Dry Water Quality Swale

Source: Southwest Conservation District

Stormwater BMP Type	
Pretreatment BMP	☐
Infiltration BMP	☐
Filtering BMP	☐
Stormwater Pond BMP	☐
Stormwater Wetland BMP	☐
Water Quality Conveyance BMP	■
Stormwater Reuse BMP	☐
Proprietary BMP	☐
Other BMPs and Accessories	☐

Stormwater Management Suitability	
Retention	■
Treatment	■
Pretreatment	☐
Peak Runoff Attenuation	■

Pollutant Removal	
Sediment*	**High**
Phosphorus	**Moderate**
Nitrogen	**Moderate**
Bacteria	**Moderate**

*Includes sediment-bound pollutants and floatables (with pretreatment)

Implementation	
Capital Cost	**Medium**
Maintenance Burden	**Medium**
Land Requirement	**Medium**

Description

Water quality swales are shallow vegetated open channels designed to treat and convey stormwater runoff. Water quality swales provide higher pollutant removal than traditional grass drainage channels, which are designed strictly for conveyance.

Dry water quality swales (also referred to as "dry swales") have a bioretention soil media below the surface of the swale that facilitates stormwater filtration and vegetative growth. Dry swales are frequently designed to infiltrate but can be designed with an underdrain to capture filtered water and assist with drainage from the system. In certain situations, bioretention swales can also be designed with impermeable liners to prevent infiltration into the underlying soil. Dry swales are planted with dense, native grasses or plants that function to slow the flow of runoff and encourage filtration. The use of check dams is recommended to enhance water quality performance by promoting ponding, filtration, and infiltration of stormwater into the underlying soil. Pollutants are removed through sedimentation, filtration, adsorption, pollutant uptake, and infiltration.

If not designed with an impermeable liner, dry water quality swales can provide retention of stormwater and reduce runoff volumes through infiltration and groundwater recharge. Dry swales may also be used to provide stormwater quantity control when designed as on-line facilities.

Dry water quality swales are valuable systems for linear projects as well. However, linear projects have alternative standards and may take an alternative approach to address constraints that are different than those that affect traditional parcel development projects. These alternative linear project standards can be found in the CTDOT drainage manual, the CTDOT MS4 General Permit and in the supporting materials that CTDOT has developed.

Advantages

- Dry water quality swales are an alternative to bioretention systems where the site requires a sloped base or must convey runoff between points.
- Can provide stormwater retention, runoff volume reduction, and groundwater recharge if designed for infiltration.
- Provide runoff conveyance and can provide some peak runoff attenuation by reducing runoff velocity and providing temporary storage.
- High pollutant removal efficiency and water quality benefits, like bioretention.

Limitations

- Individual dry swales treat a relatively small area.
- May be impractical in areas with steep topography or poorly drained soils.
- Large area requirements for highly impervious sites.
- May not be practical in areas with many driveway culverts or extensive sidewalk systems.
- Higher relative construction costs than other stormwater infiltration systems due to cost of bioretention soil media.

Siting Considerations

- **Potential Locations:** Linear nature makes swales ideal for use within roadway right-of-way areas, along shared-use paths, and within or around parking lots. Dry swales are suitable in urban and rural settings.
- **Drainage Area:** The maximum contributing drainage area is 5 acres to any single inlet, unless the flow enters the dry swale via sheet flow along a linear feature such as a road.
- **Soils:** Dry swales that return filtered runoff to the conveyance system and do not infiltrate into the ground can be used in almost any soil type. Dry swale designs that rely on infiltration should be used only when the soil infiltration characteristics are appropriate (see Chapter 10 - General Design Guidance for Stormwater Infiltration Systems for design guidance for stormwater infiltration systems).
- **Land Use:** Dry swales can be used in most land use settings where space is available.

- **Water Table and Bedrock:** For dry swales designed for infiltration (unlined systems), at least 3 feet of separation is recommended between the bottom of the system and the seasonal high groundwater table (SHGT) and bedrock. The vertical separation distance to the SHGT or bedrock may be reduced to 2 feet as described in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Horizontal Setbacks: For dry swales designed for infiltration (unlined systems), meet the minimum horizontal setback distances in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

Soil Evaluation

- Conduct an evaluation of the soil characteristics and subsurface conditions at the location of the proposed system including soil type, depth to the seasonal high groundwater table, depth to bedrock, and soil infiltration rate. Refer to Chapter 10 - General Design Guidance for Stormwater Infiltration Systems for soil evaluation guidance.

Design Recommendations

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the swale in accordance with the Pretreatment BMPs section of this Manual.

- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales, deep sump catch basins, oil grit separators, and proprietary pretreatment devices.

- Sediment forebays should have a minimum storage volume of 10% of the Water Quality Volume (WQV), while flow-through Pretreatment BMPs should treat at least the equivalent Water Quality Flow (WQF).

Sizing and Dimensions

- Dry Swale Filter Bed (Bottom) Area
    - Dry swale should be designed by either the Static or Dynamic Methods as described in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems
    - System should completely drain in 48 hours or less after the end of the design storm as described in Chapter 10.
    - For underdrained systems, use the coefficient of permeability of the bioretention soil media (1.0 feet per day or 0.52 inches per hour) in the drain time analysis. If the system is designed with a loam surface, also use a coefficient of permeability value of 1.0 feet per day or 0.52 inches per hour.
    - Install check dams to retain the applicable Water Quality Volume and to accommodate slopes greater than 2%. The volume of water retained behind check dams should be included in the system storage volume calculation.

- Bioretention Soil Depth
    - Engineered bioretention soil media should have a depth of 24 to 48 inches as necessary to accommodate the required sizing, vegetation species and root establishment, and subsurface conditions.
    - Soil depth may be limited by the requirement to maintain adequate separation to groundwater and bedrock as specified in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Ponding Depth
  - Maximum ponding depth for water quality storm: 12 inches at longitudinal mid-point of swale; 18 inches at downstream end of swale
  - Maximum ponding depth for overflow events: 36 inches
  - Minimum freeboard for overflow events: 6 inches above the 10-year, 24-hour storm water surface elevation to top of swale

- Bottom Width
  - Minimum: 2 feet
  - Maximum: 8 feet

- Bottom Slope
  - Dry swales should have a maximum longitudinal slope of 2%, provided flow velocities are non-erosive (e.g., flow velocities should not exceed 3 feet per second for grassed surfaces).
  - Dry swales can have slightly steeper slopes (up to 6%) if designed with check dams.
  - Check dams should be designed to reduce the effective slope of the bottom of the dry swale to 2.0% or less for optimum water quality performance. Consider designing as a terraced system with check dams and relatively flat bottoms in each cell.

- Side Slopes
  - 3(H):1(V) slopes or flatter are preferred especially on grassed slopes where mowing is required.
  - In ultra-urban locations or space constrained areas, side slopes of 2(H):1(V) may be utilized if properly designed to account for erosion and slope stability. Stabilize the slope with turf reinforcement matting or equivalent if the slope could potentially erode.

- Water Velocity
  - For water quality storm: 1.5 feet per second (maximum)
  - Peak flow design storm: 5.0 feet per second (maximum)

Check Dams

- Check dams should be evenly spaced and designed with a maximum height of 18 inches. Check dams should be designed to pass the design flow over the top of the check dam without exceeding maximum ponding depths.

- Spacing of check dams should be a function of both the longitudinal slope of the swale and the design volume that must be retained behind the dams. Space such that the upstream limit of ponding from one check dam is just below the downstream edge of the adjacent check dam.

- Check dams that are designed to infiltrate (with no underdrain system) should not be constructed of permeable materials like gabions, as water must sufficiently pond behind each check dam and be forced to infiltrate.
- Utilize weirs constructed from concrete or granite curbing.
- Anchor check dams into swale side slopes to prevent washout. Each side of the dam should extend 2-3 feet into the swale side slopes.
- Protect downstream side of check dams from scour with stabilized surface protection measures.

Inlet

- Design the inlet in accordance with the Inlet and Outlet Controls section of this Manual.
- Runoff can be introduced to the dry swale through overland flow, curb cuts, inlet structures, swales/channels, and/or pipes.
- Design the system in an off-line configuration to the extent feasible if runoff is delivered by a storm drainpipe or is along the main storm conveyance system.

Outlet & Overflow

- Design the outlet in accordance with the Inlet and Outlet Controls section of this Manual.
- Outlets are typically a stabilized spillway, gabion berm, concrete weir, curb cut opening, precast concrete structure, or polyethylene/polyvinyl chloride riser structure.
- Dry water quality swales should have an outlet sized to convey the 10-year, 24-hour storm event, at a minimum. Off-line systems should be designed with a bypass or overflow for flows in excess of the water quality storm.

Underdrain System

- Install an underdrain system when a proposed dry swale meets one or more of the following conditions:
    - Is in native soil that has an infiltration rate less than 0.3 inch per hour (HSG C and D soils)
    - Does not meet vertical separation distance to SHGT or bedrock (Chapter 10 - General Design Guidance for Stormwater Infiltration Systems) and should be lined
    - Does not meet minimum horizontal setback distances (Chapter 10) and should be lined
    - Is within a Land Use with Higher Potential Pollutant Loads (LUHPPL) (Chapter 10) or area of contaminated soils and should be lined.

- An underdrain is also recommended, but not required, for all other dry swales to account for potential infiltration failure due to clogging, groundwater mounding, or periods of excessive rainfall.
- Minimum underdrain pipe diameter: 4 inches
- Minimum underdrain pipe slope: 0.5%
- Use two layers of gravel with the underdrain system. Both layers of gravel should be located below and extend across the entire bottom of the system. The upper gravel layer should consist of 3 inches of pea gravel, and the lower layer should consist of a 12-inch-thick gravel sump.
- For unlined systems, install the perforated underdrain pipe 2 inches below the top of the gravel sump to promote infiltration. For systems that are lined with an impermeable liner to prevent infiltration, install the underdrain pipe 2 inches above the bottom of the gravel sump so the system can drain between storm events.
- If the system is designed without an underdrain, pea gravel and gravel sump are optional.
- Lay underdrain such that perforations are on the bottom of the pipe.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure, and/or daylights.
- Place filter fabric along sidewalls of excavation and above the pea gravel (below the bioretention soil layer) for 1 to 2 feet on both sides of the underdrain. Filter fabric shall not be placed across the entire width of the swale.
- Other considerations when designing/installing underdrains:
    - Provide a marking stake and an animal guard for underdrains that daylight at grade.
    - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain, one at the upstream end and one at the downstream end.
    - Cleanouts should be at least 4 inches in diameter, be nonperforated, and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout should be highly visible.
    - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Liner

- An impermeable liner is required for use of dry swales when receiving runoff from Land Uses with Higher Potential Pollutant Loads (LUHPPLs) (Chapter 10 - General Design Guidance for Stormwater Infiltration Systems), in locations with subsurface contamination, where the required vertical separation to SHGT cannot be met, and in locations with unacceptable horizontal setbacks for infiltration.

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner or closed bottom of the system, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.

- For lined swales within LUHPPLs, a shutoff valve can be installed on the underdrain outlet to capture and contain accidental spills or releases that reach the swale.

Materials

- Surface Cover
    - Native grasses or plants is the preferred surface cover type for dry water quality swales. 3 to 4 inches of washed river stone or smooth crushed stone sized to resist the 10-year, 24-hour storm may also be used as an alternative surface cover type. Mulch should NOT be used on the bottom of the swale.

- Vegetation
    - Vegetation should be designed for regular mowing, like a typical lawn, or less frequently.
    - Select vegetation and provide a planting plan with the guidance provided in Appendix F of this Manual.
    - Native grasses are preferred for enhanced biodiversity, wildlife habitat, and drought tolerance.
    - Grass species should be sod-forming to resist scouring; have a high stem density to help slow water and facilitate sedimentation; be tolerant to frequent inundation; and be able to survive and continue to grow after the inundation period.
    - If to be used near a road that is subject to winter salt operations, the vegetation must also be salt tolerant.
    - Establish a dense vegetative cover or adequately stabilized landscaped surface throughout swale and any upgradient areas disturbed by construction before runoff can be accepted into the facility.
    - Trees should only be planted along the perimeter of the facility and with 15 feet of separation from underdrain piping.
    - Trees should not be planted in dry swales.
    - Do not use vegetation with a mature vegetation height exceeding 24 inches above the surrounding sidewalk or pavement surface in dry swales within

medians, near intersections, or near pedestrian crossings to avoid obstruction of sight lines.

- Engineered Bioretention Soil Media

  - The engineered soil media in bioretention systems is designed to filter/treat runoff and to provide sufficient organic material to support plan establishment and growth.

  - The engineered bioretention soil media should be a homogeneous soil mix of (by volume):
    - 60–85% Sand
    - 15–25% Topsoil
    - 3–8% Organic Matter

  - **Sand** should be washed concrete sand (ASTM C33 or AASHTO M-6) or coarse washed sand that meets the gradation schedule as shown in State of Connecticut Department of Transportation Standard Specifications, Section M.01 (Aggregates), Table M.01.04-1 for Fine Aggregate Gradations.

  - **Topsoil** should contain 5–20% organic material, have a pH range of 5.5 to 7.0, and be a sandy loam, loamy sand, or loam per USDA soil texture with less than 5% clay content. Topsoil that meets the State of Connecticut Department of Transportation Standard Specifications, Section M.13.01 (Roadside Development) for Topsoil may also be used, except it should contain less than 5% clay.

  - **Organic matter** should consist of one of the following materials
    - Sphagnum Peat: Partially decomposed sphagnum peat moss, finely divided or of granular texture with 100 percent passing through a 1/2-inch (13-mm) sieve, a pH of 3.4 to 4.8.
    - Wood Derivatives: Shredded wood, wood chips, ground bark, or wood waste; of uniform texture and free of stones, sticks, soil, or toxic materials.

  - Compost shall NOT be used as organic matter since the use of compost in bioretention soil media can result in nutrient export from the system.

  - Soil amendments such as zerovalent iron and/or drinking water treatment residuals (alum) may be used to further enhance phosphorus sorption.

  - Bioretention soil mix should have a pH of 5.2 to 7.0 and meet the particle size distribution in Table 13-12.

Table 13-9. Acceptable Particle Size Distribution of Final Bioretention Soil Mix

Media Type	Sieve #	Size (inches)	Size (mm)	% Passing
Coarse Sand	4	0.187	4.76	100
Medium Sand	10	0.079	2.00	95
Fine Sand	40	0.017	0.42	40-15
Silt	200	0.003	0.075	10-20
Clay	<200	Pan	Pan	0-5

  - Bioretention soil mix should NOT contain any of the following materials: stones, clods, roots, clay lumps, and pockets of coarse sand exceeding 0.187 inches (4.76 mm) in any dimension; plants, sod, concrete slurry, concrete layers or chunks, cement, plaster, building debris, asphalt, bricks, oils, gasoline, diesel fuel, paint thinner, turpentine, tar, roofing compound, acid, solid waste, and any other extraneous materials that are harmful to plant growth.

- Pea Gravel
  - Should consist of 3/8" AASHTO No. 8 stone. Pea gravel should be clean (washed and free from dirt and debris) and rounded in shape.

- Gravel Sump
  - Should consist of 3/4" AASHTO No. 5 stone. Gravel should be clean (washed and free from dirt and debris), crushed, and angular.

- Filter Fabric
  - Use non-woven filter fabric that complies with State of Connecticut Department of Transportation Standard Specifications, Section M.08.01.19 (Drainage – Geotextiles).

- Underdrain (perforated and non-perforated pipe sections)
  - Polyethylene or polyvinyl pipe

- Liner
  - If used, should consist of a 30 mil (minimum) HDPE or PVC liner, or one of the alternative liner systems described in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems with the approval of the review authority.

- Check Dams
  - Construct of gabions, granite or concrete curbing, or precast/poured-in-place concrete. If constructed of granite or concrete curbing, curbing should conform

to State of Connecticut Department of Transportation Standard Specifications, Section M.12.06 (Stone Curbing) and Section 8.11 (Concrete Curbing).

- Poured-in-place Concrete
  - If used, should be an appropriate class of concrete based on the application and conform to State of Connecticut Department of Transportation Standard Specifications, Section 6.01 (Concrete for Structures).

- Turf Reinforcement Matting (TRM)
  - Stabilize the side slopes of the swale with TRM to limit erosion in locations where flow velocities exceed 3 to 5 feet per second (depending on soil and vegetation types) for the 1-year, 24-hour storm event.
  - If used, shall be a woven material included on the CTDOT Qualified Products List that exceeds the design velocity of the design storm and allows for the growth of the proposed vegetative species.

Other Considerations

- Roadway stability can be a design issue when installing swales along roadways. It may be necessary to provide a vertical impermeable barrier to keep water from saturating the road's sub-base. The barrier should be capable of supporting H-20 loads.

- Non-woven filter fabric should be placed along the sidewalls of the system to help direct the water flow downward, reduce lateral flows, and to reduce lateral soil migration. This is critical when installing swales in a median strip or adjacent to a roadway or parking lot.

- Non-woven filter fabric should also be placed above the pea gravel layer (below the bioretention soil layer) for 1 to 2 feet on both sides of the underdrain pipe. Filter fabric should NOT be placed across the entire width of the bioretention system because filter fabric installed in this manner can result in clogging and system failure.

Winter Operations

- Swales should not be used as dedicated snow storage areas. To the extent feasible, locate and design the system to avoid snow storage areas and potential damage from snow plowing activities. Refer to Chapter 7 - Overview of Structural Stormwater Best Management Practices for general design considerations related to winter operations.

Construction Recommendations

- The designing qualified professional should develop a detailed, site-specific construction sequence.

- The designing qualified professional should inspect the installation during the following stages of construction, at a minimum:
  - After excavation of the swale and scarification of bottom and sidewalls of excavation

  - After placement of gravel layer
  - After placement of underdrain before covering by the pea gravel layer
  - After placement of bioretention soil media
  - After installation of bypass, outlet/overflow, and inlet controls
  - After grass or other vegetation has been installed

- The designing qualified professional should provide an as-built plan of the completed system along with a certification that the system was designed in accordance with the guidance contained in this Manual and other local or state requirements and that the system was installed in accordance with the approved plans.

- The bioretention soil mix should be tested prior to placement according to the specifications in this section (at least one test per bioretention system). The designing qualified professional should certify that the bioretention soil mix meets the specifications in the previous section based on soil testing results.

- The entire contributing drainage area should be completely stabilized prior to directing any flow to the system. Adequate vegetative cover must be established over any pervious area adjacent or contributing to the system before runoff can be accepted.

- Erosion and sediment controls should be in place during construction in accordance with the Connecticut Guidelines for Soil Erosion and Sediment Control and the Soil Erosion and Sediment Control (SESC) Plan developed for the project.

- During clearing and grading of the site, measures should be taken to avoid soil compaction at the location of the proposed system.

- The system should be fenced off during the construction period to prevent disturbance of the soils.

- The system should be excavated to the dimensions, side slopes, and elevations shown on the plans. The method of excavation should avoid compaction of the bottom of the bioretention system. A hydraulic excavator or backhoe loader, operating outside the limits of the system, should be used to excavate the system. Excavation equipment should not be allowed within the limits of the system.

- The gravel, pea gravel, and bioretention soil media should be placed in the excavation by a hydraulic excavator or backhoe loader located outside the limits of the system and then hand-raked to the desired elevation.

- Place the bioretention soil in 6 to 12-inch lifts. The bioretention soil needs to settle before planting. Lightly tamp or spray the surface of the bioretention soil with water until saturated. The elevation of the bioretention soil can be a couple of inches higher at installation than the design elevation in anticipation of settling. Bring bioretention soil levels back to the design elevation if necessary.

- Install vegetation in the swale in accordance with the planting plan and plant schedule on the plans. Water vegetation thoroughly immediately after planting and as necessary until fully established. The bioretention soil mix provides enough organic material to adequately supply nutrients from natural cycling.

Maintenance Needs

- Swales should be designed with easy access to all components of the system for maintenance purposes. Refer to Chapter 7 - Overview of Structural Stormwater Best Management Practices for general design considerations to reduce and facilitate system maintenance.

- Detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance should be identified on the plans and in the Stormwater Management Plan.

- Maintenance should be detailed in a legally binding maintenance agreement.

- Maintenance activities such as sediment removal, mowing, and repairs should be performed with rakes and light-weight equipment rather than heavy construction equipment to avoid compaction of the bioretention soil media and underlying soils. Heavy equipment may be used for sediment removal and other maintenance activities if the equipment is positioned outside the limits of the system. Heavy construction equipment should not be allowed within the limits of the system for maintenance purposes.

Recommended Maintenance Activities

- Inspect after major storms (1 inch or more of precipitation) in the first few months following construction.

- Inspect swale annually.

- Refer to Appendix B for maintenance inspection checklists, including items to focus on during the inspections.

- Remove trash and organic debris (leaves) in the Spring and Fall.

- Remove sediment from the sediment forebay or other pretreatment area when it accumulates to a depth of more than 12 inches or 50% of the design depth. Clean outlet of sediment forebay or other pretreatment measures when drawdown time exceeds 36 hours after the end of a storm event.

- Remove sediment from the swale surface when the sediment accumulation exceeds 2 inches or when drawdown time exceeds 48 hours after the end of a storm event, indicating that the system is clogged.

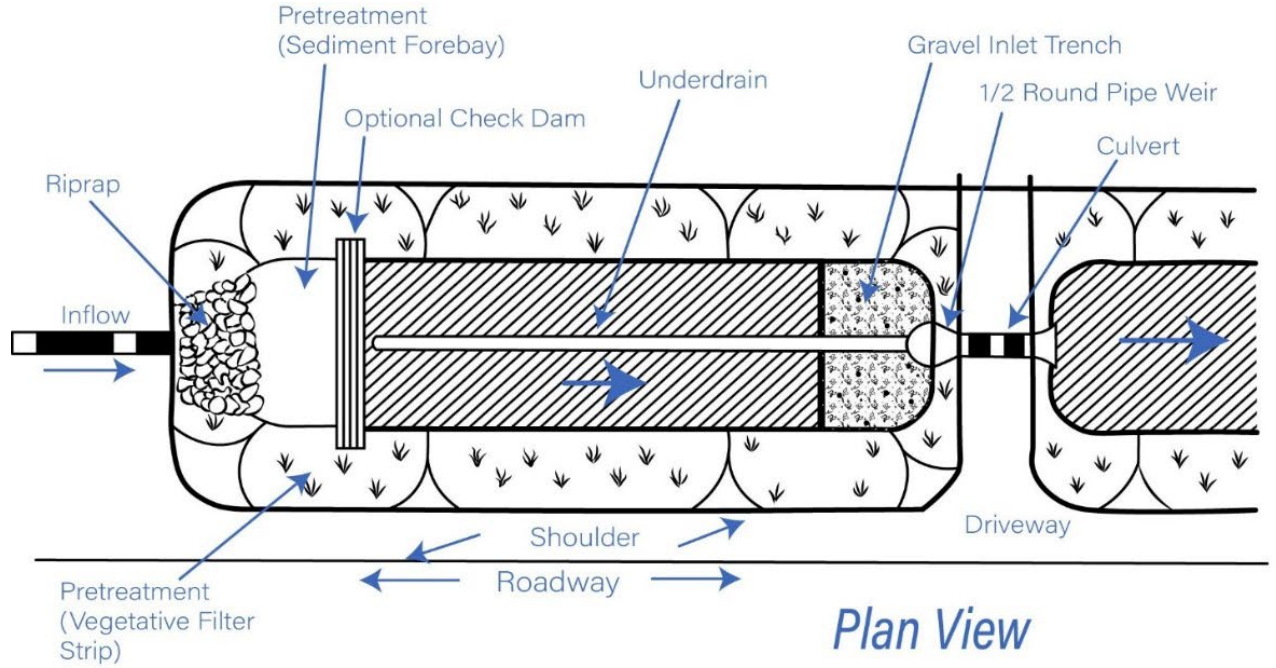
- Weed as necessary. Mow grass within swale to a height of 4 to 6 inches. Maintain a healthy, vigorous stand of grass cover, re-seed as necessary.

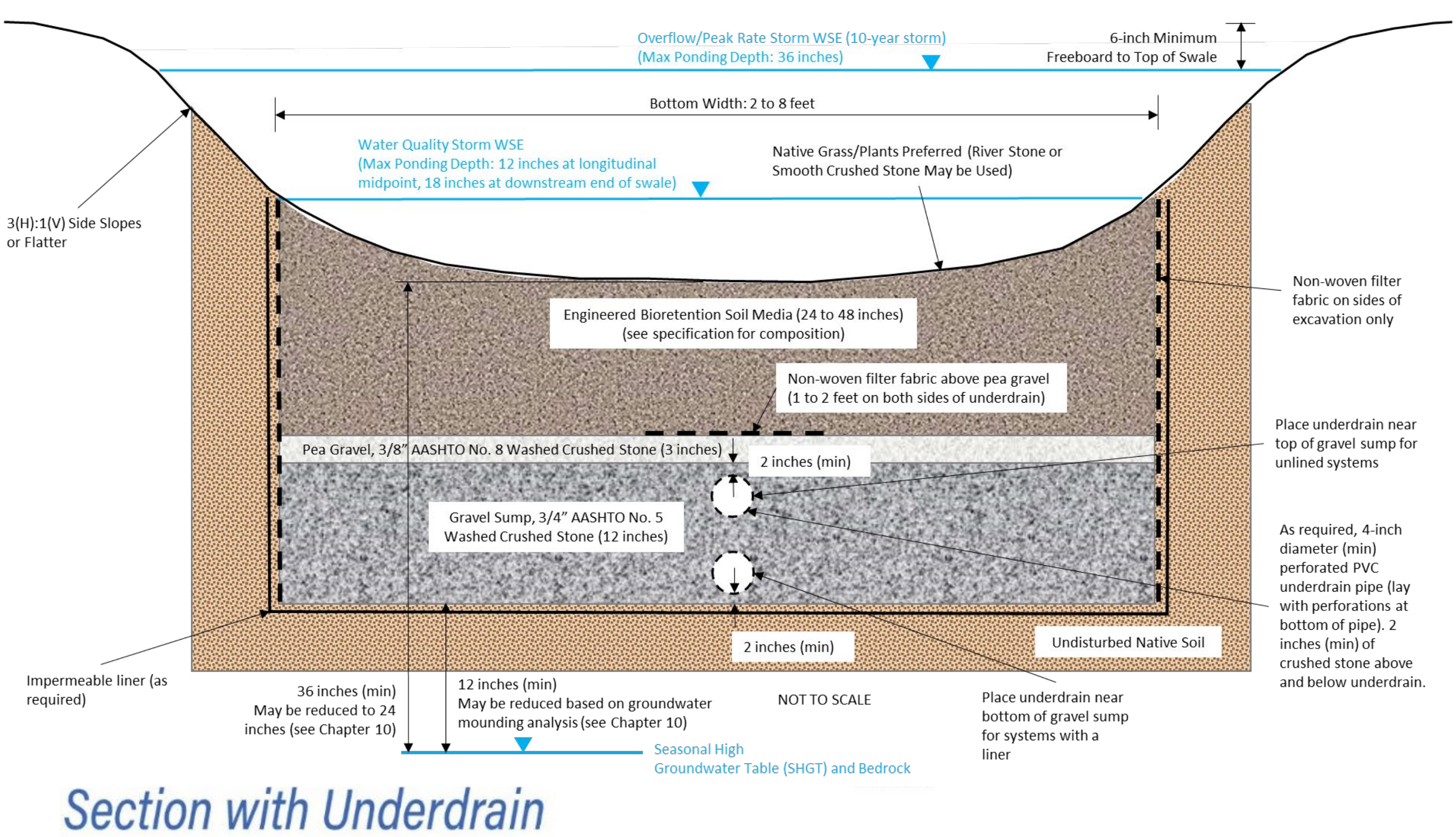
- Maintain vegetated filter strips or grassed side slopes of swale in accordance with maintenance recommendations in the Pretreatment BMPs section of this Manual.

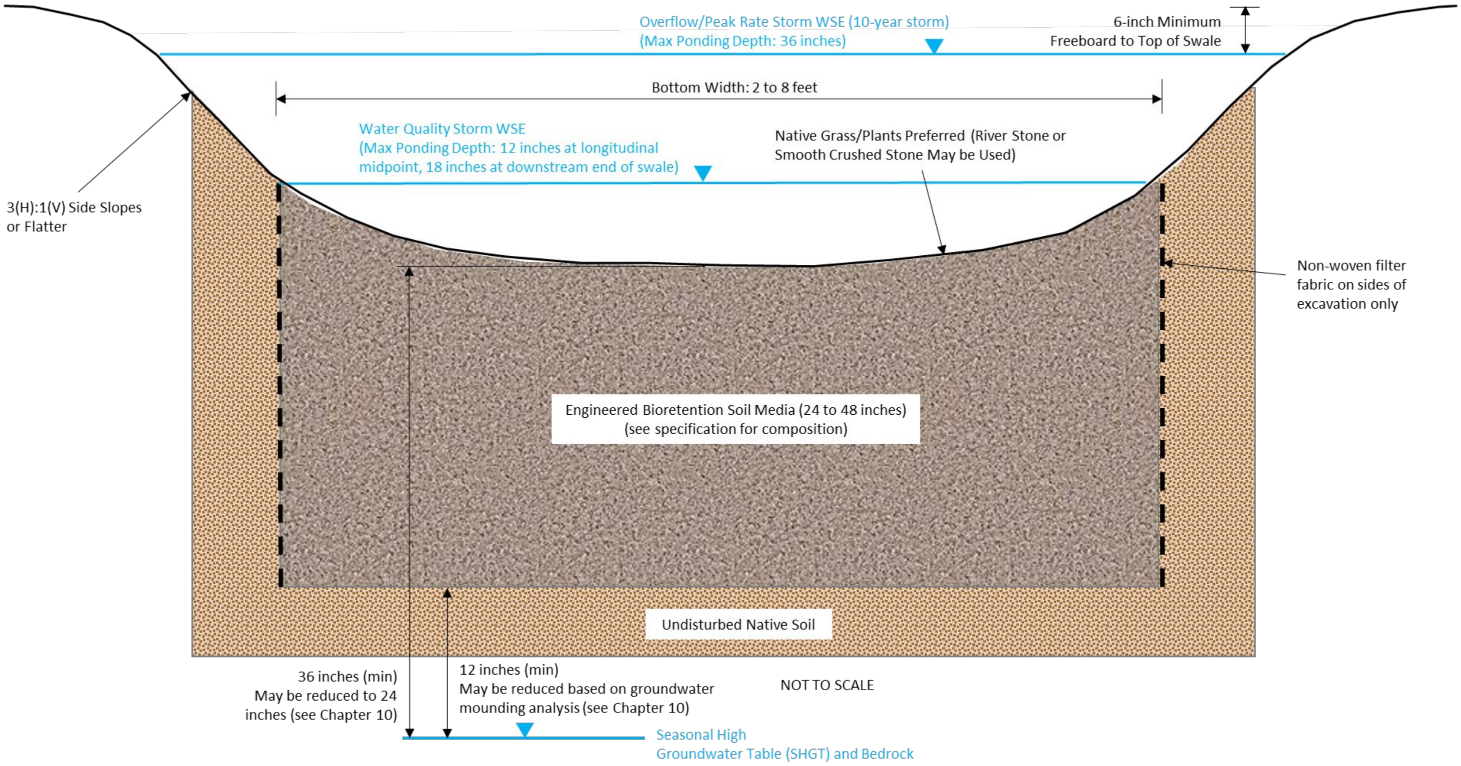
- Periodically remove grass clippings to prevent clogging of the surface of the swale.

- Mowing should not be performed when the ground is soft to avoid the creation of ruts and compaction, which can reduce infiltration.

Figure 13-30. Dry Water Quality Swale with and without Underdrain Schematics







Section without Underdrain