

Surface course inlet filters are applicable for road Catch Basin after the road surface course is placed. Place surface course inlet filters where sediment may spill over sidewalks and curbs.

Install surface course inlet filters in front of curb inlet openings. The filter has a minimum height or diameter of 9-inches and has a minimum length that is 2-feet longer than the length of the curb opening to allow sufficient length to cover the inlet with at least 1-foot of clearance beyond the inlet on both ends.

Do not completely block the inlet opening with surface course inlet filters. Install surface course inlet filters in a manner to allow overflows to enter the catch basin.

Fill the aggregate compartment to a level (at least ½ full) that will keep the surface course inlet filter in place and create a seal between the surface course inlet filter and the road surface.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each storm that produces ½-inches or more of rain. Any needed repairs should be handled immediately.
- Ponding is likely if sediment is not removed regularly.
- Inspect surface course curb inlet filters on a regular basis and immediately after major rain events.
- Clean the surface course curb inlet filter if a visual inspection shows silt and debris build up around the filter.

Surface Course Inlet Filter

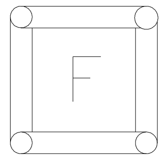
Surface Course Inlet Filter

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive sediment is entering the inlet.	Ensure that soil stabilization and sediment control devices are installed upstream of inlets. Ensure that the surface course inlet filters are installed correctly.
Sediment reaches 1/3 the height of the structure.	Remove sediment.
Surface course inlet filter material becomes clogged with sediment.	Pull surface course filters from inlet and clean them, or replace surface course inlet filters with new filter material.
Ponded water causes a traffic concern.	Use alternate BMPs upstream. Remove surface course inlet filter if necessary.

Type F - Inlet Tubes

Plan Symbol



Inlet tubes are temporary filtering devices placed around inlet structures to trap sediment and keep silt, sediment and construction debris from entering pipe systems through open inlet structures. Additionally, inlet tubes prevent the silting-in of inlets, storm drainage systems and receiving channels.

Materials

Use inlet tubes that exhibit the following properties:

- Produced by a Manufacturer experienced in sediment tube manufacturing.
- Composed of compacted geotextiles, curled excelsior wood, natural coconut fibers or hardwood mulch or a mix of these materials enclosed by a flexible netting material.
- Do not use straw, straw fiber, straw bales, pine needles or leaf mulch under this specification.
- Utilize an outer netting that consists of seamless, high-density polyethylene photodegradable materials treated with ultraviolet stabilizers or a seamless, high-density polyethylene non-degradable materials.
- Curled wood excelsior fiber, or natural coconut fiber rolled erosion control products (RECP) rolled up to create an inlet tube devices are **not** allowed under this specification.

Weighted Inlet Tubes

Weighted inlet tubes are sediment tubes capable of staying in place without external stabilization measures and may have a weighted inner core or other weighted mechanism to keep them in place.

Materials

Weighted inlet tubes meet the minimum performance requirements shown in the table below.

PROPERTY	TEST METHOD	VALUE
Diameter	Field Measured	6.0 inch to 12.0 inch
Mass per Unit Length	Field Measured	6 inch = 6 lbs/ft minimum 12 inch = 12 lbs/ft minimum
Fiber Length	Field Measured	80% of the fiber materials at least 4-inches in length
Length per Tube	Field Measured	6 foot minimum
Netting Unit Weight	Certified	0.35 oz/ft minimum

Select Type F weighted inlet tubes from the SCDOT approved products list.

Installation

Install weighted inlet tubes lying flat on the ground, with no gaps between the underlying surface and the inlet tube. Never stack weighted inlet tubes on top of one another.

Do not completely block inlets with weighted inlet tubes.

Install weighted inlet tubes in such a manner that all overflow or overtopping water has the ability to enter the inlet unobstructed.

To avoid possible flooding, two or three concrete cinder blocks may be placed between the weighted inlet tubes and the inlet.

Non-Weighted Inlet Tubes

Non-weighted inlet tubes are defined as sediment tubes that require staking or other stabilization methods to keep them safely in place.

Materials

Non-weighted inlet tubes meet the minimum performance requirements shown in the table below.

PROPERTY	TEST METHOD	VALUE
Diameter	Field Measured	6.0 inch to 12.0 inch
Mass per Unit Length	Field Measured	6 inch = 1.0 lbs/ft minimum 12 inch = 2.0 lbs/ft minimum
Fiber Length	Field Measured	80% of the fiber materials at least 4-inches in length
Length per Tube	Field Measured	6 foot minimum
Netting Unit Weight	Certified	0.35 oz/ft minimum

Select Type F non-weighted inlet tubes from the SCDOT approved products list.

Installation

Install non-weighted inlet tubes immediately after grading and construction of catch basin boxes. Maintain non-weighted inlet tubes during subgrade and base preparation until the base course is placed.

For weep hole inlet protection applications, both weighted and non-weighted inlet tubes are applicable. Install non-weighted inlet tubes in situations when stakes can be driven into the ground or subgrade to secure the tube.

Review all project specifications for special installation requirements.

Install non-weighted inlet tubes using 2-inch x 2-inch wooden stakes or steel posts consisting of standard "T" sections weighing 1.25 pounds per foot (±8%), 3-feet in length placed on 2-foot centers. Intertwine the stakes with the outer mesh on the downstream side of the inlet tube.

Drive stakes in the ground to a minimum depth of 1-foot leaving less than 1-foot of stake exposed above the non-weighted inlet tube.

An acceptable alternative installation is driving stakes on 2-foot centers on each side of non-weighted inlet tubes and connecting them with natural fiber twine or steel wire to inhibit the non-weighted sediment tube from moving vertically.

Another acceptable alternative installation for non-weighted inlet tubes is installing stakes on 2-foot centers in a crossing manner maintaining direct soil contact at all times.

Install non-weighted inlet tubes so the top of the tube is below the top of the installed curb line to ensure that all overflow or overtopping water has the ability to enter the inlet unobstructed.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each storm that produces ½-inches or more of rain. Any needed repairs should be handled immediately.
- Inlet tubes may be temporarily moved during construction as needed.
- Replace inlet tubes damaged during installation as directed by the Inspector or Manufacturer's Representative at the contractor's expense.

Weighted Inlet Tube

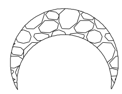
Non-weighted Inlet Tube

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive sediment is entering the inlet.	Ensure that soil stabilization and sediment control devices are installed upstream of inlets. Ensure that inlet tubes are installed correctly.
Sediment reaches 1/3 the height of the inlet tube.	Remove sediment.
Filter material becomes clogged with sediment.	Pull Inlet from tube and clean them, or replace clogged inlet tubes with inlet tubes
Ponded water causes a traffic concern.	Use alternate BMPs upstream. Remove inlet tubes if necessary.

Rock Sediment Dikes

Plan Symbol



Description

Rock sediment dikes are semi-circular sediment control structures constructed across drainage ditches, swales, low areas or other areas that receive concentrated flow. A rock sediment dike consists of a half-circular shaped rock embankment with a sump area constructed for sediment storage. Design rock sediment dikes to have an 80 percent design removal efficiency goal of the total suspended solids (TSS).

When and Where to Use It

Rock sediment dikes are most effective in areas where sediment control is needed with minimal disturbance. Use as a sediment control structures for the outfalls of diversion swales, diversion dikes, in low areas or other areas where concentrated sediment laden flow is expected. Use rock sediment dikes for drainage less than 2.0 acres. Do not place rock sediment dikes in Waters of the State (unless approved by SCDHEC, State, or Federal authorities).

Rock Sediment Dike Design Criteria

Design Aids

The Design Aids located in the rock check dam section of this handbook may be used to properly size rock sediment dikes. Sedimot III, SEDCAD4, Pond Pack and other computer models that utilize eroded particle size distributions and calculates a corresponding trapping efficiency may also be utilized.

General Design Requirements

a. Maximum Drainage Area – 2 acres
b. Maximum Design Life - 18 months
c. Maximum Rock Dike Height – 2-feet
d. Discharge and treatment capacity for the 10-year 24-hour storm event.
e. 80 percent design removal efficiency goal for TSS
f. Determine required sediment storage volume and ensure sediment dike sump provides the volume.
g. Size rock sediment dike to handle the receiving peak flow rates. Flows that overtop the structure have an assumed Trapping Efficiency of 0 percent.

Installation

Install a non-woven geotextile fabric over the soil surface where the rock sediment dike is to be placed.

Construct the body of the rock sediment dike with minimum 9-inch D_{50} Riprap. Construct the upstream face with a 1-foot thick layer of ¾-inch to 1-inch D_{50} washed stone placed at a slope of 2H:1V.

Construct rock sediment dikes with a minimum top flow length of 3-feet (two-foot flow length through the riprap and one-foot flow length through the washed stone).

Place the rock by hand or mechanical placement (no dumping of rock to form the sediment dike) to achieve the proper dimensions.

Install a sediment sump with a minimum depth of 2-feet on the upstream side of the structure to provide sediment storage. Install the upstream side of the sediment sump with a slope of 5H:1V to inhibit erosion of the sediment storage area.

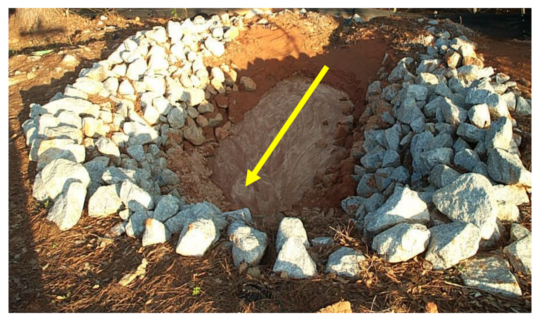
Mark the sediment cleanout level of the sediment dike with a stake in the field.

Seed and mulch all disturbed areas.

Inspection and Maintenance

- The key to a functional rock sediment dike is continual monitoring, regular maintenance and regular sediment removal.
- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Remove sediment when it reaches 50 percent of the sediment storage volume or the top of the cleanout stake. Removed sediment from the sump should be removed from, or stabilized on site.
- Remove rock sediment dikes within 30 days after final site stabilization is achieved or after they are no longer needed. Permanently stabilize disturbed areas resulting from the removal.

Rock Sediment Dike



Rock Sediment Dike

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Sediment reaches 50 percent of the sediment storage volume or the top of the cleanout stake.	Remove accumulated sediment to recover holding capacity.
Rock sediment dikes wash away.	Replace rock sediment dikes using larger stone.
Final site stabilization is achieved.	Remove rock sediment dikes from site within 30 days after stabilization, and permanently stabilize the areas that were disturbed by the dikes.

Engineering Aids and Design Guidelines for Sediment Controls

This section presents design aids developed for use in designing four types of sediment control BMPs in South Carolina;

1. Sediment basins
2. Sediment traps
3. Silt fence
4. Rock check dams.

Each of these design aids is briefly described in this section. Specific BMP examples are located in the specific BMP sections of this Handbook to demonstrate their use in realistic problems. First a common feature of each design aid, settling velocity, is discussed.

Characteristic Settling Velocity and Eroded Particle Size

A common feature of each of the design aids is that a characteristic settling velocity for the eroded soil is obtained. For South Carolina conditions, this velocity corresponds to an eroded size such that 15 percent of the sediment has particles smaller than the size specified. The procedure for empirically estimating eroded size distributions is described by Hayes et. al (1996).

The characteristic settling velocity corresponds to an eroded particle diameter that is referred to as D_{15}. This diameter represents the point on the eroded particle size distribution curve where 15 percent of the particles (by weight) are equal to or smaller than this size. Estimated eroded size distributions for South Carolina soils using an adaptation of the method described by Foster et al. (1985) were developed. The procedure uses the primary particle size information reported by the USDA Soil Conservation Service (SCS) as part of county soil surveys. This procedure may be used with USDA Soil Survey Data or site specific soil boring data. Other procedures are given by Haan et. al. (1994) for physically based estimating procedures.

If the eroded particle size D_{15} is less than 0.01 mm, then the settling velocity based upon a simplified form of Stokes Law is:

$$\mathbf{V_s = 2.81d^2}$$

Where:

V_s	=	settling velocity (ft/sec)
d	=	soil eroded particle size diameter (mm).

If the eroded particle size D_{15} is greater than or equal to 0.01 mm, then settling velocity is found using:

$$\mathbf{\log_{10}V_s = -0.34246\,(\log_{10}d)^2 + 0.98912\,(\log_{10}d) - 0.33801}$$

Where:

V_s	=	settling velocity (ft/sec)
d	=	soil eroded particle size diameter (mm) (Wilson et al., 1982)

The characteristic settling velocity is obtained using Figure SV-1. The eroded particle sizes (D_{15}) for soils found in South Carolina are provided in Appendix E.

It is important to remember that the eroded size distribution is the most critical parameter in sizing sediment controls. The eroded size distributions vary greatly from primary particle size distributions that are often determined as a result of soil strength investigations for construction purposes. Primary particle sizes yield erroneous results and should not be used. The user should note that D_{15} is often smaller for coarse textured (more sandy soils) because of the reduced clay content and the lack of aggregation.

Soil Classification by Texture

Land Resource Region	Coarse	Medium	Fine
Piedmont, Coastal	Sandy Loam	Silt Loam	Clay Loam
Sandhills	Sand	Sandy Loam	Silt Loam
Tidal with High Water Table	Sandy Loam	Silt Loam	Clay Loam

Sediment Basin Design Aids

The Sediment Basin Design Aids are designed for soils classed as either coarse (sandy loam), medium (silt loam), or fine (clay loam). The design ratio should be less than or equal to the curve value at any given trapping efficiency. The sediment basin Design Aids have been developed for the following two separate conditions:

- Basins **not** located in low lying areas and/or not having a high water table, and
- Basin located in low lying areas and/or having a high water table.

Design Aid Ratio

$$\text{Basin Ratio} = \frac{q_{po}}{A V_{15}}$$

Where:

q_{po} = Peak outflow rate from the basin for the 10-year 24-hour storm event (cfs)
A = Surface area of the pond at riser crest (acres)
V_{15} = Characteristic settling velocity (fps) of the characteristic D_{15} eroded particle (mm).

Constraints for use of Sediment Basin Design Aids:

- Watershed area less than or equal to 30 acres
- Overland slope less than or equal to 20 percent
- Outlet diameter less than or equal to 6-feet

Basin Ratios above the design curves are not recommended for any application of the design aids. If the basin ratio q_{po}/AV_{15} intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

- A basin **not** located in a low lying area and not having a high water table, has a basin ratio equal to 2.20 E5 at 80 percent trapping efficiency as shown in Figure SB-1.

- A basin that **is** located in a low lying area or in an area that has a high water table, has a basin ratio equal to 4.70 E3 at 80 percent trapping efficiency as shown in Figure SB-2.

Rock Check Dam Design Aids

Design aids for rock check dams were developed similarly to those for ponds. Again, the D_{15} eroded particle size is used for the calculation of the characteristic settling velocity.

The Rock Check Dam Design Aids have been designed for the following soil classifications:

- Coarse (sandy loam)
- Medium (silt loam)
- Fine (clay loam).

The design ratio should be less than or equal to the curve value at any given trapping efficiency. The ratio for rock check dams is defined by:

Design Aid Ratio

$$\text{Rock Check Ratio} = \frac{Sq^{(1-b)}}{aV_{15}}$$

Where:

S = Channel slope (%)
q = Unit width flow through the check for the 10-year 24-hour storm event (cfs/ft)
V_{15} = Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Coefficients *a* and Exponent *b* is interpolated from the following table.

Stone Flow Coefficient *a* and Exponent *b*

Stone Diameter(m)	Exponent b	Coefficient a		
		dl= 1m	dl = 2m	dl = 3m
0.01	0.6371	9.40	6.05	4.60
0.02	0.6540	7.40	4.65	3.55
0.03	0.6589	6.40	4.08	3.08
0.04	0.6609	5.85	3.65	2.80
0.05	0.6624	5.40	3.35	2.60
0.06	0.6635	5.05	3.15	2.40
0.08	0.6644	4.50	2.85	2.20
0.09	0.6648	4.28	2.70	2.10
0.10	0.6651	4.13	2.60	2.05
0.20	0.6662	3.20	2.05	1.57
0.30	0.6664	2.80	1.75	1.30
0.40	0.6665	2.50	1.55	1.16
0.50	0.6666	2.30	1.40	1.08

D_{50} = rock check dam average stone diameter in meters.
***dl* = average flow length through the rock ditch check in meters.**
Source: Haan et. al. (1994) pg. 151.

Constraints for the use of Rock Check Dam Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 15 percent
- Maximum depth of the ditch is less than or equal to 6-feet

Rock Check Ratios above the design curves are not recommended for any application of the design aids. If the Rock Check Ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A rock check dam located on coarse soils has a ditch check ratio equal to 1.10 E3 at 80 percent trapping efficiency as shown in Figure DC-C.

A d rock check dam located on medium soils has a ditch check ratio equal to 5.80 E3 at 80 percent trapping efficiency as shown in Figure DC-M.

A d rock check dam located on fine soils has a ditch check ratio equal to 1.20 E4 at 80 percent trapping efficiency as shown in Figure DC-F.

Silt Fence Design Aids

This design aid for applies to silt fences placed in areas down slope from disturbed areas where it serves to retard flow and cause settling. Two conditions must be met for satisfactory design.

- Trapping efficiency must meet the desired level of control.
- Overtopping of the fence must not occur.

Design Aid Ratio

The silt fence design aid is a single line grouping all soil textures together. A similar procedure was used for development of the ratio as used for the ponds and rock checks. For the silt fence, the ratio is:

$$\text{Silt Fence Ratio} = \frac{q_{po}}{V_{15} P_{area}}$$

Where:

$\mathbf{q_{po}}$	=	Peak outflow through the fence for the 10-year 24-hour storm event (cfs)
$\mathbf{V_{15}}$	=	Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm)
$\mathbf{P_{area}}$	=	Potential ponding area up slope of the fence (ft^2).

The ponding area is estimated by using the height of the fence available for flow through and extending a horizontal line from the fence to an intersection with the ground surface upslope of the fence. The unit available area is calculated by multiplying the fence height by the ground slope. Multiply this unit area by the available fence length for ponding to obtain the potential ponding area.

Using the calculated ponding area, calculate the ratio and enter the value to Figure SF-1 to determine the efficiency. Once an acceptable trapping efficiency is determined, a calculation for overtopping must be performed. The overtopping calculation must be performed using the slurry flow rate through the fence. This rate must be checked against the incoming flow to determine if enough storage exist behind the fence to prevent overtopping.

Constraints for the use of Silt Fence Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 6 percent
- Slurry flow rate through the fence is less than or equal to 10 gpm / ft
- Maximum height of the silt fence is less than or equal to 3-feet

Silt Fence Ratios above the design curves are not recommended for any application of the design aids. If the silt fence ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A silt fence ratio equal to 0.23 has an 80 percent trapping efficiency as shown in Figure SF-1.

Sediment Trap Design Aids

Sediment traps, for the purposes of this document, are small excavated ponds with rock fill outlets. Their outlet hydraulics are different from a drop inlet structure, thus the Design Aid is slightly different with the area defined as being the area at the bottom of the outlet structure. Trapping efficiencies for sediment traps are plotted in Figure ST-1 as a function of the sediment trap ratio:

Design Aid Ratio

The sediment trap design aid is a single line grouping all soil textures together. A similar procedure was used for the development of the ratio as used for basins. For the sediment trap, the ratio is:

$$\text{Sediment Trap Ratio} = \frac{q_{po}}{A\,V_{15}}$$

Where

q_{po} = Peak outflow for the 10-year 24-hour storm event (cfs)

A = Surface area at the elevation equal to the **bottom** of the rock fill outlet (acres)

V_{15} = Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Constraints for the use of Sediment Trap Design Aids are:

- Watershed area less than or equal to 5 acres
- Overland slope less than or equal to 20 percent
- Rock fill diameter greater than 0.2-feet and less than 0.6-feet
- Rock fill height less than 5-feet
- Top width of rock fill between 2- and 4-feet
- Maximum Side slopes 1:1 to 1.5:1.

Sediment Trap Ratios above the design curves are not recommended for any application of the design aids. If the sediment trap ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A sediment trap ratio equal to 9.0 E4 has an 80 percent trapping efficiency as shown in Figure ST-1.

Storm flows shall be routed through the sediment trap to calculate the required depth and storage volume of the trap.

A sediment storage volume should be calculated and provided below the bottom of the rock fill outlet structure.

Runoff Control and Conveyance Measures

Storm water runoff is rainfall or snowmelt that runs off the ground or impervious surfaces (buildings, roads, parking lots, etc.) and drains into natural or manmade drainage ways. In some cases, it drains directly into streams, rivers, lakes, sounds or the ocean. In other cases, particularly urbanized areas, it drains into streets and manmade drainage systems consisting of inlets and underground pipes commonly referred to as "storm sewers." Storm water entering storm sewers does not usually receive any treatment before it enters streams, lakes and other surface waters.

Storm water runoff problems and impacts are most evident in areas where urbanization has occurred. Changes in land use have a major effect on both the quantity and quality of Storm water runoff. Urbanization, if not properly planned and managed, can dramatically alter the natural hydrology of an area. Increased impervious cover decreases the amount of rainwater that can naturally infiltrate into the soil and increases the volume and rate of storm water runoff. These changes lead to more frequent and severe flooding and potential damage to public and private property. Under natural conditions, typically 10% of rainwater falling on a piece of property runs off the land surface into streams, rivers or lakes. The remainder either evaporates into the air or infiltrates into the soil replenishing groundwater supplies. Development of the site increases the percentage of impervious surfaces. As the percentage of impervious surfaces increases, the percentage of runoff increases since there is less vegetated area to soak up the rainwater.

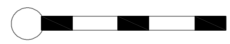
The rate of runoff and streamflow after a storm event also shows dramatic increases under post versus predevelopment conditions. The higher and more rapid peak discharge of runoff and streamflow can overload the capacity of the stream or river, causing downstream flooding and streambank erosion. Local governments spend millions of dollars each year rectifying damage to public and private property caused by uncontrolled storm water runoff. In heavily developed areas, damage to public and private property occurs during heavy rains. This damage includes road, culvert, and water and sewer line washouts, flooded homes and yards, the deposition of sediment and debris on properties and roads, and damage to bridges. When streambanks erode they clog stream channels, culverts, and pipes with sediment contributing to flooding problems. Sediment is washed into ponds, lakes, and other impoundments reducing their capacity to store water and requiring costly removal efforts. The increased volume and velocity of runoff and streamflow can also cause accelerated channel erosion and changes in streambed composition. This can destroy fish habitat and disrupt the natural ecology of the stream or river.

The following runoff control BMPs are discussed in this handbook:

- Pipe Slope Drains
- Runoff Diversion Measures
- Level Spreader
- Temporary Stream Crossing
- Subsurface Drains
- Construction De-watering

Pipe Slope Drains

Plan Symbol



Description

Pipe slope drains reduce the risk of erosion by discharging concentrated runoff from the top to the bottom of slopes. Pipe slope drains is temporary or permanent depending on installation and material used.

When and Where to Use It

Use pipe slope drains when it is necessary for water to flow down a slope without causing erosion, especially before a slope has been stabilized or before permanent drainage structures are installed. Install temporary pipe slope drains prior to construction of permanent drainage structures. Bury permanent slope drains beneath the ground surface. Stabilize the inlets and outlets of pipe slope drains with flared end sections, Erosion Control Blankets (ECBs), Turf Reinforcement Mats (TRMs) or riprap. Fully compact the soil around the pipe entrance to prevent bypassing and undercutting of the structure. Stabilize the discharge end of the pipe and along the bottom of any swales that lead to sediment trapping structures.

General Design Requirements

Typical pipe slope drains are made of non-perforated corrugated plastic pipe and are designed to pass the peak flow rates for the 10-year 24-hour storm event.

The maximum drainage area per pipe is two acres.

Installation

Secure and fasten slope drain sections together with gasket watertight fittings. Securely anchor slope drains to the soil with wooden stakes or steel posts.

Direct runoff to slope drains with diversion berms, swales, or dikes. The minimum depth of these dikes or berms should be 1.5-feet. The height of the berm around the pipe inlet should be a minimum of 1.5-feet high and at least 0.5-feet higher than the top of the pipe. The berm at the pipe inlet shall be compacted around the pipe. The area around the inlet shall be properly stabilized with ECBs, TRMs, riprap or other applicable stabilization techniques.

The area below the outlet must be properly stabilized with ECBs, TRMs, riprap or other applicable stabilization techniques.

If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.

Permanent slope drains should be buried beneath the soil surface at minimum depth of 1.5-feet.

Inspection and Maintenance

- Inspect pipe slope drain inlet and outlet points every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Inspect the inlet for undercutting, and water bypassing the point of entry. If there are problems, reinforce the headwall with compacted earth or sandbags.

- Inspect the outlet point for erosion and appropriate outlet protection.
- Remove temporary pipe slope drains within 30 days after final site stabilization is achieved or after the temporary BMP is no longer needed.
- Permanently stabilize disturbed soil areas resulting from slope drain removal.

Pipe Slope Drain

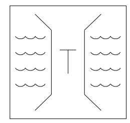
Pipe Slope Drain

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Pipe separates.	Reconnect pipe sections. Securely anchor and stabilize pipe into soil. Ensure that pipe connections are watertight.
Pipe outlet erodes.	Repair the damage and stabilize outlet with a flared end section, riprap, TRM or velocity dissipation device. If necessary, reduce flows being discharged.
Pipe becomes clogged.	Flush out pipe. Place a screen or grate at inlet to capture trash and large particles.
Erosion occurs around inlet.	Compact soil and stabilize area with flared end section, TRM or filter fabric and riprap. Re-grade around inlet to reduce the gradient angle.
Excessive sediment accumulates around inlet/outlet.	Remove accumulated sediment and stabilize upstream area.
Slope drain overtops.	Limit drainage area and flow velocity. Check pipe diameter to ensure that it is sized properly to accept flow. Add additional pipes to carry flows as necessary.

Temporary Stream Crossing

Plan Symbol



Description

A temporary stream crossing is a bridge or culvert across a stream or watercourse for short-term use by construction vehicles and heavy equipment. A stream crossing provides a means for construction vehicles to cross streams or watercourses without moving sediment to streams, damaging the stream bed or channel, or causing flooding. Prior to constructing a temporary stream crossing, the owner/person financially responsible for the project must submit an Application for Permit to construct across or along a stream to South Carolina Department of Health and Environmental Control (SCDHEC). Temporary stream crossings require authorization. Refer to the US Army Corps of Engineers and SCDHEC nationwide 401 and 404 regulations for information on permitting requirements.

When and Where to Use It

When feasible, attempt to minimize or eliminate the need to cross streams. Temporary stream crossings are a direct source of pollution; therefore, every effort should be made to use an alternate method (e.g., longer detour), when feasible. When it becomes necessary to cross a stream, a well-planned approach minimizes damage to streambanks and reduces erosion. The design of temporary stream crossings requires knowledge of the design flows.

Temporary Bridge Crossing Design Criteria

- Structures are designed in various configurations. Select construction materials capable of withstanding the anticipated heavy loading of the construction traffic.
- Crossing Alignment. Design temporary waterway crossing at right angles to the stream. Where approach conditions dictate, the crossing may vary 15^{o} from a line drawn perpendicular to the centerline of the stream at the intended crossing location.
- Design a water diverting structure such as a dike or swale across the roadway on both roadway approaches 50-feet (maximum) on either side of the waterway crossing. This prevents roadway surface runoff from directly entering the waterway. Measure the 50-feet from the top of the waterway bank. Direct the flow captured in these dikes and swales to a sediment trapping structure. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.
- Design appropriate perimeter controls such as silt fences, along stream banks.
- Design crossings with one traffic lane with a minimum width of 12-feet and a maximum width of 20-feet.

Temporary Culvert Crossing Design Criteria

- Limit the width of fill to that only necessary for the actual crossing.
- Use coarse aggregate of clean shot limestone rock and riprap with a 6-inch D_{50} or greater.
- Use clean shot rock and/or riprap as fill for crossings that will be in place for 6 to 12 months. Install a concrete cap over the rock for crossings that will be in place for more than 12 months.

- Design the stone cover over the culvert equal to ½ the diameter of the culvert or 12-inches, whichever is greater, but no greater than 18-inches.
- Design the culvert crossing to convey the flow from a two-year frequency storm without appreciably altering the stream flow characteristics.
- Place the maximum possible number of pipes within the streambanks with a maximum spacing of 12-inches between pipes.
- The minimum-sized pipe culvert used is 24-inches.
- Design culverts strong enough to support their cross-sectional area under the maximum expected heavy equipment loads.
- Design an adequate culvert length to extend the full width of the crossing, including side slopes.
- Design the minimum culvert slope to 3-inches per foot.
- Crossing Alignment. Design temporary culvert crossing at right angles to the stream. Where approach conditions dictate, the crossing may vary 15^{o} from a line drawn perpendicular to the centerline of the stream at the intended crossing location.
- Design approaches to meet the following specifications:
  1. Clean stone or concrete fill only
  2. Minimum thickness: 6-inches
  3. Minimum width: equal to the width of the structure
  4. 20-feet minimum approach length
- Design a water diverting structure such as a dike or swale across the roadway on both roadway approaches 50-feet (maximum) on either side of the waterway crossing. This prevents roadway surface runoff from directly entering the waterway. Measure the 50-feet from the top of the waterway bank. Direct the flow captured in these dikes and swales to a sediment trapping structure. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.
- The maximum design life of temporary culvert crossings is 24 months.

Installation

Install crossings prior to any other activities. Install and maintain pump-around diversions prior to any excavation and during the installation of the crossing. Place crossings in temporary construction easements only.

Minimize streambank clearing. Do not excavate rock bottom streambeds to install the crossing. Lay the culvert pipes on the streambed "as is" when applicable. Place as many pipes as possible within the low area of the stream. Place remaining pipes required to cross the stream on the existing stream bottom.

Install pipes with a maximum spacing of 12-inches between pipes. The minimum sized pipe culvert that may be used is 24-inches.

Install culverts with a length that extend the full width of the crossing, including side slopes.

Use coarse aggregate of clean limestone riprap with a 6-inch D_{50} or greater to form the crossing. Install the stone cover over the culvert equal to ½ the diameter of the culvert or 12-inches, whichever is greater, but no greater than 18-inches.

Limit all fill materials associated with the roadway approach to a maximum height of 2-feet above the existing flood plain elevation.

Inspection and Maintenance

- Inspect crossings every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation. Check the structure integrity and for excessive sediment deposition and replace fill stone as needed.
- Clean mud and/or sediment from the roadway and prevent it from entering the stream.
- The structure shall be removed when it is no longer required to provide access to the construction area. During removal, leave stone and geotextile fabric for approaches in place. Place fill over the approaches as part of the streambank restoration operation. A temporary culvert crossing should be in place no longer than 24 months.

Temporary Stream Crossing

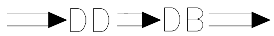
Temporary Stream Crossing

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slopes of temporary earthen crossing erodes.	Place rock layer on slope sides. Stabilize roadway at crossing.
Sediment and debris block culvert inlet.	Remove sediment and debris as necessary to keep pipe open.
Pipe outlet causes erosion.	Stabilize outlet with riprap or flared end section.
Overtopping occurs.	Incorrect design. Redesign crossing and obtain approval (stamp) of registered civil and/or structural engineer.

Runoff Diversion Measures (Diversion Berms/Dikes and Swales)

Plan Symbol



Description

Diversion dikes and berms (ridges of compacted soil) and diversion swales (excavated depressions) are used to divert upslope runoff from crossing areas where there is a high risk of erosion. Use runoff conveyance structures as temporary clean water diversions, temporary sediment laden diversions, or permanent clean water diversions. Use runoff control measures as either temporary or permanent storm water control structures.

When and Where to Use It

Runoff conveyance measures are installed around the perimeter of a construction sites before major disturbing activities takes place. When constructed along the upslope perimeter of a disturbed or high-risk area (though not necessarily all the way around it), clean water diversions prevent clear water runoff from flowing over unprotected down slope areas. Sediment laden diversions located on the downslope side of a disturbed or high-risk area prevent sediment-laden runoff from leaving the site before sediment is properly removed. For short slopes, runoff control measures at the top of the slope reduce the amount of runoff reaching the disturbed area. For longer slopes, several dikes or swales are placed across the slope at intervals. This practice reduces the amount of runoff that accumulates on the face of the slope and carries the runoff safely down the slope. In all cases, runoff is guided to sediment trapping area or a stabilized outfall before release.

General Design Requirements

Runoff conveyance measures are used in areas of overland flow. Direct runoff channeled by diversion dikes or swales to an adequate sediment trapping structure or stabilized outfall. Provide enough channel slope for drainage but not too much slope to cause erosion due to high runoff flow velocities. Temporary runoff control measures may remain in place as long as 12 to 18 months (with proper stabilization). Diversion dikes or swales remain in place until the area they were built to protect is permanently stabilized. Design permanent controls to handle runoff after construction is complete. Permanent controls should be permanently stabilized, and should be inspected and maintained on a regular basis.

Diversion Dike and Berm General Design Requirements

- Top Width. 2 foot minimum.
- Height of Dike or Berm 1.5 foot minimum measured from upslope toe.
- Side Slopes. 2H:1V or flatter.
- Grade. Limit grades between 0.5 percent and 1.0 percent.
- Stabilization. Stabilize slopes immediately using vegetation, sod, and erosion control blankets or turf reinforcement mats to prevent erosion.
- Outlet. Provide positive drainage to the upslope side of the dike so no erosion occurs at the outlet. Provide energy dissipation measures as necessary. Discharge sediment-laden runoff through a sediment trapping facility.
- Other. Minimize construction traffic over diversion dikes and berms.

Diversion Swale General Design Requirements

- Bottom Width. 2 foot minimum, with a level bottom.
- Depth. 1.5 foot minimum.
- Side Slope. 2H:1V or flatter.
- Grade. Maximum 5 percent, with positive drainage to a suitable outlet.
- Stabilization. Stabilize with erosion control blankets or turf reinforcement mats immediately.
- Outlet. Level spreader or riprap to stabilize outlet/sedimentation pond.

Installation

Stabilized using vegetation, sod, and ECBs or TRMs before any major land disturbing activity takes place.

Install the top width of diversion dikes at least 2-feet wide. Install the bottom width at ground level at least 8-feet wide.

The minimum height for earthen dikes is 18-inches, with side slopes no steeper than 2H:1V.

Minimize construction traffic over diversion dikes and berms. However, for points where vehicles must cross the dike, the slope should be no steeper than 3H:1V and the mound should be constructed of gravel rather than soil.

Prior to swale excavation or dike building, clear and grub all trees, brush, stumps, and other objects in the path of the diversion structure.

Ensure the minimum constructed cross section meets all dimensions shown on the plans.

Immediately after construction establish vegetation by placing an Erosion Control Blanket on the diversion dikes and silt ditches.

Provide positive drainage to the upslope side of the dike so no erosion occurs at the outlet. Provide energy dissipation measures as necessary. Discharge sediment-laden runoff through a sediment trapping facility.

Inspection and Maintenance

- The runoff control measure should be inspected, every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation and repairs made as necessary.
- Damage caused by construction traffic or other activity must be repaired before the end of each working day.

Diversion Berm

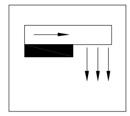
Diversion Berm

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Dikes wash out.	Re-grade, compact, and stabilize the soil used to build earthen dikes.
Area behind dikes eroded.	Stabilize the area. Use other BMPs to stabilize the uphill side of the dike.
Concentrated flow causes erosion.	Stabilize area and use check dams, ECBs, TRMs or riprap to prevent erosion.
Ditches and swales erode due to high velocity flows.	Stabilize and use check dams, ECBs, TRMs or riprap to prevent erosion.
Swales and ditches fill up with sediment.	Remove accumulated sediment from ditches and swales. Stabilize upstream contributing areas with appropriate erosion prevention BMPs.
Ditches and swales are overtaken by flows.	Determine the upstream contributing areas and size ditches and swales to handle anticipated flow velocities.
Outlet erodes.	Re-grade and stabilize outlet with ECBs, TRMs or riprap.

Level Spreader

Plan Symbol



Description

A level spreader is a permanent outlet for dikes and diversions consisting of an excavated channel constructed at zero grade across a slope that converts concentrated runoff to sheet flow and releases it onto areas stabilized by existing vegetation. Sediment-laden waters **should not** be directed towards level spreaders.

When and Where to Use It

Construct level spreaders on undisturbed areas that are stabilized by existing vegetation and where concentrated flows are anticipated to occur. Diversion channels call for a stable outlet for concentrated storm water flows. The level spreader is used for this purpose if the runoff is relatively free of sediment. If properly constructed, level spreaders significantly reduce the velocity of concentrated storm water and spread it uniformly over a stable undisturbed area.

Design Criteria

Design the grade of the channel transition for the last 20-feet before entering the level spreader less than or equal to 1 percent. The crest of the overflow is level (0 percent grade) to ensure uniform spreading of runoff.

Design the lip of the level spreader with a Turf Reinforcement Mat (TRM) able to withstand 5-lbs./ft shear stress.

Determine the spreader dimensions by estimating the flow expected from the 10-year, 24-hour design storm (Q_{10}). The maximum flow into the spreader should not exceed 30 cfs.

- The minimum width of the spreader is 6-feet.
- Design a minimum uniform depth of 0.5-feet across the entire length the of the spreader as measured from the crest of the lip.
- The maximum design the slope of the undisturbed outlet is 10 percent.

Installation

Care must be taken during construction to ensure the lower lip of the structure is level.

If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. Avoid the problem by using a grade board, a gravel lip or a TRM along the exit lip of the level spreader.

Extend the TRM 10-feet below the lip and bury it at least 6- inches within the spreader, and extend at least 12-inches beyond the lip on the outside of the spreader.

Install the grade of the channel transition for the last 20-feet before entering the level spreader less than or equal to 1 percent.

Install the crest of the overflow level (0 percent grade) to ensure uniform spreading of runoff.

Inspection and Maintenance

- The spreader should be inspected every 7 days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation to ensure that it is functioning correctly.
- The contractor should avoid the placement of any material on the structure or prevent construction traffic across the structure.
- If the spreader is damaged by construction traffic, it should be immediately repaired.

Level Spreader

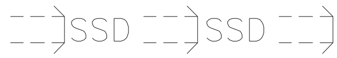
Level Spreader

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Spreader is damaged by construction traffic.	Repair immediately.
Water is channelizing and causing erosion.	Make sure level spreader lip was installed correctly, with a 0% grade to ensure a uniform distribution of flow, Repair immediately, as needed.
Too much sediment has accumulated.	Remove accumulated sediment to recover capacity. A sediment forebay may need to be constructed at the inlet of the level spreader.

Subsurface Drains

Plan Symbol



Description

A subsurface drain is a perforated pipe or conduit placed beneath the surface of the ground at a designed depth and grade.

When and Where to Use It

Subsurface drains are used to do the following:

- Drain areas by intercepting and conveying groundwater.
- Lower the water table.
- Drain or de-water storm water detention structures.
- Prevent sloping soils from becoming excessively wet and subject to slippage.

There are two types of subsurface drains: relief drains and interceptor drains.

- Relief drains are used to de-water an area where the water table is high. They are placed in a gridiron, herringbone, or random pattern.
- Interceptor drains are used to remove water where soils are excessively wet or subject to slippage. They are usually placed as single pipes instead of patterns.

Subsurface drains are suitable only in areas where the soil is deep enough for proper installation. They are not recommended where they pass under heavy vehicle crossings.

General Design Criteria

- Size subsurface drains for the required flow capacity. The minimum diameter for subsurface drains is **4-inches.**
- The minimum velocity required to prevent silting is **1.4-feet/second**. Grade the line to achieve this velocity.
- Use filter material and/or fabric around all drains for proper bedding and filtration of fine materials. Place a minimum of 3-inches of material on all sides of the pipe.
- If free of sediment, design the outlet to discharge into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining. Locate the outlet point above the mean water level of the receiving channel. The outlet consists of a 10-foot section of corrugated metal, cast iron, steel or schedule 40 PVC pipe without perforations.
- Acceptable materials for subsurface drains include perforated, continuous closed-joint conduits of corrugated plastic pipe meeting the requirements of AASHTO M252 for polyethylene tubing, AASHTO M278 Class PS 50 for polyvinyl requirements, or AASHTO A1 196 for Type III aluminum alloy pipe.
- Subsurface drains are not designed to flow under pressure and the hydraulic gradient is parallel with the grade line. The flow is considered to be open channel and Manning's Equations is used. The required subsurface drain size is determined from the following steps:
  - Determine the flow rate that the subsurface drain must carry.
  - Determine the gradient of the drain.
  - Determine the appropriate Manning's n value for the selected subsurface drain pipe.
  - Select the appropriate subsurface drain capacity chart.
  - Enter the gradient of the pipe and the design flow of the pipe.

Installation

Install relief drains through the center of wet areas that drain in the same direction of the slope.

Install interceptor drains on the up-slope side of wet areas and install them across the slope to drain to the side of the slope.

Locate subsurface drains in areas where there are no trees within 50-feet of the drain.

Construct the installation trench on a continuous grade with no reverse grades or low spots.

Stabilize soft or yielding soils under the drain with gravel or suitable material.

Do not use deformed, warped, or otherwise unsuitable pipe.

Place filter material at least 3-inches of material on all sides of pipe.

Backfill trenches after pipe placement with no pipe remaining uncovered overnight or during a rainstorm. Place backfill material in the trench so that the pipe is not displaced or damaged. Use highly permeable open granular soil for backfill.

The outlet should consist of a 10-foot section of corrugated metal, cast iron, steel or schedule 40 PVC pipe without perforations. At least two-thirds of outlet pipe should be buried.

The outlet consists of a 10-foot section of corrugated metal, cast iron, steel or schedule 40 PVC pipe without perforations.

Inspection and Maintenance

- Inspect subsurface drains on a regular schedule and check for evidence of pipe breaks or clogging by sediment, debris, or tree roots.
- Remove blockage immediately, replace any broken sections, and re-stabilize the surface. If the blockage is from tree roots, it may be necessary to relocate the drain.
- Check inlets and outlets for sediment or debris. Remove and dispose of these materials properly.
- Check the drainage line where heavy vehicles cross drains to ensure that pipes are not crushed or damaged.

Subsurface Drain

Subsurface Drain Pipe

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Discharge or treated water causes erosion.	Install outlet protection or velocity dissipation device.
Treatment unit fills with sediment.	Remove sediment when unit reaches 1/3 its capacity to preserve settling efficiency.
Dewatering discharge flow is higher than expected.	Alter the treatment unit to handle increased flow.
Water spread on the construction site is not infiltrating fast enough and is entering the storm drain system or receiving water body.	Stop dewatering. Install a sediment treatment system and test discharge as necessary.

Construction De-Watering

Description

Construction de-watering involves removing storm water or ground water from bore pits, trenches, and other excavations on a construction site. Typically, this removal of water involves the pumping of the water to an appropriate receiving area. Direct pumping to lakes, rivers, and streams is illegal and must be avoided.

Design Criteria

Size the pump utilized for de-watering purposes properly. Each pump has its own unique rating curve, therefore it is not feasible to list them in this chapter. The pump rating curve is used to calculate pump design flows based on head loss through the pump system.

Pump sediment-laden groundwater directly to:

- A sediment control structure (sediment basin, sediment trap manufactured de-watering device)
- An infiltration trench
- A buffer strip or zone

Inspection and Maintenance

Pumping to a Sediment Control Structure:
It is recommended that sediment basins or temporary sediment traps receive sediment-laden water from bore pits and trenches. Ensure that the pumping of this water does not cause the sediment control structure to fail. In addition, ensure that erosion does not occur at the outlet of the hose from the pump due to high concentrated flows.

Pumping to an Infiltration Trench:
Ensure that erosion does not occur at the outlet of the hose from the pump due to high concentrated flows.

Pumping to a Vegetated Buffer Zone:
Ensure that erosion does not occur at the outlet of the hose from the pump due to high concentrated flows.

Construction Dewatering

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Discharge or treated water causes erosion.	Install outlet protection or velocity dissipation device.
Treatment unit fills with sediment.	Remove sediment when unit reaches 1/3 its capacity to preserve settling efficiency.
Dewatering discharge flow is higher than expected.	Alter the treatment unit to handle increased flow.
Water spread on the construction site is not infiltrating fast enough and is entering the storm drain system or receiving water body.	Stop dewatering. Install a sediment treatment system and test discharge as necessary.

Alternative Erosion Prevention and Sediment Control BMPs

To encourage the development and testing of innovative alternative EPSC BMPs, alternative management practices that are not included in the Handbook, Standard Specifications and Standard Drawings may be accepted upon review and approval. To use an alternative BMP, submit substantial evidence that the proposed measure will perform at least equivalent to currently approved BMPs contained in the Handbook, Standard Specifications, and Standard Drawings. Evidence may include, but is not limited to:

- Supporting hydraulic and trapping efficiency calculations.
- Peer-review by a panel of licensed professional engineers.
- Research results as reported in professional journals.
- Manufacturer literature.

To justify the efficiency of innovated EPSC BMPs, the owner may be required to monitor the trapping efficiency of the structure. If satisfactory results showing trapping efficiencies of greater than 80 percent are obtained, the innovative BMP may be used and no other monitoring studies should be required. If monitoring shows that a certain BMP is not sufficient or if SCDHEC finds that a BMP fails or is inadequate to contain sediment, other upstream and downstream BMPs should be implemented to reach the required efficiency.

Post Construction Water Quality Control

Post-construction storm water management in areas undergoing new development or redevelopment is necessary because runoff from these areas significantly affects receiving waterbodies. There are two forms of substantial impacts of post-construction runoff. The first is an increase in the type and quantity of pollutants in storm water runoff. As runoff flows over areas altered by development, it picks up harmful sediment and chemicals such as oil and grease, pesticides, heavy metals, and nutrients. These pollutants become suspended in runoff and are carried to receiving waters, such as lakes, ponds, and streams. Once deposited, these pollutants enter the food chain through small aquatic life, eventually entering the tissues of fish and humans.

The second kind of post construction runoff impact is increasing the quantity of water delivered to the waterbody during storms. Increased impervious surfaces interrupt the natural cycle of gradual percolation of water through vegetation and soil. Instead, water is collected from surfaces such as asphalt and concrete and routed to drainage systems where large volumes of runoff quickly flow to the nearest receiving water. The affects of this process include streambank scouring and downstream flooding, which often lead to a loss of aquatic life and damage to property.

Water Quality Regulations

Water quality control consists of post-development controls that reduce the impacts of development on the water quality of receiving downstream water bodies. Use the following design criteria for water quantity control unless a waiver is granted on a case-by-case basis.

- Design permanent water quality ponds and detention structures having a permanent pool elevation to store and release the first ½-inch of runoff from the site over a minimum period of 24-hours. Design the water quality storage volume of these water quality structures to accommodate at least one-half (½) inch of runoff from the contributing drainage area.

- Design permanent water quality structures **not** having a permanent pool elevation to store and release the first one 1-inch of runoff from the site over a minimum period of 24-hours.

- Design permanent water quality ponds and detention structures within ½-mile of a receiving water body in the coastal zone to store a volume of ½-inch of runoff from the entire site or the first 1 inch of runoff from built-upon portions of the property, which ever is greater.

- Design projects located within 1,000 feet of shellfish beds to retain the first 1.5 inches of runoff from built-upon portions of the property.

- Design permanent water quality infiltration practices to accommodate at a minimum the first 1-inch of runoff from impervious areas located on the site.

- When existing wetlands are intended to be water quality structures, the Storm Water Management Permit is not implemented until all necessary Federal and State permits have been obtained.

Water Quality Volume

The water quality volume is the storage needed within a water quality control BMP to control the "first flush" of runoff during a storm event. The water quality volume can be calculated as:

$$WQV = \frac{FFV * DA}{12}$$

Where:
FFV = First flush runoff depth inches (½, 1.0, or 1-½ dependent upon site conditions)
WQV = Water quality volume (acre-feet)
DA = Design drainage area to water quality BMP (acres)

Variances

SCDHEC may grant variances from the State Storm water Management Regulations for post-construction water quality if the applicant provides sufficient data and acceptable justification. The applicant must provide a written request for a variance in the Permit application package specifically stating the variances sought and all data that supports the variance. SCDHEC has the authority to reject a written request for a variance if the justification is deemed unacceptable or is associated with a project located in sensitive areas of South Carolina where variances have been deemed to be unacceptable.

A project may be eligible for a waiver from water quality control requirements if the applicant can justly verify that:

- The proposed land development activity will return the disturbed areas to the pre-development land use and runoff conditions.
- The proposed land development will create land use conditions that have the potential to discharge less pollutants than the pre-development land use conditions.
- The pre-development land use conditions are unchanged at the end of the project.
- An alternative water quality plan is designed that provides a reasonable alternative to water quality storage and release time requirements and that still fulfills the intent of the regulations. Specific development sites may not have enough land area to incorporate traditional water quality structures that provide the required storage volume. Alternative technologies and development techniques may be acceptable provided that sufficient documentation exists as to the effectiveness and reliability of the proposed structures or techniques.
- Exceptional circumstances exist such that strict adherence to the regulations could result in unnecessary hardship and not fulfill the intent of the regulations.

This variance does not exclude water quality, erosion prevention, sediment control from being implemented during the active construction phases of a particular project.

Water Quality BMPs

Water Quality control BMPs can be classified into two major classifications:

- Non-structural Controls
- Structural Controls.

The following post construction water quality BMPs are discussed in this BMP Manual:

Non-Structural Low Impact Development Controls

Vegetated Conveyance Systems
Stream Buffers
Disconnected Rooftop Drainage to Pervious Areas
Cluster Development
Natural Infiltration

Structural Controls

Wet Detention Ponds
Dry Detention Ponds
Underground Detention Systems
Storm Water Wetlands
Bioretention Areas
Infiltration Trench
Enhanced Grassed Swales
Pre-Fabricated Control Devices
Vegetated Filter Strips (VFS)
Grass Paving and Porous Paving Surfaces

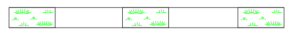
Innovative Technologies

To encourage the development and testing of innovative alternative water quality BMPs, alternative management practices that are not included in the Handbook, Standard Specifications and Standard Drawings may be accepted upon review and approval.

Non-Structural Low Impact Development Controls

Vegetated Conveyance Systems

Plan Symbol



Description

Vegetated conveyances are designed and installed as an alternative to curb and gutter and hard piping storm water conveyance systems. Open vegetated conveyances improve water quality by providing partial pollutant removal as water is filtered by the vegetation and by the opportunity to infiltrate into the soil. Open vegetated conveyances also are designed to reduce flow velocities when compared to hard piping systems.

When and Where to Use It

Open vegetated conveyance systems are incorporated into moderate to low density development sites where land is available and where the land surface is gently sloping (less than 5 percent). The soil must be able to withstand the design tractive forces and flow velocities of the open conveyance, or an applicable

Design Criteria

Design Turf Reinforcement Mats or Erosion Control Blankets to protect the open conveyance. Install a dense cover of strong rooted vegetation in the conveyance systems. For maximum water quality benefits, design vegetated open conveyances with a flat longitudinal slope to promote low velocity flow.

Installation

Construct vegetated conveyances with trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3H:1V).

Install a flat bottom between 2 and 8 feet wide.

During construction, it is important to stabilize the channel before the turf has been established, either with a temporary grass cover or with the use of natural or synthetic erosion control products.

Inspection and Maintenance

- The useful life of a vegetated swale system is directly proportional to its maintenance frequency. If properly designed and regularly maintained, vegetated swales can last indefinitely.
- The maintenance objectives for vegetated swale systems include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover.
- Maintenance includes periodic mowing (with grass never cut shorter than the design flow depth), weed control, watering during drought conditions, re-seeding of bare areas, and clearing of debris and blockages.
- Remove accumulated sediment manually to avoid the transport of resuspended sediments in periods of low flow and to prevent a damming effect from sand bars. Minimize the application of fertilizers and pesticides.
- Repair damaged areas within a channel.
- Inspect for a healthy thick grass cover. Re-seed as necessary.

Stream Buffers

Description

A stream buffer is an area along a shoreline, wetland or stream where development is restricted or prohibited. The primary function of the buffer is to physically protect and separate a stream, lake, or wetland from future disturbance or encroachment.

The general function of the buffer is to:

- Protect the overall stream quality by providing shade for the stream and provide wildlife habitat.
- Remove pollutants, sediments, bacteria, and excess nutrients from storm water runoff through infiltration and filtering.
- Help detain and slow down flow rates from developed areas.
- Provide a setback from the stream to prevent damage to structures or improved property due to flooding or changes in the stream channel.

When and Where to Use It

Effective water quality protection stream buffers consist of undisturbed natural vegetation including maintaining the original tree line along the stream or channel banks. Promptly stabilize disturbed buffers with a dense cover of strong rooted grasses, native plants, and native trees.

Buffer Classification

Major streams, drainageways and waterbodies are recommended to have buffer protection. Buffer recommendations are based on the following classifications:

Class 1: Streams thhave a drainage area greater than or equal to 100 acres.
Class 2: Streams that have a drainage area greater than or equal to 300 acres.
Class 3: Streams that have a drainage area greater than or equal to 640 acres.

Stream Buffer Recommendations

Stream Class	Stream Side Zone (ft)	Managed Use Zone (ft)	Upland Zone (ft)	Total Buffer Width on Each Side of the Stream (ft)
1	30	None	15	45
2	30	20	15	65
3	30	45	25	100

**All buffer widths are measured from the top of the streambank.

Stream Side Zone

This zone is the closest to the stream and this area and remains undisturbed. The stabilization and protection of this zone is critical to water quality. Clearing and cutting of vegetation is prohibited in this zone with the desirable vegetation being mature forest. Use of this zone includes flood control structures, streambank stabilization and restoration, footpaths, and utility or road crossings.

Managed Use Zone

This area provides space for the storage of floodwaters and the filtering of pollutants. A limited number of trees may be removed from this zone provided that the remaining tree density is a minimum of eight healthy trees of a minimum 6-inch caliper per 1,000 square feet. The vegetative target for this zone is managed forest but turfgrass can also be a vegetative target. Do not place fill materials in this area, and do not conduct grading and other land disturbing activities. Some storm water BMPs, greenway trails and bike paths may be designed in this area.

Upland Zone

This zone is located furthest from the streambank. Grading is permitted in this zone, in a manner that does not damage the roots of the trees located in the adjacent Managed Use Zone. Grass or other suitable ground covers may be planted in this zone. Do not place fill material in the Upland Zone unless the replacement of deficient soil is required. The volume of fill material shall not exceed the volume of deficient soil removed. Personal gardens, gazebos, decks, and storage building less than 150 square feet in size are permitted in the Uplands Zone.

Buffer Design Requirements

For optimal storm water treatment, the following buffer designs are recommended:

- The buffer consists of three lateral zones; Stream Side, Managed Use and Upland Zones.
- The buffer has a storm water depression area that leads to a grass filter strip before entering the Managed Use Zone. Design the storm water depression to capture the first flush runoff from the site and bypass larger storm flows directly to the receiving water body.
- Spread the captured runoff across a grass or wooded filter in a sheet flow condition. The forest buffer of the Stream Side and Managed Use Zones infiltrates the sheet flow and does not discharge any surface runoff to the receiving water body.

Buffer Maintenance

An effective buffer management plan includes establishment, management, and distinctions of allowable and unallowable uses in each Zone. Buffer boundaries are well defined and clearly marked during, and after construction is complete. Buffers designed to capture storm water runoff from urban areas require more maintenance if the first zone is designated as a bioretention or other engineered depression area.

Disconnected Rooftop Drainage to Pervious Areas

Description

Disconnected rooftop drainage reduces the runoff flow rates from developed areas. The disconnection involves directing storm water runoff from rooftops towards pervious areas where it is allowed to filter through vegetation and other landscaped material and infiltrate into the soil. Use erosion control devices such as splash blocks or level spreaders at the downspout discharge point to transfer the flow from concentrated flow to sheet flow.

Disconnected rooftop drainage has the following benefits:

- Increase the time of concentration by disconnecting runoff from any structural storm water drainage systems.
- Provide water quality benefits by allowing runoff to infiltrate into the soil. Downspouts from rooftops should discharge to gently sloping, well-vegetated areas, vegetated filter strips, or bio-retention areas.

When and Where to Use It

This practice is applicable and most beneficial in low-density residential or commercial developments having less than 50 percent impervious area. Disconnection is not applicable to large buildings where the volume of runoff from the rooftops will cause erosion or degradation to receiving vegetated areas.

Cluster Development

Description

Cluster development practices concentrate development away from environmentally sensitive areas such as streams, wetlands, and mature wooded areas. The clustering of development in one area reduces the amount of roadways, sidewalks, and drives required when compared to development sprawled over the entire land area.

Install clustering and conservation of natural area practices at least to some extent on all development sites not only to reduce the impacts to natural resources by minimizing disturbance and impervious areas, but also to maintain some of the natural beauty of the site.

Reducing the amount of disturbed area and impervious area reduces the amount of runoff volume treated for water quantity and water quality control. Concentrating development away from environmentally sensitive areas will also reduce the amount of time and expenses to get federal and state permits for impacting jurisdictional waters.

Concentrate development on the flattest part of the development parcel away from environmentally sensitive areas such as steep slopes, streams, and wetlands. This reduces the impacts to these areas, and reduces the amount of earth moving necessary for the development.

Natural Infiltration

Description

Natural infiltration is a method in which an undisturbed land area covered with natural vegetation accepts runoff from new development and infiltrates the runoff into the soil.

When and Where to Use It

Use natural infiltration areas only where the soils are suitable. The area is typically in a forested condition with the land surface covered by leaves, pine needles, and other forest floor organic materials. Natural infiltration areas are designated for passive recreation only.

Design Criteria

Use a natural infiltration area as a storm water quality control if it meets the design criteria of this section. The size of a natural infiltration area is calculated using the following equation:

$$A = \frac{(K\ T\ I)}{[(cd) - K]}$$

Where:

A	=	Natural infiltration area required (acres)
K	=	Runoff volume to infiltrate (inches)
T	=	Total site area or total drainage area (acres)
I	=	Built upon area ratio (Built upon area / T)
c	=	Effective water capacity (in/in), should be determined from site-specific soil samples.
d	=	Depth of soil A horizon (inches), should be determined from site-specific soil samples.

Runoff enters the infiltration area as sheet flow with a non-erosive velocity. Stabilize and vegetate the areas draining to the Natural Infiltration area a minimum of 20-feet in length.

Natural infiltration areas have the following characteristics:

- Appropriate soils that have a minimum infiltration rate of 0.3-inches per hour, low erosion potential, and good drainage (not in a wetland or floodplain).
- Mature forest cover (if the natural infiltration area (A) is not located in a mature forest, then double the area of that calculated by the equation above).
- Slopes less than 10 percent.
- Remains permanently undisturbed.

The limitations of natural infiltration areas include:

- Not suitable for soils that have greater than 30 percent clay content or greater than 40 percent clay and silt content.
- Not suitable in areas with high water tables or shallow depth to highly impervious strata such as bedrock or clay layers.
- High sediment loadings or lack of maintenance clogs the surface layer therefore inhibiting any water infiltration into the soil.

Structural Controls

Structural water quality control structures are recommended for use with a wide variety of land uses and development types. These controls have demonstrated the ability to effectively treat runoff volume to reduce the amounts of pollutants discharged to the downstream system. Structural storm water quality controls are classified into the following categories:

General Application Controls

General application structural controls are recommended for use in a wide variety of application situations. These structural controls have demonstrated the ability to effectively treat water quality volumes and are presumed to be capable of removing 80 percent of the total suspended solids (TSS) load typically found in urban post-development runoff.

Limited Application Controls

Limited application structural controls are those that are recommended only for limited use for special site or design conditions. Generally, these practices can not alone achieve 80 percent TSS removal goal and are intended for hotspots for specific land use constraints or conditions. Limited application controls may be used within a system of water quality controls and are very effective pre-treatment structures for the General Application Controls. Limited application structural controls should be designed and used only in development situations where regular maintenance is guaranteed.

Wet Detention Ponds

Description

A wet or permanent pool detention pond is one of the most commonly used BMPs to meet water quality protection requirements. The advantages of permanent pool ponds have over other water quality treatment controls are:

- Ponds are durable and require less maintenance than other applicable water quality controls.
- Ponds required for water quantity control are easily modified to treat storm water runoff for water quality.
- Well designed ponds are effective in treating storm water runoff for water quality control.

Wet storm water detention ponds are classified as being:

- Wet Detention Pond. Wet ponds have a permanent (dead storage) pool of water equal to the water quality volume. Temporary storage (live storage) may be added above the permanent pool elevation for larger flows.
- Wet Extended Pond. A wet extended pond is a wet pond where the water quality volume is split evenly between the permanent pool and extended detention storage provided above the permanent pool. During storm events, water is stored above the permanent pool and released over 24-hours. The design has similar pollutant removal efficiencies as traditional wet ponds, but consumes less space.
- Micropool Extended Pond. The micropool extended pond is a variation of the wet extended detention pond where only a small "micropool" is maintained at the outlet to the pond. The outlet structure is designed to detain the water quality volume for 24-hours. The micropool prevents resuspension of previously settled sediments and prevents clogging of the low flow orifice.

When and Where to Use It

Permanent pool ponds improve storm water quality by detaining storm water runoff for an extended period of time to allow pollutants that are suspended in the runoff to settle out. During any given storm event, runoff enters wet ponds and replaces the "treated" water in the permanent pool that has been detained from the previous storm event. As runoff enters the pond, the velocity is significantly decreased, allowing suspended pollutants to settle out of the runoff. Many pollutant particles suspended in storm water runoff are very small in size, therefore the pond must be designed to provide adequate detention time to allow the smaller particles to settle out.

Design Criteria

The components of wet detention ponds that help increase the pond's pollutant removal efficiency are:

- Permanent wet pool
- Temporary pool or overlaying zone
- Aquatic bench
- Forebay
- Flow length
- Low flow orifice
- Emergency spillway.

Permanent Wet Pool

A permanent wet pool is the design feature with the single greatest effect on water quality. Permanent pools have the following design requirements:

- For Wet Detention Ponds, the design permanent pool volume is equal to 1-inch of runoff per impervious acre on the site to reliably achieve moderate to high removal rates of storm water pollutants.
- For Wet Extended Ponds with an Aquatic Bench, the design permanent pool is equal to ½- inches of runoff per impervious acre on the site to reliably achieve moderate to high removal rates of storm water pollutants.
- For Micropool Extended Ponds, the design permanent pool volume is equal to 0.1-inches of runoff per impervious acre on the site to reliably achieve moderate to high removal rates of storm water pollutants.
- An average pool depth of 4 to 6 feet is optimal for water quality treatment. The depth of the permanent pool prevents particles that have settled to the pond bottom from re-suspending when runoff enters the pond.

Temporary Pool

The temporary pool is the designed storage above the permanent pool that controls the designed water quality volume. Consider storm water quantity management when designing the temporary pool volume. To increase the detention time of the runoff, the temporary pool is slowly released through a low flow orifice.

Aquatic Bench

Aquatic vegetation can play an important role in pollutant removal in a storm water pond. Vegetation can enhance the appearance of the pond and stabilize side slopes. The selection of the proper plant species and planting locations is an integral part in designing a successful aquatic bench in the wet detention pond. Prepare a planting plan by a qualified landscape architect or wetland ecologist for the aquatic bench.

Forebay

Provide a forebay for all inlets to a wet water quality pond and place the forebay upstream of the main wet pond area. Design the forebay to trap the majority of the coarse fractions of the suspended solids in the runoff before it enters the main wet pond area. The forebay is separated from the larger wet detention pond area by barriers or baffles that may be constructed of earth, stones, riprap, gabions, or geotextiles. Design the top of the forebay barrier ranging from foot below the normal pool elevation up to an elevation above the permanent pool. A forebay may be designed using manufactured treatment devices.

Flow Length

Optimizing the wet pond flow shape and flow distance through the pond promotes better water quality treatment. For maximum water quality benefits, design the ratio of flow length to flow width in the wet pond at least 3L:1W. Due to site constraints, the minimum allowable design ratio of flow length to flow width is 1.5L:1W. To increase the pond's flow length, the pond may be configured with baffles.

Low Flow Orifice

Design a low flow orifice to slowly release the water quality volume over a period of 24-hours or longer depending upon the design criteria for the water quality structure. These structures are prone to becoming clogged. Protect the low flow orifice from clogging by designing appropriate trash guards. Acceptable trash guards include:

- Hoods that extend at least 6-inches below the permanent pool water surface elevation.
- Reverse flow pipes where the outlet structure inlet is located below the permanent pool water surface elevation.
- Trash boxes made of sturdy wire mesh.

Emergency Spillway

Design emergency spillways to safely pass the post-development 100-year 24-hour storm event without overtopping any dam structures. Design the 100-year water surface elevation a minimum of 1-foot below the top of the embankment.

Inspection and Maintenance:

Regular inspection and maintenance is critical to the effective operation of storm water ponds as designed. Maintenance responsibility for a pond and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. The agreement may contain but is not limited to the following items:

- Mow side slopes of the pond monthly.
- Since decomposing vegetation captured in the wet pond can release pollutants, especially nutrients, it may be necessary to harvest dead vegetation annually. Otherwise the decaying vegetation can export pollutants out of the pond and also can cause nuisance conditions to occur.
- Clear debris from all inlet and outlet structures monthly.
- Repair all eroded or undercut areas as needed.
- Place a sediment marker in the forebay to determine when sediment removal is required.
- Monitor sediment accumulations in the main pond area and remove sediment when the permanent pool volume has been significantly filled and/or the pond becomes eutrophic.

Average Pollutant Removal Capability

Total Suspended Solids:	65-80%	Metals:	35-75%
Copper:	40-65%	Lead:	60-85%
Zinc:	50-75%	Total Phosphorus:	50-70%
Total Nitrogen:	30-45%	Pathogens/Bacteria:	45-75%

Wet Pond

Wet Pond

Summary of Maintenance Requirements

Required Maintenance	Frequency
Clean and remove debris from inlet and outlet structures.	Monthly, or after large storm events
Mow side slopes.	Monthly, or as needed
Removal of invasive vegetation.	Semi-annual
Inspect for damage to control structure.	Annual
Inspect sediment accumulation in the facility and forebay.	Annual
Inspect for operational inlet and outlet structures.	Annual
Repair embankment, side slopes, undercut or eroded areas.	Annual, or as needed
Perform wetland plant management and harvesting.	Annual
Remove sediment from the forebay.	Per design cycle, as needed, after 50% of total forebay capacity is filled
Remove sediment accumulations in the main permanent pool.	5 to 10 year cycle, after 25% of the permanent pool volume is filled

Dry Detention Ponds

Description

A dry (extended) detention pond provides temporary storage of storm water runoff. Dry ponds have an outlet structure that detains runoff inflows and promotes the settlement of pollutants. Unlike wet ponds, dry detention ponds do not have a permanent pool.

A dry pond is designed as a multistage facility that provides runoff storage and attenuation for both storm water quality and quantity. Design dry detention ponds as either single-stage or two-stage. Single-stage ponds are normally used strictly for flood control and are not recommended for water quality benefits. A two-stage pond contains a water quality volume in the lower stage, and has an upper stage for detention of larger storms for flood control.

The lower stages of a dry pond are controlled by outlets designed to detain the storm water runoff for the water quality volume for a minimum duration of 24-hours, which allow sediment particles and associated pollutants to settle out. Higher stages in the pond detain the peak rates of runoff from larger storms for flood and erosion control. Dry detention ponds are designed for complete drawdown of runoff and normally remain dry between storm events.

When and Where to Use It

Apply dry detention ponds to new or existing developments. Dry ponds are considered permanent, year-round control measures. Use dry detention ponds at sites where significant increases in runoff are expected from site development. Use dry detention ponds for residential, commercial, or industrial development sites.

Do not use dry ponds in areas with a high water table. A permanently wet bottom is a mosquito breeding ground.

While dry extended detention ponds are widely applicable, they have some limitations that may make other storm water management options preferable. Dry pond limitations include:

- Possible nuisance due to mosquito breeding.
- While wet ponds can increase property values, dry ponds may detract from the value of a home.
- Dry detention ponds have only moderate pollutant removal when compared to other structural storm water practices, and have limited effectiveness in removing both particulate and soluble pollutants.

Design Criteria

Items to incorporate in dry pond design are: pretreatment, pond shape, pond volume, low flow channel, outfall, emergency spillway, and anti-seep collar.

- Ponds shall be designed for the 2 and 10-year storms
- The 10-year storm should not pass through the emergency spillway
- A minimum 6-inch freeboard between the 10-year water surface and emergency spillway is required
- The 100-year storm should not overtop the embankment

Pretreatment

Pretreatment extends the functional life and increases the pollutant removal capability of dry ponds. Pretreatment reduces incoming velocities and captures coarser sediments, trash, and debris, extending the life of the pond and reduce the frequency of long-term maintenance requirements.

Pretreatment is accomplished with vegetative filters, forebays, or manufactured treatment devices. Size the pretreatment to capture and hold the sediment volume expected between scheduled maintenance clean-outs.

Pond Shape

Design dry ponds with a high length to width ratio and incorporate other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short circuit the pond. A dry pond relies on the process of sedimentation for removal of runoff pollutants. Therefore, design the pond to maximize the degree of sedimentation. Design flow path lengths with long, narrow pond configurations with length to width ratios of 2:1. Ponds that are shallow and have larger surface area to depth ratios provide better pollutant removal efficiencies than smaller, deeper ponds. Designing ponds with relatively flat side slopes also helps to lengthen the effective flow path.

Do not design dry pond inside side slopes should not be more than 2H:1V. The recommended inside pond slopes is 3H:1V with a 2H:1V maximum.

The pond floor should have a minimum slope of 0.5% toward the outlet or underdrain system. The recommended slope is 2.0% to ensure that the pond fully drains between storm events.

Provide adequate maintenance access for all dry detention ponds.

Pond Volume

Dry detention ponds are sized to temporarily store the runoff volume to provide normal peak flow reduction (reduce the post-development peak flow of the design storm event to the pre-development rate). Routing calculations must be used to demonstrate that the storage volume is adequate.

A properly designed dry pond will accumulate sediment over time, leading to the loss of detention volume, runoff quality control and quantity control. An increase in a dry detention pond's maximum design storm storage volume should be considered to compensate for this expected loss of storage volume.

Low Flow Channel

A low flow channel is recommended to prevent standing water conditions. Protect this channel with a TRM or other stabilization method to prevent scouring. Design the remainder of the pond to drain toward this channel. Where recreational uses are desired, design the low-flow channel to one side instead in the middle of the pond.

Outfall

Size the outlet structure for water quality control and water quantity control (based upon hydrologic routing calculations.) The outlet may consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure.

Provide a low flow orifice capable of releasing the water quality volume over 24 hours. The water quality orifice has a minimum diameter of 2-inches and is adequately protected from clogging by an acceptable external trash rack.

Stabilize the outfall of dry ponds to prevent scour and erosion. If the pond discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance.

Emergency Spillway

Design an emergency spillway to pass the 100-year storm event. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. Design the spillway to protect against erosion problems.

Anti-seep Collars

Provide seepage control or anti-seep collars for all outlet pipes.

Inspection and Maintenance

A Pond Maintenance Plan/Agreement is required before approval.

Regular inspection and maintenance is critical to the effective operation of dry ponds as designed. Maintenance responsibility for a pond should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Conduct inspections semi-annually and after significant storm events to identify potential problems early. Direct maintenance efforts toward vegetation management and basic housekeeping practices such as removal of debris accumulations and vegetation management to ensure that the pond dewaters completely to prevent mosquito and other habitats.

Average Pollutant Removal Capability

Total Suspended Solids:	45%-68%	Metals:	26%-54%
Copper:	15%-38%	Lead:	31%-67%
Zinc:	15%-45%	Total Phosphorus:	14%-25%
Total Nitrogen:	19%-29%	Pathogens/Bacteria:	20%-50%

Dry Pond

Dry Pond

Summary of Maintenance Requirements

Required Maintenance	Frequency
Note erosion of pond banks or bottom	Semi-Annual Inspection
Inspect for damage to the embankment Monitor for sediment accumulation in the facility and forebay. Ensure that inlet and outlet devices are free of debris and operational	Annual Inspection
Repair undercut or eroded areas Mow side slopes Pesticide/ Nutrient management Litter/ Debris Removal	Standard Maintenance
Seed or sod to restore dead or damaged ground cover.	Annual Maintenance (As needed)
Removal of sediment form the forebay	5 to 7 year Maintenance
Monitor sediment accumulations, and remove sediment when the pond volume has been reduced by 25%.	25 to 50 year Maintenance
Repair undercut or eroded areas Mow side slopes Pesticide/ Nutrient management Litter/ Debris Removal	Standard Maintenance

Underground Detention Systems

Description

Detention tanks and vaults are underground structures used to attenuate peak storm water flows through detention or extended detention of storm water runoff. They are constructed out of concrete pipe (RCP), corrugated metal pipe (CMP), High Density Polyethylene Pipe (HDPE) or concrete vaults. The design and material selections considers the potential loading from vehicles on the vault or pipe.

When and Where to Use It

Due to the costs associated with underground detention systems for construction and maintenance, these systems are used when space is limited and there are no other practical alternatives.

In the ultra-urban environment, costs for developable land may be high enough that these systems become a feasible alternative.

Relatively expensive to construct, use concrete vaults in areas where system replacement costs are high.

Less expensive, use CMP or HDPE systems to control significant volumes of runoff in parking lots, adjacent to rights-of-way, and in medians, where they is replaced or maintained if necessary.

Design Criteria

Locate underground detention systems downstream of other structural storm water controls providing treatment of the water quality volume.

The maximum contributing drainage area to be served by a single underground detention vault or tank is 25-acres.

Size underground detention systems to mitigate flows from the 2- and 10 –year design storm event and up. Design the systems to meet detention and water quality requirements set forth in local and state regulations.

Use routing calculations to demonstrate that the storage volume is adequate.

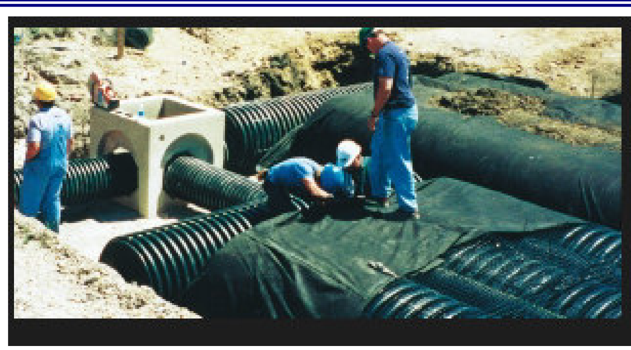
Inspection and Maintenance

- Design the system for easy access for inspection and maintenance.
- Remove any trash/debris and sediment buildup in the underground vaults or tanks annually by pumping them out.
- Perform structural repairs to inlet and outlets as needed based on inspections.

Average Pollutant Removal Capability

Total Suspended Solids:	50%-85%	Metals:	NA
Copper:	35%-70%	Lead:	50%-90%
Zinc:	35%-90%	Total Phosphorus:	55%-70%
Total Nitrogen:	35%-55%	Pathogens/Bacteria:	10%-60%

CMP Underground Detention



HDPE Underground Detention

Storm Water Wetlands

Description

Storm water wetlands remove pollutants primarily through physical filtration and settling, by biological processes of wetland plants, and bacteria in substrates. The storm water wetland is similar in design to the wet pond but has significant vegetation differences. The major difference in the wetland design is the creation of varying depth zones in the shallow marsh area of the wetland to support emergent wetland vegetation. Because consideration must be paid to creating various depth zones and establishing a plant community that can survive in the different zones, the design, construction, and maintenance of storm water wetlands is more complex than wet ponds. There are several different wetland applications including:

- Storm Water Wetland. Constructed shallow marsh system that is designed to treat both urban storm water runoff and control runoff volume. As storm water runoff flows through the wetland, pollutant removal is achieved through settling and uptake by marsh vegetation.
- Shallow Wetland. Most of the water quality treatment takes place in the shallow high marsh or low marsh depths. The only deep sections of the wetland are the forebay and the micropool at the outlet. A disadvantage of shallow wetlands is that a relatively large amount of land is required to store the desired water quality volume.
- Extended Detention Shallow Wetland. This design is similar to the shallow wetland, but part of the water quality treatment volume is provided as extended detention above the surface of the marsh and is released over a period of 24-hours. This application can treat a greater volume of storm water in a smaller space than the shallow wetland design. Plants that can tolerate both wet and dry periods are required in the extended detention area.
- Pond/Wetland System. The system has two separate cells, a wet pond and a shallow marsh. The wet pond is designed to trap sediment and reduce runoff velocities before the runoff enters the shallow marsh. The primary water quality benefits are achieved in the shallow wetland. Less land is required for the pond/wetland system than the shallow wetland and the extended detention shallow wetland.
- Pocket Wetland. A pocket wetland is intended for smaller drainage areas of 5 to 10 acres, and requires excavation down to the water table for a reliable source of water to support the wetland vegetation.

Design Criteria

Do not convert natural wetlands to storm water wetlands. Do not remove natural wetland soils and vegetation to provide a “seedbank” for a constructed storm water wetland without the regulating approval from the US Army Corps of Engineers by obtaining a Section 404 permit. Water quantity storage can be incorporated into the vegetated wetland if the vegetation selected can withstand being submerged for the depth and duration of the water quantity storage time.

Design the wetland with a minimum 2:1 length to width ratio, with 3:1 being the preferred ratio. Maximize the distance between the storm water wetland inlet and outlet to increase the flow length. The flowpath within the wetland is increased through the use of internal berms and shelves used to create the desired varying depth zones within the wetland.

Creating varying depth zones within the wetland increases the pollutant removal efficiency. These depth zones are classified as deep-water zones, which consist of the forebay and outlet micropool, and the shallow water zone that consists of the high marsh, and low marsh area of the wetland. Designing the wetland with varying depth zones prevents the wetland from being taken over by a dominant plant species such as cattails.

Shallow Water Zones

The shallow water zone is defined as being the zones within the constructed storm water wetland that have water depths ranging from 0 to 18 inches. The shallow water zone is designed to promote the growth of emergent wetland plantings and variations in depth allow for a diversity species to survive. Design a level bottom elevation across the width of a wetland cross-section to promote sheet flow and prevent short circuiting or the creation of stagnate dead areas.

High Marsh

Design one-half (½) of the total shallow water zone as high marsh. This zone extends up from 6-inches below the permanent pool water level (6-inches deep). This zone supports a greater density and diversity of wetland species than the low marsh zone.

Low Marsh

Design one-half (½) of the total shallow water zone as low marsh. This zone extends from a depth of 18- to 6-inches below the permanent pool water level. This zone is suitable for the growth of several emergent wetland plant species.

Deep Water Zones

The deep water zones ranges from a depth of 1.5- to 6-feet and includes the forebay, low flow channels, and the outlet micropool. This zone supports little emergent wetland vegetation, but may support submerged or floating vegetation.

Forebay

Design the forebay to reduce the incoming velocities into the wetland. The forebay provides initial settling for sediments, minimizing the amount of suspended sediments that enter the constructed wetland area. Design the forebay as a level spreader distributing the flow evenly and equally across the width of the wetland area. Construct the forebay of an earthen berm no lower than the normal permanent pool depth. Design all inlets to the constructed storm water wetland to discharge to the forebay, and be protected with a properly designed Turf Reinforcement Mat.

Low Flow Channels

A minimum dry weather flowpath is required from the inlet to the outlet for storm water wetlands.

Outlet Micropool.

Design an outlet micropool allowing adequate depth for the extended detention outlet to function properly. Design a drain in the outlet micropool to drain the wetland when needed. Design the outlet micropool 4- to 6-feet deep.

Semi-Wet Zones

The semi-wet zones includes the areas above the permanent pool that will be submerged during larger storm events. This zone supports vegetation that can survive during flooding.

Wetland Planting Plan

Design a wetland planting plan and submit it as part of all constructed wetland design submittals. The selection of the proper plant species and planting locations is an integral part in designing a successful storm water wetland. Have a qualified landscape architect or wetland ecologist prepare a wetland planting plan.

Water Quality Treatment Orifice

Design a low flow orifice to slowly release the water quality volume over a period of 24-hours. Place additional orifice at outlet structures above the temporary water quality pool to provide water quantity control. Protect the water quality orifice from clogging by incorporating an appropriate trash guard.
Select a durable trash guard that extends at least 6-inches below the normal pool surface of the wetland.

Acceptable trash guards include:

- Hoods that extend 6-inches below the permanent pool water surface elevation.
- Reverse flow pipes where the outlet structure inlet is located 6-inches below the permanent pool water surface elevation.
- Trash boxes made of sturdy wire mesh.

Principle Spillway

Design the principle spillway of the constructed storm water wetland to safely pass the 2- and 10-year 24-hour storm event. Equip the spillway with a trash rack.

Emergency Spillway

Design the emergency spillway of the constructed storm water wetland to safely convey discharges resulting from the 100-year 24-hour storm event. Design the 100-year water surface elevation a minimum of 1-foot below the top of the embankment. The emergency spillway may be incorporated into the principle spillway where accommodating the emergency spillway elsewhere is not feasible for the given site characteristics.

Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of storm water wetlands. Maintenance responsibility for the constructed storm water wetland should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

- Maintenance requirements for constructed wetlands are particularly high while vegetation is being established. Monitoring during the first year is critical to the success of the wetland.
- Monitor wetlands after all storm events greater than 2-inches of rainfall during the first year to assess erosion, flow channelization and sediment accumulation. Inspection should be made at least once every six months during the first three years of establishment.
- Place a sediment cleanout stake in the forebay area to determine when sediment removal is required.
- Debris should be removed from the inlet and outlet structures monthly.
- Monitor wetland vegetation and replaced as necessary once every 6-months during the first three years of establishment.
- Annually inspect and maintain the depth of the zones within the wetland.
- Annually remove invasive vegetation.
- Repair all eroded or undercut areas as needed.

Average Pollutant Removal Capability

Total Suspended Solids:	66%-78%	Metals:	14%-72%
Copper:	29%-50%	Lead:	62%-76%
Zinc:	32%-52%	Total Phosphorus:	42%-53%
Total Nitrogen:	28%-39%	Pathogens/Bacteria:	58%-78%
Hydrocarbons:	80%		

Storm Water Wetland

Summary of Maintenance Requirements

Required Maintenance	Frequency
Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants.	Once every 6-months during the first three years of establishment
Clean and remove debris from inlet and outlet structures.	Frequently (3 to 4 times/year)
Mow side slopes.	Frequently (3 to 4 times/year)
Monitor wetland vegetation and perform replacement planting as necessary.	Semi-annual (every 6-months)
Examine stability of the original depth zones.	Annual
Inspect for invasive vegetation, and remove where possible.	Annual
Inspect for damage to the embankment and inlet/outlet structures.	Annual, repair as necessary
Monitor for sediment accumulation in the facility and forebay.	Annual
Inspect for operational inlet and outlet structures.	Annual
Repair undercut or eroded areas.	As needed
Harvest wetland plants that have been “choked out” by sediment buildup.	Annual
Removal of sediment from the forebay.	Per design cycle, as needed, after 50% of total forebay capacity is filled
Remove sediment accumulations in the main permanent pool.	5 to 10 year cycle, after 25% of the permanent pool volume is filled

Bioretention Areas

Description

Bioretention areas are designed to mimic natural forest ecosystems with a combination of soil filtration and plant uptake by utilizing a planting soil layer, mulch, plantings, and an underdrain system. Bioretention areas appear as landscaped or natural areas giving this BMP an appealing image. Storm water runoff enters the Bioretention area and is temporarily stored in a shallow pond on top of the mulch layer. The ponded water then slowly filters down through the planting soil mix and is absorbed by the plantings. As the excess water filters through the system it is temporarily stored and collected by an underdrain system that eventually discharges to a designed storm conveyance system.

When and Where to Use It

Bioretention areas are applicable for small sites where storm water runoff rates are low and typically are received into the Bioretention area as sheet flow. Bioretention drainage areas range from 1-2 acres and are well stabilized to prevent excessive debris and sediment from collecting in the Bioretention area. Because Bioretention areas are sensitive to fine sediments, they are not be placed on sites where the contributing area is not completely stabilized or is periodically being disturbed. Applicable sites include:

- Parking lots,
- Individual residential home sites, and
- Small commercial facilities.

Design Criteria

Bioretention areas work best when constructed off-line, capturing only the water quality volume. Divert excess runoff away from Bioretention areas or collect it with an overflow catch basin. Design Bioretention areas to fit around natural topography and complement the surrounding landscape. Design Bioretention areas with any reasonable shape that fits around sensitive areas, natural vegetation, roads, driveways, and parking lots. The minimum width of Bioretention areas is 10 feet in order to establish a strong healthy stand of vegetation.

Surface Area

The Bioretention surface area may be calculated by the following equation from research by the North Carolina Extension Service, 1999:

$$\text{BSA} = \frac{(\text{DA})(Rv)}{D_{avg}}$$

Where:

BSA	=	Bioretention surface area ($feet^2$)
DA	=	Contributing drainage area of Bioretention area ($feet^2$)
R_v	=	Runoff volume (feet) 0.083-feet (1-inch) for SCDHEC
D_{avg}	=	Average ponding water depth above ground (feet)

The Bioretention surface area may also be calculated by the following equation from research by Prince George's County, MD:

$$\text{BSA} = 0.1(Rv)(DA)$$

Where:

BSA	=	Bioretention surface area (feet^2)
0.1	=	Empirical conversion factor
R_v	=	Runoff volume (inches) 1-inch for SCDHEC
DA	=	Contributing drainage area of Bioretention area (feet^2)

Pre-treatment

Pre-treatment of storm water runoff is required to reduce the incoming velocities, evenly spread the flow over the entire Bioretention area, and provide for removal of coarse sediments. The pre-treatment may consist of the following:

- Gravel, landscape stone, or geotextile level spreader located along the upstream edge of the Bioretention area.
- Gently sloping vegetated filter areas along the upstream edge of the Bioretention area.
- Vegetated swale along the upstream edge of the Bioretention area.

The level spreader option is the most desirable because level spreaders successfully reduce incoming energy from the runoff and convert concentrated flow to sheet flow that is evenly distributed across the entire Bioretention area.

Planting Mix

Install the planting mix of the Bioretention area at level grade (0%) to allow uniform ponding over the entire area. The maximum ponding depth should be set at 6-inches to 12-inches to allow the cell to drain within a reasonable time and to prevent long periods of submerging the plantings. The planting mix provides a medium for physical filtration for the storm water runoff plus a source of water and nutrients for plant life. Select a soil mixture with a minimum hydraulic conductivity or permeability of 0.5 in/hour. The planting mix has a significant amount of organic content to support plant life. The average porosity of the planting mix is 0.45.

The planting mix is approximately 60-75 percent sand, 25 percent silt or topsoil, and 10 percent organic or leaf compost. The maximum clay content is less than 5 percent. The minimum depth of the planting mix is based on the following:

- 1.5-foot Bioretention areas utilizing grass as the only vegetative media,
- 3.0-feet for Bioretention areas that utilize shrubs, and
- 4.0-feet for Bioretention areas that utilize trees.

Mulch Layer

The mulch layer provides an environment for plant growth by reducing erosion of the filter bed, maintaining soil moisture, trapping fine sediments, and promoting the decomposition of organic matter. The mulch layer plays an important role in pollutant removal. Liberally apply shredded hardwood mulch 2- to 3-inches deep. Shredded hardwood mulch is the mulch of choice because it resists floatation better than other landscape covers. Pine needles are also applicable for certain situations. Avoid pine bark mulch due to its ability to float.

Water Draw Down Time

The under drain system is designed using the draw down time. The general equation used to determine draw down time is Darcy's Equation:

$$Q = 2.3e^{-5}\ K\ A\frac{\Delta H}{\Delta L}$$

Where:

Q	=	Flow rate through Bioretention (cfs)
K	=	Hydraulic conductivity of the planting mix (in/hr) This value will vary based on the actual planting mix used
A	=	Surface area of Bioretention (feet^2)
ΔH	=	Maximum ponding depth above bottom of soil mix (feet)
ΔL	=	Depth of soil mix (feet)

General Hydraulic Conductivity of Soils

Determining the total draw down time is a three-step process.

1. Determine the time it takes to drain the ponded water.

- Utilize Darcy's Equation to calculate the flow rate (cfs).
- Calculate the total ponded water volume (feet^3) by multiplying the Bioretention area (feet^2) by the ponded water depth (feet).
- Divide the total ponded water volume (feet^3) by the flow rate (cfs) to calculate the time to drain the ponded water (seconds)

2. Determine the time it takes to drain the saturated planting mix.

- Calculate the total volume of water contained in the planting mix (feet^3) by multiplying the Bioretention area (feet^2) by the planting mix depth (feet) by the porosity (dimensionless) of the planting mix.
- Divide the planting mix water volume (feet^3) by the flow rate from Darcy's Equation (cfs) to calculate the time to drain the ponded water (seconds).

3. Add up the time to drain the ponded water with the time that it takes to drain the planting mix to calculate the total Bioretention area draw down time.

Under Drain System

Many of the native soils found in South Carolina do not allow for adequate infiltration. Therefore, all Bioretention cells require an under drain system placed beneath the planting mix.

The under drain system consists of a minimum 4-inch diameter perforated PVC pipe (AASHTO M 252), an 8-inch minimum gravel jacket filter layer, and non-woven geotextiles to separate the piping from the native soils and the gravel from the planting mixture. Design the under drain system to safely pass the peak draw down rate calculated.

Select perforated, continuous closed-joint conduits of corrugated plastic pipe, placed on top of an underlying geotextile fabric. The longitudinal slope of the drain pipe is a minimum of 0.5 percent. The perforated drain pipe may be connected to a structural storm water conveyance system or receiving natural water system.

Place filter gravel around the drainage pipe at a minimum depth of 8-inches. Place a geotextile between the boundary of the gravel and the planting mix to prohibit the planting mix from filtering down to the perforated drain pipe.

Several non-perforated PVC pipes should vertically connect to the under drain pipe and extend to the surface of the planting mix to provide access to clean out the perforated drainage pipe.

Overflow System

Design an overflow system to pass runoff volumes greater than the water quality volume away from the Bioretention area. If the Bioretention area collects sheet flow from a parking area, design a catch basin at the elevation of the maximum 6-inch to 12-inch ponding depth of the Bioretention area to carry the excess runoff from the Bioretention area to the storm sewer system or receiving natural water system.

Planting Plan

A Bioretention landscape plan includes all vegetation types, total number of each species, and the location of each species. A description of the contractor's responsibilities including a planting schedule, installation specifications, initial maintenance, a warranty period, and expectations of plant survival. Include long-term inspection and maintenance guidelines in the planting plan. Have a qualified landscape architect, botanist or qualified extension agent prepare the planting plan.

Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of Bioretention areas as designed. Maintenance responsibility of the Bioretention area should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

The surface of the ponding area may become clogged with fine sediments over time. Core aeration or cultivating unvegetated areas may be required to ensure adequate filtration. Other required maintenance includes but is not limited to:

- Conduct pruning and weeding to maintain appearance as needed.
- Replace or replenish mulch as needed.
- Remove trash and debris as needed.

Average Pollutant Removal Capability

Total Suspended Solids:	50%-85%	Metals	NA
Total Phosphorus:	55%-70%	Lead:	50%-90%
Pathogens/Bacteria:	10%-60%	Copper:	35%-70%
Total Nitrogen:	35%-55%	Zinc:	35%-90%

Bioretention Area with uncut clean outs

Summary of Maintenance Requirements

Required Maintenance	Frequency
Pruning and weeding.	As needed
Remove trash and debris.	As needed
Inspect inflow points for clogging. Remove any sediment.	Semi-annual (every 6-months)
Repair eroded areas. Re-seed or sod as necessary.	Semi-annual (every 6-months)
Mulch void areas.	Semi-annual (every 6-months)
Inspect trees and shrubs to evaluate their health.	Semi-annual (every 6-months)
Remove and replace dead or severely diseased vegetation.	Semi-annual (every 6-months)
Removal of evasive vegetation.	Semi-annual (every 6-months)
Nutrient and pesticide management.	Annual, or as needed
Water vegetation, shrubs, and trees.	Semi-annual (every 6-months)
Remove mulch, reapply new layer.	Annual
Test planting mix for pH.	Annual
Apply lime if pH < 5.2.	As needed
Add iron sulfate + sulfur if pH > 8.0.	As needed
Place fresh mulch over entire area.	As needed
Replace pea gravel diaphragm.	Every 2 to 3 years if needed

Infiltration Trenches

Description

Infiltration trenches are excavations typically filled with stone to create an underground reservoir for storm water runoff. The runoff volume gradually exfiltrates through the bottom and sides of the trench into the subsoil over a maximum period of 72 hours (three days), and eventually reaches the water table. By diverting storm water runoff into the soil, an infiltration trench not only treats the water quality volume, but it also preserves the natural water balance by recharging groundwater and preserving channel baseflow. Using natural filtering properties, infiltration trenches remove a wide variety of pollutants from the runoff through adsorption, precipitation, filtering, and bacterial and chemical degradation.

When and Where to Use It

Infiltration trenches are limited to areas with highly porous soils where the water table and or bedrock are located well below the trench bottom. They are only applicable for Hydrologic Soil Group A soils, or soils that have a minimum infiltration rate of 0.3-inches per hour. Infiltration trenches are not intended to trap sediment and are designed with a sediment forebay or other pre-treatment measure to prevent clogging in the gravel. Infiltration trenches are used for medium- to high- density residential, commercial, and institutional developments. They are most applicable for impervious areas where there are low levels of fine particulates in the runoff and the site is completely stabilized and the potential for possible sediment loads is very low. Do not use Infiltration trenches for manufacturing and industrial sites where there is potential for high concentrations of soluble pollutants and heavy metals. Infiltration trenches are designed to capture sheet flow from a drainage area or function as an off-line device. Due to the relatively narrow shape, infiltration trenches are adapted to many different types of sites and are utilized in retrofit situations. Unlike some water quality BMPs, infiltration trenches can easily fit into margin, perimeter or other unused areas of development sites.

Design Criteria

- The maximum drainage area for any one infiltration trench is five (5) acres.
- Direct runoff from areas draining to infiltration practices thorough stabilized vegetated filters at least 20-feet in length.
- Underlying soils have an infiltration rate of 0.3-inches per hour or greater determined from site-specific field soil boring samples.
- Do not place infiltration practices in fill material because piping along the fill-natural ground interface may cause slope failure.
- The area of the infiltration trench is determined from the following equation:

$$A = \frac{V}{\left(nd + \frac{kT}{12}\right)}$$

Where:
A = Surface area of infiltration trench (feet^2)
V = Water Quality volume (1-inch)
n = Porosity of stone in infiltration trench (0.3 to 0.5 depending on stone)
d = Depth of trench (ft)
K = Percolation rate of soil (in/hour)
T = Fill time (hours) (A fill time of 2 hours is recommended for most design calculations).

- Use a conservative porosity value (**n**) of 0.32 in volume calculations unless an aggregate specific value is known.
- Design at least (½)-feet between the bottom of the infiltration trench and the elevation of the seasonally high water table, whether perched or regional.
- Determine the seasonally high water table using on-site soil borings and textural classifications to verify the actual site and seasonal high water table conditions.
- The minimum depth of the excavated trench is 3-feet, the maximum depth is 8-feet, and the trench is lined with a permeable geotextile filter fabric.
- Locate infiltration practices greater than 3-feet deep at least ten feet from basement walls.
- Locate infiltration practices a minimum of 150-feet from any public or private water supply well.
- The maximum width of the infiltration trench is 25-feet.
- The stone fill media consists of 1.0- to 2.5-inch D_{50} crushed stone with 6-inches of pea gravel located on top separated by a permeable geotextile filter fabric. This filter fabric prevents sediment from passing into the stone media, and should be easily separated from the geotextiles that protect the sides of the excavated trench.
- Install a 6-inch sand filter or permeable filter fabric on the bottom of the trench.
- The maximum slope bottom of the infiltration practice is 5 percent.
- Design the infiltration trench to fully de-watered within a 24- to 72-hour period depending on trench dimensions and soil type.
- Install an observation well spaced a maximum of 100-feet. The well is made of 4- to 6-inch PVC pipe. Extend the well to the bottom of the trench. The observation well shows the rate of de-watering after a storm event, and helps predict when maintenance is required. Install the observation well along the centerline of the trench, and flush with the ground elevation of the trench. Cap the top of the well and lock it to discourage vandalism and tampering.

Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of infiltration trenches as designed. Maintenance responsibility for the infiltration trench should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of the Storm Water Management Permit approval. Typical maintenance responsibilities include:

- Keep a record of the average de-watering time of the infiltration trench to determine if maintenance is required.
- The top 6-inch layer of pea gravel and geotextile separating the pea gravel from the stone media serve as a sediment barrier and require replacement when full of sediment.
- Clear debris and trash from all inlet and outlet structures monthly.
- Check the observation well after three consecutive days of dry weather after a rainfall event. If complete de-watering is not observed within this period, there may be clogging within the trench requiring proper maintenance.
- Remove trees, shrubs, or invasive vegetation semi-annually.
- If complete failure is observed, perform total rehabilitation by excavating the trench walls to expose clean soil, and replacing the gravel, geotextiles, and topsoil.

Average Pollutant Removal Capability

Total Suspended Solids:	80%-90%	Metals:	70%-85%
Copper:	50%-60%	Lead:	80%-90%
Zinc:	80%-90%	Total Phosphorus:	50%-60%
Total Nitrogen:	35%-55%	Pathogens/Bacteria:	90%-98%
Hydrocarbons:	85%		

Infiltration Trench

Summary of Maintenance Requirements

Required Maintenance	Frequency
Ensure that the contributing area is stabilized with no active erosion.	Monthly
Grass filter strips should be mowed and grass clippings should be removed.	Monthly
Check observation wells after 72 hours of rainfall. Wells should be empty after this time period. If wells have standing water, the underdrain system or outlet may be clogged.	Semi-annual (every 6-months)
Remove evasive vegetation.	Semi-annual (every 6-months)
Inspect pretreatment structures for deposited sediment.	Semi-annual (every 6-months)
Replace pea gravel, topsoil, and top surface filter fabric.	When clogging or surface standing water is observed
Perform total rehabilitation of infiltration trench.	Upon observed failure

Enhanced Dry Swales

Description

Enhanced dry swales are conveyance channels engineered to capture, treat, and release the storm water quality runoff volume from a particular drainage area. Enhanced swales are different from normal drainage swales in that they have a designed structure implemented in them to enhance detention and storm water pollutant removal. Enhanced dry swale systems are designed primarily for storm water quality and have only a limited ability to provide storm water runoff volume control and downstream channel protection. Enhanced dry swales are vegetated channels designed to include a filter bed of prepared soil that overlays an underdrain system. Dry swales are sized to allow the entire water quality storage volume to be filtered or infiltrated through the swale bottom. Because these swales are predominantly dry, they are preferred in residential settings.

When and Where to Use It

Enhanced swales are applicable in moderate to large lot residential developments and industrial areas with low to moderate density where the impervious cover (parking lots and rooftops) of the contributing drainage areas is relatively small. Enhanced swales are also useful along rural roads and highways that have driveway entrances crossing the swale.

Design Criteria

Design enhanced swales with minimal channel slope, forcing the flow to be slow and shallow. This aspect of the enhanced swale allows particulates to settle out of the runoff and limits the effects of erosion. Place berms, check dams, weirs, and other structures perpendicular to the swale flow path to promote settling and infiltration.

- Enhanced swales are open conveyance channels that have a filter bed of permeable soils overlaying an underdrain system. Runoff is detained in the main swale section where it filters through the filter bed. The runoff is then collected and conveyed to the desired outlet through a perforated pipe and gravel system.
- The maximum designed de-watering time is 48 hours, with the recommended de-watering time being 24-hours.
- Enhanced swales have a contributing drainage area less than five (5) acres.
- Design the swale to capture the required water quality runoff volume, and safely pass larger flows. Flow enters the swale through a pretreatment forebay or along the sides of the swale as sheet flow produced by level spreader trenches along the top of the bank.
- Limit swale slopes between 1 and 2 percent, unless site topography dictates larger slopes. In this instance, place drop structures in the swale to limit the slope of a particular section of the swale. Set the spacing between drop structures a minimum of 50-feet. Add energy dissipation techniques on the downstream side of the drop structures.
- The maximum overall depth of the water quality runoff volume detained in the channel is 1.5-feet.
- The bottom width of the swale ranges between 2- and 8-feet where applicable to ensure an adequate filtration area. Wider channels may be designed to increase the filtration area, but consideration must be given to prevent uncontrolled sub-channel formation.
- The maximum side slopes of the swale are 2H:1V, and 4H:1V is recommended for ease of maintenance and for side inflow to remain as sheet flow.
- Design the peak velocity for the 2-year 24-hour storm event to be non-erosive for the soil and vegetation selected for the swale.

Filter Bed

The filter bed for an enhanced dry swale consists of a permeable soil layer at least 2.5-feet deep. The drainage pipe is a minimum 4-inch diameter perforated PVC pipe (AASHTO M 252) in a 6-inch gravel layer. Select a soil media that has a minimum infiltration rate of 1.0-foot per day, and a maximum infiltration rate of 1.5-feet per day. Place a permeable geotextile filter between the gravel and the overlaying permeable soil.

Forebay

Protect flow inlets to an enhanced dry swale forebay to reduce erosive forces of the runoff. The preferable material is a TRM. Riprap may also be used. Provide swale pretreatment with a sediment forebay. The pretreatment volume is equal to 0.1-inches per impervious acre of the drainage area. The forebay is typically provided by designing a check dam at the inlet of the swale.

Outlet Structures

The underdrain system of the enhanced dry swale discharges to the storm drainage system on site, or discharges to a stable protected outlet point.

Overflows

For maximum performance, enhanced dry swales are recommended to be off-line structures. If a swale is designed to be an online structure, it must be able to safely pass the 25-year 24-hour storm event.

Landscape Plan

Design the enhanced dry swale landscape plan to include the type of turf grass species required along with a permanent maintenance guideline. Have the planting plan prepared by a qualified landscape architect, botanist or qualified extension agent.

Inspection and Maintenance

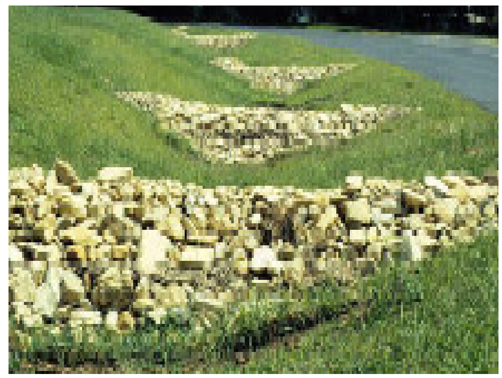
Regular inspection and maintenance is critical to the effective operation of enhanced swales. Maintenance responsibility should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

The surface of the filter bed may become clogged with fine sediments over time. Light core aeration is required to ensure adequate filtration. Other required maintenance includes but is not limited to:

- Mowing to maintain storage volume and appearance as needed.
- Remove trash and debris as needed.

Average Pollutant Removal Capability

Total Suspended Solids:	70%-80%	Hydrocarbons:	65%
Total Phosphorus:	35%-50%	Lead:	60%-70%
Pathogens/Bacteria:	10%-60%	Copper:	15%-45%
Total Nitrogen:	40%-60%	Zinc:	40%-65%



Enhanced Swales

Summary of Maintenance Requirements

Required Maintenance	Frequency
Mow grass to maintain design height and remove clippings.	As needed (frequent/seasonally)
Nutrient and pesticide management.	Annual, or as needed
Inspect side slopes for erosion and repair.	Annual, or as needed
Inspect channel bottom for erosion and repair.	Annual, or as needed
Remove trash and debris accumulated in forebay.	Annual
Inspect vegetation. Plant an alternative grass species if original cover is not established.	Annual (semi-annually first year)
Inspect for clogging and correct the problem.	Annual
Roto-till or cultivate the surface of the bed if swale does not draw down in 48 hours.	As needed
Remove sediment build-up within the bottom of the swale.	As needed, after 25% of the original design volume has filled

Pre-Fabricated Control Devices

Description

The need for urban water quality BMPs that are very efficient and present less space constraints has produced the industry of innovated storm water BMP technology and products. These pre-manufactured products combine settling, filtration, and various biological processes into one controlled system. By combining these different processes, these BMPs are designed to focus on removing many different types and concentrations pollutants. Even where pre-fabricated control devices are not able to meet the 80 percent TSS removal goal alone, they can provide excellent pre-treatment in a series of water quality control BMPs or inlet to permanent pool detention basins or storm water wetlands.

Post construction pre-fabricated storm water quality BMPs are designed to filter and trap trash, floatable contaminates, sediment, oil and grease, and other pollutants. These BMPs are incorporated into storm water conveyance systems for pretreatment of storm water runoff. In some instances, pre-fabricated storm water quality BMPs serve as the only treatment mechanism before the runoff is discharged. Post construction pre-fabricated storm water quality BMPs are classified in to three separate categories:

1. Catch Basin Inserts
2. Separation Devices
3. Filtration Devices

When and Where to Use It

Pre-fabricated control devices may be used to treat runoff as long as they are designed to treat the first 1-inch of runoff and/or are proven to provide 80 percent TSS removal. Pre-fabricated control devices include the following beneficial attributes for water quality control over conventional water quality BMPs:

- Pre-fabricated control devices are placed almost anywhere on a site where they can receive concentrated flows from storm drainage pipes.
- Pre-fabricated control devises are safe to the public because storm water is treated within the unit and no surfaces are open to the environment, unlike the permanent pool detention pond or storm water wetland.
- Minimal on-site construction is required because pre-fabricated control devices are typically assembled before they reach the site.

Design

Catch Basin Inserts

Catch Basin Inserts are defined as BMPs designed to be installed directly into storm drain catch basins to treat the runoff before it enters the primary conveyance system.

There are three basic Catch Basin Inserts available: tray, bag, and basket. These inlets typically are made of a stainless steel or a high strength corrugated plastic frame that supports a sedimentation chamber and filter media designed to absorb specific pollutants such as oil, grease hydrocarbons, and heavy metals. Catch Basin Inserts sometime include a high flow bypass mechanism to prevent scouring and re-suspension of previously trapped pollutants during larger rainfall events.

Pollutant removal efficiencies are variable and highly dependent on storm frequency, influent pollutant concentrations, rainfall intensity and other factors. Catch Basin Inserts exhibit the following properties:

- Utilize settling, separation, swirling, centrifugal force, and filtering techniques to remove pollutants from storm water runoff.
- Contain no moving components that require an external power source such as electricity, gas powered engines or generators.
- Have posted data from third party test results.

Catch Basin Insert Average Pollutant Removal Capability

Total Suspended Solids:	50%-85%	Metals	NA
Copper:	35%-70%	Lead:	50%-90%
Zinc:	35%-90%	Total Phosphorus:	55%-70%
Total Nitrogen:	35%-55%	Pathogens/Bacteria:	10%-60%

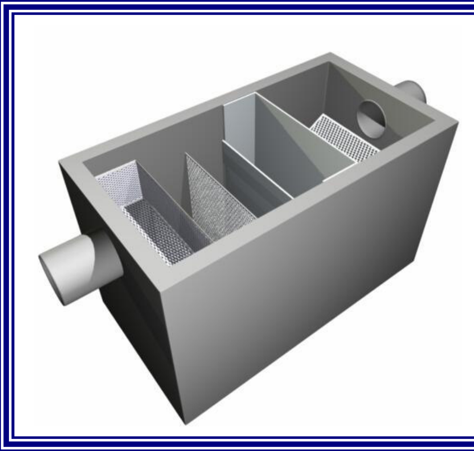
Catch Basin Inserts

Separation Devices

Separation Devices are defined as BMPs designed and sized to capture and treat storm water runoff to prevent pollutants from being transported downstream. Separation Devices contain a sump for sediment deposition and a series of chambers, baffles, and weirs to trap trash, oil, grease and other contaminants. These BMPs are designed as flow-through structures where the inflow rate into the structure is regulated. These structures are not designed to store the entire water quality volume. Separation Devices sometime include a high flow bypass mechanism to prevent scouring and re-suspension of previously trapped pollutants during larger rainfall events.

Pollutant removal efficiencies are variable and are highly dependent on storm size, influent pollutant concentrations, rainfall intensity, and other factors. Separation Devices exhibit the following properties:

- Utilize settling, separation, swirling, and centrifugal force techniques to remove pollutants from storm water runoff.
- Contain no moving components that require an external power source such as electricity, gas powered engines or generators.
- Have posted data from third party test results.



Separation Devices

Filtration Devices

Filtration Devices are defined as BMPs designed and sized to capture and treat storm water runoff to prevent pollutants from being transported downstream. Filtration Devices are used in areas with impaired receiving waters where high pollutant removal efficiencies are required. Filtration Devices usually contain a sedimentation chamber and a filtering chamber. These devices may contain filter materials or vegetation to remove specific pollutants such as nitrogen, phosphorus, copper, lead, or zinc.

Pollutant removal efficiencies are variable and are highly dependent on storm size, influent pollutant concentrations, rainfall intensity and other factors. Filtration Devices shall exhibit the following properties:

- Utilize filtering techniques to remove pollutants from storm water runoff.
- Have posted data from third party test results.

Filtration Device

Separation and Filtration Device Average Pollutant Removal Capability

Total Suspended Solids:	80%	Metals	60%
Copper:	50%	Lead:	60%
Zinc:	70%	Total Phosphorus:	40%
Total Nitrogen:	30%	Hydrocarbons:	80%

Products

There are many pre-fabricated water quality structures on the market that may be used as water quality control BMPs.

Installation

Install in accordance with the Manufacturer's written installation instructions and in compliance with all OSHA, local, state, and federal codes and regulations. A Manufacturer's representative is required to certify the installation of all post construction pre-fabricated storm water quality BMPs.

Proper site stabilization is essential to ensure that post construction pre-fabricated storm water quality BMPs function as designed. These structures are not interned to trap eroded sediment from during construction operations. Post construction pre-fabricated storm water quality BMPs are the last storm water runoff structures installed on-site, or shall remain off-line until final stabilization is achieved.

Inspection and Maintenance

- Inspect and maintain in accordance with the Manufacturer's written recommendations.
- The specific maintenance requirements and schedule prepared by the Manufacturer is signed by the owner/operator of the BMP.
- Require frequent inspection and maintenance to maximize pollutant removal.
- Maintain BMPs at least bi-annually to ensure that the BMPs are working properly.

- Keep a maintenance log to track routine inspections and maintenance. Lack of maintenance is the most common cause of failure for post construction pre-fabricated storm water quality BMPs.
- Remove accumulated sediment and other trapped pollutants when the BMP becomes full. Typical removal of pollutants requires the use of a Vactor truck.

Summary of Maintenance Requirements

Required Maintenance	Frequency
Inspect separation and filtration units.	Regularly (quarterly)
Clean out sediment, oil and grease, and floatables. Manual removal of pollutants may be necessary.	As needed
Perform requirements obtained from manufacturer.	As needed
Inspections.	Frequency of inspection and maintenance is dependent on land use, accumulated solids climatological conditions, and design of pre-fabricated device

Vegetated Filter Strips

Description

Vegetated Filter Strips (VFS) are zones of vegetation where pollutant-laden runoff is introduced as sheet flow. VFS may take the form of grass filters, grass filter strips, buffer strips, vegetated buffer zones, riparian vegetated buffer strips, and constructed filter strips.

When and Where to Use It

Applicable in areas where filters are needed to reduce pollutant impacts to adjacent properties and water bodies. VFS are used to remove pollutants from overland sheet flow but are not effective in removing sediment from concentrated flows. There are two main classifications of VFS:

- Constructed filter strips: Constructed and maintained to allow for overland flow through vegetation that consists of grass-like plants with densities approaching that of tall lawn grasses.
- Natural vegetative strips: Area where pollutant-laden flow is directed in an overland manner, including riparian vegetation around drainage channels. Vegetation ranges from grass-like plants to brush and trees with ground cover.

VFS remove pollutants primarily by three mechanisms:

1. Deposition of bedload material and its attached chemicals as a result of decreased flow velocities and transport capacity. This deposition takes place at the leading edge of the filter strip.
2. Trapping of suspended solids by the vegetation at the soil vegetation interface. When suspended solids settle to the bed, they are trapped by the vegetated litter at the soil surface instead of being re-suspended as would occur in a concentrated flow channel. When the litter becomes inundated with sediment, trapping no longer occurs by this mechanism.
3. Trapping of suspended materials by infiltrating water. This is the primary mechanism by which dispersed clay sized particles are trapped.

VFS effectiveness fluctuates considerably depending on vegetation type, vegetation height and density, season of the year, eroded particle characteristics, size of drainage area, and site topography.

Design Criteria

Select a vegetation type, a ground slope, filter strip width, and strip length. Locate VFS on the contour perpendicular to the general direction of flow. Select vegetation to be dense, turf-forming grass in order to minimize water channelization. Never assume that natural vegetation is adequate for VFS. Design a ponding area at the leading edge of the VFS for bedload deposition.

General Design Requirements

a. Select an applicable area for the VFS
   Minimum Ground Slope = 1 percent
   Maximum Ground Slope = 10 percent
b. Select a vegetation type.
c. Select the design life and maximum allowable sediment deposition. A design life of 10 years and deposition of 0.5-feet is recommended.
d. Estimate the long-term sediment yield entering the filter strip and a 10-year 24-hour design single-storm sediment yield.
e. Determine desired Trapping Efficiency- 80 percent design removal efficiency goal of the total suspended solids (TSS) in the inflow.
f. Estimate the filter length necessary to prevent deposition within the filter greater than 0.5-feet. (Assume filter width is equal to disturbed area width but no smaller than 15-feet.)
g. Use the filter length to calculate Trapping Efficiency for the design storm.
h. Repeat (d) and (e) until the lengths match.

Inspection and Maintenance

- Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short circuit the practice. They require similar maintenance to other vegetative practices.
- Inspect vegetation for rills and gullies annually and correct. Seed or sod bare areas.
- Inspect grass after installation to ensure it has established. If not replace with an alternative species.
- Inspect to ensure that grass has established annually. If not, replace with an alternative species.
- Mow grass to maintain a height of 3- to 4-inches.
- Remove sediment build-up from the bottom when it has accumulated to 25% of the original capacity.

Average Pollutant Removal Capability

75 feet in length		**150 feet in length**		**Average**	
Total Suspended Solids:	54%	TSS:	84%	TSS:	70%
Lead:	16%	Lead:	50%	Metals	40%-50%
Zinc:	47%	Zinc:	47%	Total N:	30%
Total Phosphorus:	- 25%	Total Phosphorus:	-40%	Total P:	10%
Nitrate Nitrogen:	-27%	Nitrate Nitrogen:	-20%	Nitrate Nitrogen:	0%
				Pathogens/Bacteria:	NA

Roadside Vegetated Filter Strip

Summary of Maintenance Requirements

Required Maintenance	Frequency
Mow grass to maintain design height.	Regularly (frequently)
Remove litter and debris.	Regularly (frequently)
Inspect for erosion, rills and gullies, and repair.	Annual, or as needed
Repair sparse vegetation.	Annual, or as needed
Inspect to ensure that grass has established. If not, replace with an alternative species.	Annual, or as needed
Nutrient and pesticide management.	Annual, or as needed
Aeration of soil.	Annual, or as needed

Grass Paving and Porous Paving Surfaces

Description

Grass Paving

Grass paving technology allows for the reduction of paved areas by implementing grass paving in areas that are infrequently used such as fire lanes and overflow parking where applicable. A variety of grass paving materials are available on the market. Grass paving units are designed to carry vehicular loading and may be composed of different types of materials. The pavers are typically covered with sod to make the areas indistinguishable from other grassed areas. Grass pavers allow water quality benefits by allowing storm water to infiltrate into the underlying soils and by the filtering of storm water as it flows through the grass.

Grass pavers provide a more aesthetically pleasing site and reduce the impact of complete asphalt surfaces. Grass pavers should not be used for frequently traveled or parked in areas. Grass pavers reduce the runoff volume and extend the time of concentration for a particular site. Some pavers provide enough infiltration to be considered a pervious area.

Porous Paving

Porous pavement is a permeable pavement surface with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. This porous surface replaces traditional pavement, allowing parking lot storm water to infiltrate directly and receive water quality treatment, and also reducing runoff from the sit

When and Where to Use It

Porous pavement options include porous asphalt, pervious concrete, and grass pavers. The ideal application for porous pavement is to treat low-traffic or overflow parking areas. Porous pavement also has highway applications where it is used as a surface material to reduce hydroplaning.

Porous pavements are a good option in ultra-urban areas because they consume no space since there is very little pervious area in these areas. Since porous pavement is an infiltration practice, do not apply it on storm water hot spots due to the potential for ground water contamination. The best application of porous pavement for retrofits is on individual sites where a parking lot is being resurfaced.

Design Criteria

Take soil boring to a depth of at least 4 feet below bottom of stone reservoir to check for soil permeability, porosity, depth of seasonally high water table, and depth to bedrock.

Not recommended on slopes greater than 5% and best with slopes as flat as possible.

Minimum setback from water supply wells: 100 feet.

Minimum setback from building foundations: 10 feet down gradient, 100 feet upgradient.

Not recommended where wind erosion supplies significant amounts of sediment.

Use on drainage areas less than 15 acres.

Minimum soil infiltration rate of 0.3-0.5 inches per hour.

Typically design for storm water runoff volume produced in the tributary watershed by the 6-month, 24-hour duration storm event.

A typical porous pavement cross-section consists of the following layers:

1) Porous asphalt course 2-4 inches thick,
3) Reservoir course of 1.5 to 3 inch stone,
2) Filter aggregate course, and
4) Filter fabric.

Use a geotextile meeting AASHTO M288 Class 1, 2, or 3 in all cases as a filter to protect the long-term performance of the system.

Inspection and Maintenance

- Porous pavement requires extensive maintenance compared with other practices.
- Avoid sealing or repaving with non-porous materials.
- Ensure that paving area is clean of debris, paving dewaters between storms, and that the area is clean of sediments monthly.
- Mow upland and adjacent areas, and seed bare areas as needed.
- Vacuum sweep frequently to keep the surface free of sediment as needed.
- Inspect the surface for deterioration or spalling annually.
- Perform high pressure hosing to free pores in the top layer from clogging as needed.

Grass Paver

Porous Paving

Innovative Technologies

Innovative technologies are encouraged and should be accepted providing there is sufficient documentation as to the effectiveness and reliability of the proposed structure. To justify the efficiency of innovated water quality control structures, the owner may be required to monitor the pollutant removal efficiency of the structure. If satisfactory results are obtained, the innovative water quality structure may be used and no other monitoring studies should be required. If the control is not sufficient, other on-site and/or downstream controls should be designed to trap the required pollutants.

Calculating Pollutant Loads Using IDEAL Model

Background

The intent of legislation such as the South Carolina Storm Water Management and Sediment Reduction Act is that developments in South Carolina will not negatively impact water quality and downstream habitats. The potential for problems present challenges to engineers and developers to design and install best management practices that will not cause the state's waters to be impaired by pollutants such as nutrients, sediment, or bacteria. Simplified methods and the IDEAL (Integrated Design and Assessment for Environmental Loadings) Model for calculating pollutant removal efficiency of BMPs and treatment systems will assist designers and regulators in meeting state and federal requirements.

The IDEAL Model provides SCDHEC specific design methods that give reasonable assurance that effluent meets desired performance without the lengthy design process typically associated with designs developed to meet a performance standard. The use of area specific design methods provides a means of achieving control without the steep learning curve associated with simulation techniques. For large-scale developments or in sensitive areas, it is still anticipated that site specific data and other procedures such as modeling be used for detailed evaluation of controls.

Approach

The IDEAL Model includes estimation of performance of detention/retention ponds, extended detention ponds, sand filters, and riparian buffers. The performance of each control is modeled using SCDHEC specific conditions (including soils, topography, and climate) and compared with removal efficiency. For each structure, spreadsheet modeling was developed that is consistent with performance standards.

Effectiveness of control, or removal efficiency, is commonly determined by either a water quality design standard or a performance standard. A water quality performance standard dictates a maximum acceptable level (i.e., concentration) in the effluent. The control is designed such that this level is not exceeded. On the other hand, a water quality design standard establishes a standard specification based on a given drainage area or similar criterion. There are obvious benefits associated with each method. Performance standards offer site specific water quality control, but require considerable on-site collection of information for design purposes and are much more difficult to design and review. Structures designed for performance standards have a higher design cost than structures designed for water quality design standards. However construction costs tend to be considerably less, since design standards are inherently conservative. Design standards, on the other hand, are more easily employed and complied with but often entail risk that the structure is either grossly over designed, resulting in added installation costs, or grossly under designed so that the measure may not perform satisfactorily, particularly in sensitive areas. A preferable alternative to these methods is to provide a design procedure that can meet a desired performance without incurring excessive design costs. To achieve this, the design is typically expected to be slightly conservative, but considerably less conservative than if developed from a design standard.

The IDEAL Model is based on site visits at numerous construction locations throughout South Carolina in order to see innovative BMPs, as well as areas needing improvement. Cooperation with regulatory personnel included discussions as to what specific BMPs should/should not be considered for evaluation. It is recognized that there are a large number of potential post construction BMPs that can potentially be used.

Evaluation of existing modeling capabilities led to the development of a new model known as IDEAL. The IDEAL Model, a model for hydrology, sedimentology, and water quality, contains much detail and ties water quality modeling together with physical, chemical, and biological relationships to provide a much more realistic description of reactions that are taking place in the real world.

It should be recognized that selection of an appropriate water quality model to allow evaluation of a wide range of pollutant control technologies in a seamless manner depends on the user's application. This process led to some modifications in the program to account for selected BMPs, treatment trains, topography, soil properties, and climate. Data bases of rainfall records for three SCDHEC locations were analyzed to simplify user data requirements and simplify input for spreadsheets.

Since the method selected for accomplishing the simulation is critical, several items were considered:

- Combine hydrologic, and hydraulic routines with accepted pollutant removal routines.
- Impact on channels or ponds on adjacent wetlands.
- Consider each of the pollutants of interest (nutrients, sediment, and bacteria indicator).

Each of these tasks was accomplished, and the results analyzed to produce spreadsheets that are used as an aid for designing BMPs based on pollutant removal. It should be recognized that aids such as these are developed for typical conditions. More detailed evaluation methods should be utilized if the situation is environmentally sensitive or hazardous. In all cases, good engineering judgment should be considered as an essential ingredient in design.

The IDEAL Model

The IDEAL Model is not a rule or regulation promulgated by the agency, but is guidance for evaluation and implementation of best management practices for storm water design. The IDEAL Model was developed by means of a comprehensive literature review and then use of best available science and valid scientific principles. State environmental agencies and the EPA have traditionally used guidance documents to provide preferred methodology to assist its staff with consistent application and to provide information and guidance to persons outside the agency to allow them to more effectively and efficiently implement program requirements. Because the IDEAL Model is not binding rules, alternative approaches, methodologies and solutions are allowed; however, it is incumbent on one proposing an alternative to adequately demonstrate both the effectiveness and equivalency of that alternative.