INDIANA DEPARTMENT OF TRANSPORTATION

Post-Construction Stormwater Management

Revisions as of September 1, 2024

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POST-CONSTRUCTION STORMWATER MANAGEMENT

1.0 INTRODUCTION

This document serves as the implementation guidance for meeting the requirements of the Indiana Department of Environmental Management (IDEM) National Pollution Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) General Permit and the Construction Stormwater General Permit (CSGP).

The United States Environmental Protection Agency (EPA) defines an MS4 as a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains), that is owned by a state, city, town, village, or other public entity that discharges to waters of the United States (40 CFR 122.26). INDOT has a NPDES MS4 General Permit from IDEM and must comply with EPA and IDEM requirements.

As of December 18, 2021, Indiana no longer administers the construction stormwater program under Indiana Administrative Code (327 IAC 15-5 or Rule 5). Permitting coverage is now issued under the CSGP. The CSGP is a performance-based regulation designed to reduce pollutants that are associated with construction and/or land-disturbing activities.

The requirements of CSGP applies to all construction projects which include clearing, grading, excavation, and other land-disturbing activities that results in the disturbance of one (1) acre or more of total land area. If the land-disturbing activity results in the disturbance of less than one (1) acre of total land area but is part of a larger common plan of development or sale, the project must obtain permit coverage under the CSGP. Projects that may have noncontiguous land disturbance require prior approval by the INDOT Post-Construction Stormwater Team via project-by-project review for CSGP coverage.

A minimum control measure (MCM) of the MS4 permit requires INDOT to develop post-construction stormwater management practices or best management practices (BMPs) for post-construction stormwater run-off control and treatment. The term post-construction stormwater BMP (PCBMP) will be used to differentiate these treatment practices from temporary construction soil erosion and sediment control practices.

1.01 Applicability of the Construction Stormwater General Permit

IDEM's Construction Stormwater General Permit (CSGP) applies to all projects where the proposed land disturbance, including staging areas for construction, is one (1) acre or more. To meet the requirements of the IDEM permits, post-construction stormwater runoff control and treatment as defined in Section 1.02 of this document will be implemented on INDOT projects.

Local Public Agency (LPA) projects shall follow the CSGP requirements. LPA projects are not exempt from designing and constructing post-construction stormwater runoff control and treatment practices.

1.02 Post-Construction Stormwater Best Management Practices Requirement

PCBMPs are required when the total disturbed area is 1 acre or more and there is new net impervious surface area of 1 acre or more. If both conditions are not met, post-construction stormwater best management practices for water quality are not required.

LPA projects must adhere to the requirements in the CSGP. If there are no local MS4 requirements in place, IDEM's requirements shall be followed.

Unless stormwater is being discharged into a county regulated drain, non-LPA INDOT projects will adhere to the requirements in this document and not the local or county MS4 requirements.

1.03 Target Pollutants

The U.S. EPA lists sediment as the most common pollutant in rivers, streams, lakes, and reservoirs. By targeting sediment removal in stormwater run-off, other types of pollutants will be removed as well. Sediment is the primary pollutant in stormwater run-off from the pavement on INDOT project sites once vegetation is properly established. Accordingly, the permanent stormwater quality control practices discussed in this document will target sediment removal. The required sediment removal rate as total suspended solids (TSS) for all qualifying INDOT projects is 80%.

If stormwater run-off discharges to an IDEM Total Maximum Daily Load (TMDL) Watershed or a stream on the 303(d) List of Impaired Waters, and there are pollutants of concern in INDOT's stormwater run-off, additional water quality treatment may be required if feasible. The Indiana Stormwater Quality Manual can be referenced for design guidance if additional treatment beyond TSS removal is required. The designer shall coordinate with INDOT prior to using the Indiana Stormwater Quality Manual for design guidance.

2.0 DEFINITIONS

A parenthetical number which follows a definition corresponds to the number of the cited reference shown in Section 11.0.

Best Management Practice (BMP). A method that has been determined to be the most effective and practical means of preventing or reducing non-point source pollution to help achieve water quality and quantity goals.

Biological Treatment. The removal of contaminants from stormwater using vegetation and/or microbiological activity by means of various physical and chemical processes.

Design Storms. A theoretical storm used to analyze existing or new drainage systems often using a hyetograph or isohyetal map to show the time and spatial distribution of rainfall.

Detention. The interception of a volume of stormwater run-off to be temporarily stored in a constructed stormwater facility for gradual release to a receiving stream or system.

Diversion System. A system of pipes or conduits that divert stormwater discharges in excess of Water Quality Volume or Water Quality Treatment Rate from treatment facilities.

Dry Swale. A vegetated channel that conveys stormwater runoff and should completely drain between rainfall events.

Filtration. The process of removing contaminants from stormwater by allowing it to flow through vegetation or a bed of porous media such as sand, organic material, or soil.

Forebay. A pool of water upstream of another body of water or structural practice that acts as a settling basin for sediment in stormwater run-off.

Hydrograph Routing. A technique used to confirm that a detention facility provides adequate storage and will drain within the allotted timeframe.

Impervious Surface. Any land surface with a low or no capacity for soil infiltration, including but not limited to pavement (sidewalks, streets, parking areas, and driveways), packed gravel or soil, and rooftops. IDEM CSGP Appendix B.

Infeasible. Not technologically possible, or not economically practicable and achievable in light of best industry practices. IDEM CSGP Appendix B.

Infiltration. The process by which stormwater flows from the ground surface and percolates through the soil.

Level Spreader. A stormwater device that reduces the erosive energy of concentrated flows by distributing runoff as sheet flow to stabilized vegetative surfaces.

Non-structural BMP. Institutional and pollution-prevention practices designed to prevent or minimize pollutants from entering stormwater run-off and/or reduce the volume of stormwater requiring management.

Peak Flow Rate. The maximum flow rate for a given design storm at a specific location.

Retention. The interception of a volume of stormwater run-off to be permanently stored in a constructed stormwater facility.

Sedimentation. The process by which soil particles with a density greater than that of water settle to the bottom of a stormwater facility over time.

Soil Disturbance. The movement of soil that results from activities such as clearing, grading, excavation, and pavement removal.

Stormwater Management Measure. A practice or a combination of practices selected to improve the quality of run-off discharges, divert run-off, or mitigate the impacts related to quantity of run-off. IDEM CSGP Appendix B.

Stormwater Quality Measure. A practice, or a combination of practices, to control or minimize pollutants associated with stormwater run-off. IDEM CSGP Appendix B.

Structural Practices. Temporary or permanent facilities that are built to remove contaminants from stormwater run-off.

Total Maximum Daily Load. The calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.

Treatment Train. Two or more structural practices placed in series (one downstream of another) to help achieve stormwater pollutant reduction goals.

Water Quality. The quality of water based on aquatic life criteria, biological criteria, human health criteria, and microbial/recreational criteria.

Water Quality Event. A rainfall event of one inch which produces the Water Quality Volume and Water Quality Treatment Rate used to design post-construction structural practices.

Water Quality Volume. The volume of run-off generated by the Water Quality Event for treatment in a post-construction structural practice.

The volume of run-off generated by one inch of rainfall on a site. IDEM CSGP Appendix B.

Water Quality Treatment Rate. The peak flow rate of stormwater run-off generated by the Water Quality Event for treatment in a flow-through post-construction structural practice.

Wet Swale. A vegetated channel that conveys stormwater runoff and that should maintain a permanent pool of water.

3.0 STRUCTURAL PRACTICE SELECTION

3.01 Structural Practices

Although there are numerous structural post-construction practices available and in-use, INDOT has developed a list of preferred practices for selection, including the following:

- Dry Turf Grass Swale
- Dry Native Grass Swale
- Vegetated Turf Grass Filter Strip
- Vegetated Native Grass Filter Strip
- Dry Detention Pond
- Dry Detention Swale
- Wet Swale
- Wet Retention Pond
- Infiltration Swale
- Infiltration Basin
- Hydrodynamic Separator

Figure 3A includes INDOT's preferred structural practices along with their pollutant removal mechanism. Each practice is prioritized, with a value of "1" being most preferred and a value of "4" being least preferred. In some cases, practices in series will be required to achieve 80% TSS removal, often referred to as a treatment train.

3.02 Planning and Design-Related Minimum Practices

There are several design-related minimum practices that should be considered for INDOT projects. When possible, maximize vegetative conveyance of stormwater to reduce flow velocity, promote sedimentation, filtration, and uptake of pollutants; reduce run-off volumes through infiltration and evapotranspiration; and in some cases, provide wildlife habitat. This objective can be achieved by using swales for stormwater conveyance instead of storm sewers, for example. In some cases, it may be possible to avoid directly connected impervious areas (DCIAs) by allowing run-off to flow from the roadway through vegetation rather than directly into a storm sewer system. Preserving naturally vegetated areas and soil types helps to slow run-off, filter pollutants, and facilitate natural infiltration. It is also ideal to treat pollutants where they are generated or prevent their generation. However, site-specific constraints will affect which practices are appropriate for each project. Additionally, choosing the right practice(s) for each project requires sound engineering judgement and consideration of roadway layout, site specific conditions, environmental context, and hydrologic and hydraulic design. A flowchart can be seen in **Figure 3B** to help choose the most suitable practice for a given project.

3.02(01) Roadway Project Layout/Site-Specific Conditions

There are several site-specific factors that can limit post-construction treatment practice selection.

- Available right-of-way can limit available space needed for some facilities such as dry detention and wet retention ponds. It is costly to acquire right-of-way in some locations, making the implementation of these practices infeasible.
- Steep slopes greater than 15% and other topographic constraints can also limit practice selection. Gentle slopes are preferred because they increase hydraulic retention time and sediment removal.
- Infiltration practices are discouraged in areas of karst topography, which are common in the southern part of the state.
- A high water-table can also impact the function of stormwater facilities designed to fully drain between rainfall events.
- In areas where the bedrock is close to the ground surface, excavation can be expensive.
- The contributing drainage area, both on-site and off-site, will affect practice selection. Large run-off volumes and high velocities can damage the stormwater facility and impact pollutant removal efficiency.
- Adjacent land-use can affect the off-site run-off draining to INDOT right-of way. Development can lead to increased flow rates and sediment loading.
- A practice should not encroach onto the roadway or an adjacent property.

- Underlying soils are important due to their ability to infiltrate run-off and support needed vegetation.
- A practice should not be placed in a jurisdictional stream.

3.02(02) Environmental Context

Treatment practice selection and design are often influenced by pollutants that are reasonably expected to be present in stormwater run-off and the pollutants of concern in the receiving waterbody. Receiving streams on the current 303(d) List of Impaired Waters and TMDL Watersheds are to be considered by all Indiana MS4s. INDOT's temporary erosion and sediment control requirements remove TSS from INDOT's stormwater run-off during construction activities. For qualifying projects, this document provides design criteria to remove 80% of TSS from INDOT's stormwater run-off by installing permanent PCBMPs.

3.02(03) Hydrologic and Hydraulic Design Context

The permanent stormwater quality controls in this document are designed using the Water Quality Volume or the Water Quality Treatment Rate, which are both based on the Water Quality Event (1 inch of rainfall). The Water Quality Volume is the treatment volume required to remove a significant percentage of stormwater pollutant load. The Water Quality Treatment Rate is the peak rate of discharge for the water quality design storm needed for the sizing of flow-through practices.

It is important to note the Water Quality Volume and the Water Quality Treatment Rate are based on the total onsite contributing drainage area within INDOT right-of-way to the respective stormwater pollution prevention practice. Individual practices are sized for the total portion of the drainage area directed towards the practice. If off-site run-off is not separated from run-off generated within the right-of-way, the required treatment practice size may be significantly increased. All stormwater from newly added impervious surfaces for qualifying projects (**or equivalent impervious area**) must pass through a structural post-construction stormwater practice. The design process for each practice using either the Water Quality Volume or the Water Quality Treatment Rate is described in detail in sections 4.0 through 10.0. The Water Quality Volume and Water Quality Treatment Rate can be determined using the following equations:

Water Quality Volume

$$WQ_v = \frac{(P*R_v*A)}{12}$$ [Equation 3.1]

Where:

WQ_v = water quality volume, acre-feet

P = rainfall, inches (use 1.0 inches)
R_v = volumetric run-off coefficient
A = total proposed onsite drainage area, acres

And:

$$R_v = 0.05 + (0.009 * I)$$ [Equation 3.2]

Where:

I = percent new impervious cover, %

And:

$$I = \frac{P_{ia} - E_{ia}}{A} * 100$$ [Equation 3.3]

Where:

P_{ia} = Proposed Onsite Impervious Area
E_{ia} = Existing Onsite Impervious Area

The Water Quality Volume in inches can be calculated with the equation below:

$$Q_{wv} = P * R_v$$ [Equation 3.4]

Where:

Q_{wv} = water quality volume, inches
P = rainfall, inches (use 1.0 inches)
R_v = volumetric run-off coefficient

Water Quality Treatment Rate

The following procedure will be used to estimate the Water Quality Treatment Rate (Q_{wq}, cfs) which is needed for flow-through practices.

1. Using Q_{wv}, a corresponding Water Quality Curve Number (CN_{wq}) is computed:

$$CN_{wq} = \frac{1000}{10 + (5 * P) + (10 * Q_{wv}) - (10 * [Q_{wv}^2 + 1.25 * Q_{wv} * P]^{1/2})}$$

[Equation 3.5]

Where:

Q_{wv} = water quality volume, inches
P = rainfall, inches (use 1.0 inches)

Alternatively, **Figure 3C** can be used to determine CN_{wq}. This graphical method is as acceptable as using Equation 3.5. Note, the CN_{wq} is not the same as a typical CN. The CN_{wq} is only used to determine the Water Quality Treatment Rate and should not be used in other applications.

2. Calculate the Time of Concentration (T_c) following the requirements in *Indiana Design Manual* (IDM) Chapter 202.

3. Using the CN_{wq}, T_c, and total onsite area draining to the practice, compute the Water Quality Treatment Rate (Q_{wq}) in cfs following hydrograph-oriented procedures approved in the IDM. Use NRCS Type II rainfall distribution and a rainfall depth of 1.0 inches. Software programs that use TR-55 and TR-20 methodologies are acceptable.

TSS Removal Rates for Structural Practices in Series

If 80% TSS removal cannot be achieved using one practice, multiple practices placed in series may be required. The following equation shall be used to calculate the TSS removal rate for practices in series.

$$R_t = R_1 + R_2 - \frac{R_1 * R_2}{100}$$ [Equation 3.6]

Where:

R_t = Total TSS Removal Rate, %
R_1 = TSS Removal Rate of the First or Upstream practice, %
R_2 = TSS Removal Rate of the Second or Downstream practice, %

TSS Removal Rates for Projects with Multiple Discharge Points

If there are multiple discharge points from the project site with corresponding sub-areas, a weighted average of the TSS removal rates may be used. However, the discharge points must ultimately flow to the same receiving stream.

$$R_{avg} = \frac{(A_1 * R_1) + (A_2 * R_2)}{A_1 + A_2}$$ [Equation 3.7]

Where:

R_{avg} = Average TSS Removal Rate, %
R_1 = TSS Removal Rate of the First Onsite Area, %
R_2 = TSS Removal Rate of the Second Onsite Area, %
A_1 = First Onsite Area, acres
A_2 = Second Onsite Area, acres

3.03 Construction, Inspection and Maintenance Considerations

Although proper design is critical for structural practices to function correctly, proper construction and maintenance are equally important. The practice designer should consider location-specific constraints and constructability, in addition to other design requirements provided in this document, because each practice will present unique construction and maintenance issues.

3.03(01) Construction

When designing a structural practice, the engineer should choose a layout that facilitates equipment access to ensure ease of constructability and reduce construction costs. The construction plans should be detailed and clearly address any constraints. Critical design criteria should be clearly documented in the construction plans and critical dimensions should be discussed at preconstruction meetings. The time of year the practice will be constructed should be considered due to vegetation establishment needs. Through adequate planning and coordination, many potential problems can be avoided.

3.03(02) Inspection and Maintenance

All post-construction structural practices will be put on an inspection schedule and maintenance activities will be performed as needed. It is important for the practice designer to understand the type of maintenance activities required for the practice and provide adequate permanent drainage easement or right-of-way around the practice for these activities. Safety should always be considered; the design should include safe access for inspection and maintenance activities. In some locations, a permanent access drive may need to be constructed to avoid lane closures, especially along interstates.

Each permanent structural practice will be given an asset identification number and will require an inspection and maintenance plan. Templates in editable format are provided on the INDOT Stormwater webpage. The Engineer of Record is required to fill out the appropriate template and provide it along with the other submittal documents.

3.04 Infeasibility Determination

In some circumstances, it may not be feasible to construct one or more PCBMPs in the project area. It may be possible to install the PCBMPs outside of the project area but within the same watershed to satisfy the requirement. Prior coordination with the INDOT Environmental Services Division will be necessary.

3.04(01) Infeasibility Documentation

If it is determined that it will be infeasible to treat INDOT's stormwater run-off to remove 80% TSS within the project limits, infeasibility documentation must be submitted. If it is only feasible to remove a smaller percentage of TSS from the run-off, infeasibility documentation will also be required. The documentation will include the following:

- Description of project purpose, with exhibits showing location, outlets, and existing and proposed features and topography
- Calculations of Water Quality Volume and/or Water Quality Treatment Rate
- Reason(s) constructing post-construction structural practices is not feasible
- Construction cost estimate for practices if cost is a factor
- Proposed plans
- If applicable, percentage of TSS that is feasible to remove from run-off
- Potential alternatives to treat existing impervious areas of equivalent size in another location instead of proposed added pavement

4.0 DRY TURF GRASS AND NATIVE GRASS SWALES

4.01 Dry Swale Overview

A dry swale used for water quality treatment can be natural or engineered and is designed to convey and treat run-off from the roadway. A dry swale will convey flow during wet weather events but should completely dry out between events. Dry swales are often most preferred because they generally take the least amount of right-of-way to implement compared to other green infrastructure post-construction stormwater practices. Dry swales can be planted with turf grass or native vegetation and are referred to as turf grass swales and native grass swales in this chapter. The only difference between the two dry swale types are the plantings. **Figures 4A** and **4B** depict a turf grass swale and a native grass swale, respectively. When possible, turf grass swales should be utilized instead of native grass swales when they are located within 30 feet of the edge of pavement; native grass swales should be utilized when they are located beyond that limit. Adjacent land use should be considered when choosing native grass. If there is a residential or commercial property adjacent to native grass planting, future mowing preferences should be considered.

Swales typically have either a trapezoidal or V-shaped cross section. There should not be an underdrain. The objective of a dry swale is to decrease the velocity of flow to promote sedimentation and physical filtration of solids and biological uptake from the grass. In steep terrain, a check dam is sometimes needed to slow the velocity of flow within a dry swale.

4.02 Dry Swale Applications

Dry turf grass and native grass swales can be ideal for linear highway, interchange, and facility applications and are best suited for small drainage areas. Water depth and velocity are important factors when implementing swales in larger drainage areas because as the flow deepens and the velocity increases, the swales effectiveness is thereby reduced. Erosion within the swale can also become an issue. However, grass swales can be integrated into treatment trains when needed.

4.03 Dry Swale Advantages and Limitations

The biggest advantage to choosing dry swales for water quality treatment is the relatively low cost. Right-of-way requirements are lower for swales compared to some other green infrastructure practices and construction costs are also typically less. Additionally, many INDOT roadways already have dry grass swales within the right-of-way.

A disadvantage is that before vegetation is established, significant erosion can occur, so a temporary erosion-resistant lining may be required during construction. It is extremely important that adequate vegetation is established in the swale otherwise TSS will not be removed. If the contributing drainage area has a high sediment loading, the extra sediment may have to be removed to maintain available flow area. Additionally, rills may form if the bottom width of the swale is greater than 10 feet.

4.04 Dry Swale Design

Flow rate is the critical hydraulic parameter for swale design. The swale should be designed to meet requirements in IDM Chapter 203 in addition to the requirements in this chapter. The CN_{wq} must be calculated using the percent impervious area going to the swale rather than the percent *added* impervious area going to the swale. After the Water Quality Treatment Rate (Q_{wq}) and other applicable flow rates are determined, water quality swale design is primarily composed of determining the swale geometry and swale length. Manning's Equation should be used to determine the velocity, and it is recommended to use a Manning's calculator or modeling program because this is often an iterative process.

4.04(01) Dry Swale Geometry

Side slopes must be 3:1 or flatter for maintenance purposes. The dry swale geometry should be determined using Manning's Equation and the Water Quality Treatment Rate (Q_{wq}) in addition to requirements in IDM Chapter 203 (that pertain to stormwater conveyance). When designing a dry turf grass or native grass swale to meet INDOT water quality requirements, the depth of flow must be at or below the height of the grass in the bottom of the swale during the Water Quality Event, and a Manning's n value of 0.15 is used. The maximum allowable depth of flow in the swale during the water quality event is based on the type of grass planted in the swale, as listed in **Figure 4C**. When higher flow rates are analyzed to meet requirements in IDM Chapter 203, Manning's n values listed in Chapter 203 shall be used.

The velocity in the swale during the Water Quality Event (v_{wq}) should not be greater than 4 feet per second (fps). If the water depth in the swale during the water quality event is higher than the values listed in **Figure 4C,** the swale geometry shall be adjusted. Although the depth of flow in the swale cannot be higher than the height of the grass during the Water Quality Event, it can be deeper during higher flows.

4.04(02) Dry Swale Length

Removal of sediment by settling is dependent on the hydraulic residence time in the swale. The hydraulic residence time (T_{ahr}) is determined by the following equation:

Hydraulic Residence Time

$$T_{ahr} = \frac{(L_{swale}/v_{wq})}{60} \qquad \text{[Equation 4.1]}$$

Where:

T_{ahr} = hydraulic residence time, minutes
L_{swale} = length of swale, feet
v_{wq} = peak flow velocity at water quality event, ft/s

The swale length should be sized so that the hydraulic residence time in the swale is greater than or equal to 9 minutes to achieve 80% sediment removal. See **Figure 4D** for TSS removal rates achieved at various hydraulic residence times. These calculations can be performed on an existing swale to determine if it can be used to meet the requirements in this chapter.

4.04(03) Dry Swale with Check Dams

In areas with steep terrain, permanent modified check dams may need to be constructed to reduce velocity and increase hydraulic residence time. A minimum longitudinal slope of 1 percent is required if check dams are to be installed. If the longitudinal slope is less than 1 percent, prior approval from INDOT Post-Construction Stormwater Team is required. The foreslope and backslope of the check dams will be 2:1 or flatter with a 1.5-foot minimum top width. Revetment riprap will be used, keyed in 1.5 feet below the flowline. The check dam will be completely made up of stone. **Figure 4E** depicts a dry swale with a check dam.

The maximum allowable check dam height is 2 feet. Taller check dams require prior approval from the INDOT Post-Construction Stormwater Team. During larger rainfall events, flow can overtop the check dam.

The check dam is required to detain the WQ_v for the area draining to the swale. The Hydraulic Residence Time calculation does not apply. If the WQ_v cannot be detained with one check dam, multiple check dams may be needed. The volume of storage available upstream of the check dam is determined by the following equation:

Volume of Storage Behind Check Dam

$$V_1 = \left[\frac{W_1 S_p {L_1}^2}{2} + \frac{{S_p}^2}{6S_{xf}} {L_1}^3 + \frac{{S_p}^2}{6S_{xb}} {L_1}^3\right] \quad \text{[Equation 4.2]}$$

Where:

- V_1 = storage volume above swale, cubic feet
- W_1 = swale bottom width, feet
- S_p = profile slope of swale, feet/feet
- L_1 = distance water can be stored from the toe of dam, feet
- S_{xf} = swale foreslope, feet/feet
- S_{xb} = swale backslope, feet/feet
- S_{cd} = check dam face slope, feet/feet
- d = height of dam, feet, where $S_p L_1 \leq d$
- a = horizontal distance of swale foreslope, feet
- b = horizontal distance of swale backslope, feet

See **Figure 4F** for check dam design parameters diagram. It should be noted that $V_t = V_1 + V_2$; however, V_2 is negligible. If desired, V_2 can be calculated similarly to V_1. When the profile slope of the swale and corresponding length are calculated, the height of the check dam should be accounted for; water can only be stored up to the elevation of the top of the check dam.

If check dams are installed for peak flow mitigation, the procedures outlined in IDM Chapter 203 shall be followed and the design should be coordinated with INDOT Hydraulic Engineering. Regardless of the purpose for check dam installation, roadway serviceability requirements shall be met.

4.04(04) Offsite Flow Entering Swale

In some cases, there will be off-site flow coming into the water quality swale. If the off-site flow cannot be diverted around the water quality swale, then the offsite flow must be accounted for to ensure the depth of water in the swale during the Water Quality Event is not above the height of the vegetation. To account for off-site flow into the swale, assume the following:

- T_c will be derived following typical TR-55 and IDM Chapter 202 procedures.
- CN will be derived using the same process as the CN_{wq}, using percent impervious area instead of percent new impervious area.
- Calculate flow using NRCS Type II rainfall distribution and a rainfall depth of 1.0 inches
- Two basins are then required, one for the onsite area and another for the offsite area.
- The two basins should be analyzed together with the same outlet (the dry swale) to determine the peak flow to the swale during the Water Quality Event.

4.04(05) Dry Swale Seeding

Dry swales with a longitudinal slope of less than 1% can be planted with seed. Dry swales with longitudinal slopes greater than 1% or less than 3% will be sod-lined or check dams may need to be installed. Dry swales with longitudinal slopes greater than 3% may require check dams due to the need for plant establishment.

Turf grass swales should be planted with Seed Mixture R in rural areas and Seed Mixture U in urban areas, following INDOT's Seed Mixtures and Seed Requirements Standard Specifications. Native grass swales can be planted with the Native Grass Mix provided in the Appendix. Alternatively, a site-specific Native Grass Mix can be proposed. For both types of swales, a plant growth layer, following INDOT Standard Specifications, should be included in the design.

5.0 VEGETATED FILTER STRIP

5.01 Vegetated Filter Strip Overview

A filter strip is a vegetated, uniformly graded area that receives sheet flow and is typically located between a pollutant source and either another practice or a waterbody. These strips generally have mild slopes and can be planted with turf grass or native grasses or can use existing vegetation including trees and shrubs. When possible, turf grass should be utilized instead of native grass when the filter strip is located within 30 feet of the edge of pavement; native grass should be utilized when the filter strip is located beyond that limit. Adjacent land use should be considered when choosing native grass. If there is a residential or commercial property adjacent to native grass planting, future mowing preferences should be considered. A vegetated filter strip is depicted in **Figure 5A**.

The effectiveness of a vegetated filter strip for TSS removal is controlled by the underlying soil, the type of vegetation, and the cross-sectional slope of the strip. Stormwater run-off sheet-flows through the vegetation which promotes sedimentation, filtration, adsorption, infiltration, biological uptake, and microbial activity.

5.02 Vegetated Filter Strip Applications

Vegetated filter strips are ideal for linear projects such as roadways without curb and gutter. There is often adequate space for a filter strip between the edge of the roadway pavement and the roadside ditch. If flow is concentrated, a filter strip alone is not appropriate. However, a level spreader can be installed to redistribute flow in some cases.

5.03 Vegetated Filter Strip Advantages and Limitations

Vegetated filter strips have a relatively low cost compared to other practices if adequate space is available. They also require relatively low maintenance once vegetation is established.

A vegetated filter strip is only effective if the run-off entering and flowing through the strip is sheet flow. Because the flow through the filter strip must be sheet flow, the area draining to the strip must be uniformly graded, or in the case of existing areas, the surface must have features that pond or disperse the run-off before it enters the strip. Additionally, larger drainage areas cannot be treated with a vegetated filter strip. It is also extremely important that vegetation be well established for a filter strip to remove TSS from run-off.

5.04 Vegetated Filter Strip Design

Flow must enter the vegetated filter strip as sheet flow and remain as sheet flow until it leaves the strip. The length of the filter strip is measured between the edge of the pavement, or area sheet flow is received, to the receiving stream, as shown in **Figure 5A**. The length of the drainage area contributing to sheet flow to the filter strip cannot be more than 100 feet for impervious surfaces and 150 feet for pervious surfaces. The longitudinal slope is calculated along the length of the filter strip. The Hydrologic Soil Group (HSG) of the underlying soil beneath the filter strip should be obtained using information available through Natural Resources Conservation Service (NRCS), soil testing, or another resource if available.

To determine the percent TSS removal for a vegetated filter strip, **Figures 5B** to **5E** will be used. The filter strip longitudinal percent slope is shown on the X axis of the graphs and the filter strip length, in feet, is shown on the Y axis of the graphs. The percent TSS removal for strips planted with turf grass, native grasses, and existing woods can then be determined based on the HSG of the existing underlying soil. Although existing trees can be used, the intent is not to plant trees on these filter strips due to proximity to the roadway.

5.05 Vegetated Filter Strip Seeding

Vegetated filter strips can be planted with Seed Mixture R in rural areas and Seed Mixture U in urban areas, following INDOT's Seed Mixtures and Seed Requirements Standard Specifications. If the vegetated filter strip is designed to include native grasses, the designer can use the Native Grass Seed Mix provided in the Appendix. Alternatively, a site-specific Native Grass Mix can be proposed. For both types of vegetation, a plant growth layer, following INDOT Standard Specifications, should be included in the design.

6.0 DRY DETENTION

6.01 Dry Detention Overview

A dry detention practice is a pond or swale that captures and temporarily detains stormwater run-off for a specific duration. Dry detention practices can serve as peak flow mitigation devices while also providing water quality benefits by promoting the settlement of suspended pollutants. Because traditional dry detention practices are not meant to have a permanent pool of water, the entire pond or swale must be designed to drain within 72 hours. A dry detention practice is depicted in **Figure 6A**. Additional information about dry detention practices is provided in IDM Chapter 203.

6.02 Dry Detention Applications

A dry detention practice may not be the ideal practice to choose to meet the requirements if there is not already a dry detention practice needed for peak flow mitigation. However, if an INDOT project requires peak flow mitigation based on design criteria in IDM Chapter 203, the dry detention practice should also be accounted for to help meet the requirements of this document.

6.03 Dry Detention Advantages and Limitations

Because stormwater is detained within a dry detention practice, erosive velocities downstream may be reduced, which also helps reduce TSS and other negative hydrologic impacts in the receiving waterbody. Dry detention practices can be implemented in series with other structural practices such as filter strips and swales.

In some cases, inline ditch detention is used, requiring less right-of-way. However, dry detention ponds often require a relatively large footprint to meet peak flow mitigation requirements. They also require more frequent inspections than some other structural practices because they require inspection after large rainfall events, primarily to ensure the outlet structures are not clogged with trash or debris.

6.04 Dry Detention Design

When using a dry detention practice for water quality treatment, the minimum flow length-to-width ratio is 3:1 to prevent short-circuiting and promote filtration and sedimentation. For dry detention ponds, if it is not possible to achieve a minimum length-to-width ratio of 3:1, baffles can be installed to lengthen the flow path through the pond, or a meandering pilot channel can be constructed. Detention ponds with a higher length-to-width rations will resemble a swale, and some designers may refer to these practices as ditch detention. A dry forebay is recommended but not required.

The dry detention practice should detain the Water Quality Volume and release it over a time of 24 hours or more to achieve 80% TSS removal. A multi-stage outlet structure may be needed. The smallest allowable outlet pipe diameter is 4 inches due to clogging concerns. If the outlet pipe has a diameter of less than 6 inches, a reducer is required. If the outlet pipe diameter is 6 inches or less, 50 feet of perforated pipe (one nominal size larger than the outlet pipe diameter) shall be installed in a stone trench and connected to the outlet structure. The stone trench width will include a minimum of one foot on each side of the perforated pipe and 1:1 side slopes. The depth should include a minimum of 6 inches (12 inches preferred) above the perforated pipe and 6 inches below it. Clean washed #2 stone will be used in the trench, with geotextiles lining the bottom and sides. Soil will not be placed on top of the stone trench. The stone trench and perforated pipe length minimum is 50 feet. An inspection cleanout port must be included at the upstream end of the perforated pipe. For some dry detention practices with larger contributing drainage areas, a longer stone trench and perforated pipe may be required.

If a stone trench and perforated pipe system is required, a perforated riser structure surrounded in clean washed #2 stone is also needed. The perforated riser structure should be located just upstream of the F7 inlet. The perforated riser structure diameter should be 6 inches lower than the casting elevation of the F7, but no taller than 3 feet. Therefore, the difference in elevation between the perforated riser structure and the casting elevation can be larger than 6 inches, if needed. The cap on the perforated riser structure should be grated. The gravel should be placed with 2:1 side slopes.

The detention practice will be modeled with the small outlet pipe used to detain the water quality volume, another opening for the design storm (if applicable), and the 100-year opening. The perforated pipe underdrain system does not need to be modeled. A software program that allows for multiple pond outlets will be required. **Figure 6B** shows a dry detention pond outlet structure with a perforated pipe underdrain.

Alternatively, the dry detention practice could be analyzed as a swale using the Water Quality Treatment Rate. If this approach is chosen, a meandering pilot channel may be required, and the depth of flow during the Water Quality Event must be at or below the height of the vegetation in the pilot channel. This approach is preferred when possible. **See Section 4.04**.

6.05 Dry Detention Seeding

When possible, turf grass should be utilized instead of native grass when the detention pond is located within 30 feet of the edge of pavement; native grass should be utilized when the detention pond is located beyond that limit. The Native Grass Mix provided in the Appendix can be used or a site-specific Native Grass Mix can be proposed.

Dry detention practices will be planted with Seed Mixture R in rural areas and Seed Mixture U in urban areas, following INDOT's Seed Mixtures and Seed Requirements Standard Specifications. A plant growth layer, following INDOT Standard Specifications, should be included in the design.

7.0 WET SWALE

7.01 Wet Swale Overview

Like a dry swale, a wet swale used for water quality treatment can be natural or engineered and is designed to convey and treat run-off from the roadway. The objective of a wet swale is to detain the Water Quality Volume to allow sediment particles to settle out of the stormwater run-off. A check dam without an outlet structure is typically required. Larger flows can overtop the check dam and convey to an offsite outlet. **Figure 7A** depicts a wet swale.

Swales typically have either a trapezoidal or V-shaped cross section. There should be no underdrain. A wet swale needs to have a high water-table or poorly drained soils to properly retain water.

7.02 Wet Swale Applications

Wet swales can be used to treat stormwater run-off when the water table is high or when there are poorly drained existing underlying soils. It might be desirable to choose a wet swale over a dry swale if only a relatively short swale length is available or if it is not possible for the swale to fully drain between rainfall events.

7.03 Wet Swale Advantages and Limitations

One advantage of wet swales is they can provide aquatic wildlife habitat. Additionally, wet swales are known to treat other pollutants that can come from offsite such as nutrients, metals, and pathogens through biological removal.

Unfortunately, there are several common problems associated with wet swale application. Vegetation establishment can be difficult due to the need for emergent plant life, and emergent plant life requires proper pH levels in the swale to thrive. The wet swale water can become stagnated, causing unpleasant odors. Wet swales also tend to attract nuisance insects, resulting in mosquitoes breeding and ant mounds. For this reason, it is often not desirable to construct a wet swale in a residential or commercial area unless the swale will be properly maintained.

7.04 Wet Swale Design

Wet swale design must meet hydraulic capacity and serviceability requirements in IDM Chapter 203 in addition to the requirements in this document. Side slopes must be 3:1 or flatter unless an existing wet swale is being used. The wet swale must detain the Water Quality Volume and the permanent pool volume should be larger than the WQ_v. In some cases, such as if the wet swale practice drains to another waterbody and will remain wet due to the high-water table, a check dam may not be required.

If a check dam is required, typically it should not have an outlet pipe. In some cases, such as when the wet swale receives larger offsite flows, the integrity of the check dam could be compromised. If larger flows are entering the wet swale, the check dam should include a riser pipe connected to an outlet pipe, with the riser pipe set at the 100-year water surface elevation (or lower), and the top of the berm 1 foot above that (like a wet retention pond berm). Alternatively, the check dam can include an overflow weir with capacity for the 100-year event. In either situation, the structural integrity of the berm must be considered by the designer.

7.05 Wet Swale Seeding

In areas above the permanent pool elevation, wet swales should be planted with Seed Mixture R in rural areas and Seed Mixture U in urban areas, following INDOT's Seed Mixtures and Seed Requirements Standard Specification (if turf grass is desired). Alternatively, native grass can be planted with the Native Grass Seed Mix provided in the Appendix. Alternatively, a site-specific Native Grass Mix can be proposed. When possible, turf grass should be utilized instead of native grass when the wet swale is located within 30 feet of the edge of pavement; native grass should be utilized when the wet swale is located beyond that limit. If a Native Grass Mix is used within 30 feet of the edge of pavement, signs are required for maintenance purposes. Below the permanent pool elevation, the Emergent Plant Seed Mixture provided in the Appendix should be used. A plant growth layer, following INDOT Standard Specifications, should be included in the design.

8.0 WET RETENTION POND

8.01 Wet Retention Pond Overview

A wet retention pond is a detention basin that maintains a permanent pool of water. Wet retention ponds can serve as peak flow mitigation devices while also providing water quality benefits by promoting the settlement of TSS and biological uptake of suspended pollutants. Additional storage is provided in the pond above the permanent pool of water. **Figure 8A** depicts a wet retention pond.

8.02 Wet Retention Pond Applications

Although wet retention ponds can be used for linear highway projects, they are more typically seen in residential and commercial areas where they can add to property value and provide recreational activities. A wet retention pond may be best suited to sites where there is adequate space in a low-lying area with a high water-table. Wet retention ponds will rarely be used for INDOT projects.

8.03 Wet Retention Pond Advantages and Limitations

In addition to removing TSS from stormwater run-off by allowing particles to settle out, wet retention ponds reduce velocities in the downstream receiving water body, which helps prevent erosion and other negative hydrologic impacts. The plants, algae, and bacteria in wet retention ponds help remove other pollutants that can come from offsite such as nutrients, metals, and pathogens. Wet retention ponds also provide aquatic wildlife habitat.

Wet retention ponds are not recommended for linear roadway projects due to the limited available space and maintenance requirements. Excess nutrients can result in eutrophication, so regular chemical treatment or aeration is required.

8.04 Wet Retention Pond Design

For 80% TSS removal, the permanent pool volume within the wet pond must be larger than the WQ_v. The pond can be designed to permanently detain a larger volume or temporarily store a larger volume for peak flow mitigation. Extended detention can be provided by slowly releasing the volume of water above the permanent pool elevation. An outlet structure and emergency overflow structure are required as described in IDM Chapter 203. Erosion protection must be installed downstream of the outlet structure.

8.05 Wet Retention Pond Seeding

Wet Retention Ponds will be planted with Seed Mixture R in rural areas and Seed Mixture U in urban areas above the permanent pool elevation, following INDOT's Seed Mixtures and Seed Requirements Standard Specifications. Alternatively, native grass can be planted above the permanent pool elevation with the Native Grass Seed Mix provided in the Appendix. However, a site-specific Native Grass Mix can be proposed. When possible, turf grass should be utilized instead of native grass when the retention pond is located within 30 feet of the edge of pavement; native grass should be utilized when the retention pond is located beyond that limit. If a Native Grass Mix is used within 30 feet of the edge of pavement, signs are required for maintenance purposes. A plant growth layer, following INDOT Standard Specifications, should be included in the design in planted areas. Plantings are not required below the permanent pool elevation.

9.0 INFILTRATION

9.01 Infiltration Overview

An infiltration feature is a structural practice that collects run-off and allows it to drain through the underlying soil. Infiltration practices can be used to meet both water quantity and water quality goals when proper site selection, design, construction, and maintenance processes are followed. When designing infiltration facilities, design criteria in IDM Chapter 203 shall also be adhered to.

Infiltration practices are used in various post-construction stormwater practices, including bioretention basins, infiltration trenches, sand filters, infiltration swales, and infiltration basins. For INDOT projects, the only acceptable infiltration features are infiltration basins or infiltration swales. In some cases, infiltration features will also be used to meet peak flow mitigation goals, or when a suitable site outlet does not exist. An infiltration basin is depicted in **Figure 9A** and an infiltration swale is depicted in **Figure 9B**.

9.02 Infiltration Applications

Infiltration practices may only be used when the existing underlying soils are composed of loam, sandy loam, loamy sand, and sand. Engineered soil media will not typically be used in infiltration basins and swales for INDOT projects. Instead, the existing underlying soil should be capable of achieving proper infiltration. Infiltration features cannot be installed in areas with a high water-table. It is preferred to have a 4-foot separation between the infiltration feature bottom and the seasonal high water-table; however, a 2-foot separation will be allowed.

9.03 Infiltration Advantages and Limitations

Because all the water quality volume is infiltrated into the soil, infiltration basins promote groundwater recharge and are considered to have a high pollutant removal capacity. Not only do infiltration features remove TSS, they also prevent dissolved pollutants from directly entering the receiving stream. As the stormwater percolates through the underlying soil, physical, chemical, and biological processes remove a majority of contaminants.

In Indiana, most areas do not have the proper underlying soil types to use infiltration. Infiltration practices have been historically known for high rates of failure due to clogging caused by high sediment loading, poor design, improper construction, and neglected maintenance. Infiltration basins and swales should not be used in areas of karst topography or well-head protection areas.

9.04 Infiltration Design

If the infiltration feature is also being used as a peak flow mitigation facility, all requirements in Chapter 203 must be adhered to. Although not required, pretreatment by means of a vegetated filter strip or dry sediment forebay is recommended. Otherwise, the infiltration feature will likely require more maintenance to address clogging.

Soil testing is required per the guidelines provided in IDM Chapter 203 for infiltration basins and swales. To demonstrate an infiltration basin or swale will reduce the TSS in run-off by 80%, all the Water Quality Volume must be infiltrated. The basin or swale must also provide enough above ground storage to allow water to pond while it is being infiltrated.

If the infiltration feature is also being used for peak flow mitigation or due to a lack of a suitable site outlet, it is likely a computer model will be used. If the infiltration basin was modeled using a computer model, the volume infiltrated can be obtained from the model.

If the infiltration feature is being solely used to treat the Water Quality Volume, the following procedure can be followed once the Water Quality Volume is calculated (assuming a computer model was not used). If there is offsite flow going into the infiltration feature, it must also be considered.

$$V_i = A_b * k * T_c \qquad \text{[Equation 9.1]}$$

Where:

V_i = volume of water infiltrated, ft^3

A_b = basin or swale bottom surface area, ft^2

k = infiltration rate of existing underlying soil, ft/hr

T_c = time of concentration to feature, hr

If the volume of water infiltrated is greater than or equal to the WQ_v, no further calculations for water quality are required. If the volume of water infiltrated is less than the WQ_v, additional calculations are required to determine how much above ground storage volume is required in the feature and if the feature will fully drain within 72 hours. If the infiltration feature is a swale requiring above ground storage, the swale will be modeled as a basin.

Based on NRCS hydrograph analyses performed by others, the effective filling time for most infiltration basins will generally be less than two hours. Using a max filling time of two hours results in the equation below:

$$V_b = WQ_v - (T_f * k * A_b) \quad \text{[Equation 9.2]}$$

Where:

V_b = basin volume, ft^3
T_f = 2 hr
k = infiltration rate of existing underlying soil, ft/hr
A_b = basin or swale bottom surface area, ft^2

Check to ensure the basin will fully drain within 72 hours:

$$T_d = \frac{WQ_v}{A_b} * k \quad \text{[Equation 9.3]}$$

Where:

T_d = time to drain, hr

9.05 Infiltration Seeding

Infiltration basins and swales will be planted with the Native Grass Seed Mix found in the Appendix. Alternatively, a site-specific Native Grass Mix can be proposed. If a Native Grass Mix is used within 30 feet of the edge of pavement, signs are required for maintenance purposes. A plant growth layer should not be included because the infiltration rate of the soil will be affected. The Native Grass Seed Mix was designed to include seeds that require less organic material.

10.0 HYDRODYNAMIC SEPARATORS

10.01 Hydrodynamic Separators Overview

There are many different types of proprietary post-construction structural stormwater practices in use, such as hydrodynamic separators, gravity oil-grit separators, and catch basin inserts. For INDOT projects, typically only hydrodynamic separators should be proposed.

Hydrodynamic separators, also referred to as swirl concentrators and other proprietary names, are modifications of traditional oil-grit separators and are a type of flow-through device. These devices use a swirl or vortex to remove solids and trash via gravity from stormwater run-off. Although swirl concentration is most common, some devices use circular screening or cylindrical sedimentation.

10.02 Hydrodynamic Separators Applications

The small size of hydrodynamic separators makes them ideal when right-of-way is very limited and are often used in urban areas. However, they generally are part of a storm sewer system, with inflow entering the unit through one pipe and exiting out of another pipe. If a hydrodynamic separator is used in combination with another structural practice, it is ideal to install it upstream rather than downstream.

10.03 Hydrodynamic Separators Advantages and Limitations

The biggest advantage of a hydrodynamic separator is the small footprint. They are often the only feasible solution for removing TSS from run-off for projects in urban settings with storm sewer systems and limited right-of-way. Hydrodynamic separators can also be retrofitted into existing drainage systems.

Although very effective at removing TSS from run-off, hydrodynamic separators will only function if properly maintained. Frequent inspection and cleanout are required. The initial cost of hydrodynamic separators can be relatively high.

10.04 Hydrodynamic Separators Design

The Water Quality Treatment Rate is required for hydrodynamic separator design. Flows in excess of the Water Quality Treatment Rate or Volume should be diverted around the separator using diversion structures. Offline units should be used unless prior approval from the INDOT Post-Construction Stormwater Team is obtained. Contact the INDOT Post-Construction Stormwater Team for unit selection guidance. Adequate space for safe inspections and maintenance should be provided in the design. A permanent access road or bump out along the highway may be required for hydro excavation truck access. The plans will list the Water Quality Treatment Rate with the Hydrodynamic Separator and the contractor will choose a unit from the INDOT Qualified Products List. The unit make and model should not be listed in the plans.

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APPENDIX – SEED MIXES

NATIVE GRASS SEED MIX

Common Name	Botanical Name	Pure Live Seeds Oz/Acre
Common Milkweed	*Asclepias syriaca*	2
Frank's Sedge	*Carex frankii*	6
Spreading Oval Sedge	*Carex normalis*	6
Bottlebrush Sedge	*Carex lurida*	6
Awl-fruited Sedge	*Carex stipata*	6
Fox Sedge	*Carex vulpinoidea*	8
Common Rush	*Juncus effusus*	2
Canada Wild Rye	*Elymus canadensis*	36
Virginia Wild Rye	*Elymus virginicus*	36
Stiff Goldenrod	*Oligoneuron rigidum*	1
Switch Grass	*Panicunm virgatum*	4
Little Bluestem	*Schizachyrium scoparium*	96
Woolgrass	*Scirpus cyperinus*	2
Reddish Bulrush	*Scirpus pendulus*	4
Prairie Cord Grass	*Spartina pectinata*	6
Common Spiderwort	*Tradescantia ohiensis*	2
	Total	**223**

Cover Crop		Pure Live Seeds Oz/Acre
Common Oats	*Avena Sativa*	560

EMERGENT PLANT SEED MIX

Common Name	Botanical Name	Pure Live Seeds Oz/Acre
Common Water Plantain	*Alisma subcordatum*	1
Swamp Milkweed	*Asclepias incarnata*	2
River Bulrush	*Bolboschoenus fluviatilis*	2
Bluejoint Grass	*Calamagrostis canadensis*	3
Common Fox Sedge	*Carex stipata*	3
Fox sedge	*Carex vulpinoidea*	6
Blunt Spike Rush	*Eleocharis obtusa*	1
Great Spike Rush	*Eleocharis palustris*	1
Virginia Wild Rye	*Elymus virginicus*	16
Spotted Joe Pye Weed	*Eutrochium maculatum*	1
Fowl Manna Grass	*Glyceria striata*	3
Canadian Rush	*Juncus canadensis*	1
Common Rush	*Juncus effusus*	2
Rice Cut Grass	*Leersia oryzoides*	2
Chairmakers Rush	*Schoenoplectus pungens*	1
Softstem Bulrush	*Schoenoplectus tabernaemontani*	2
Dark Green Rush	*Scirpus atrovirens*	1
Wool Grass	*Scirpus cyperinus*	1
Red Bulrush	*Scirpus pendulus*	1
Wild senna	*Senna hebecarpa*	2
Common Bur Reed	*Sparganium eurycarpum*	4
Prairie Cord Grass	*Spartina pectinata*	3
New England Aster	*Symphyotrichum novae-angliae*	0.5
Blue vervain	*Verbena hastata*	1
Total		60.5

Cover Crop		**Pure Live Seeds Oz/Acre**
Common Oats	*Avena Sativa*	540

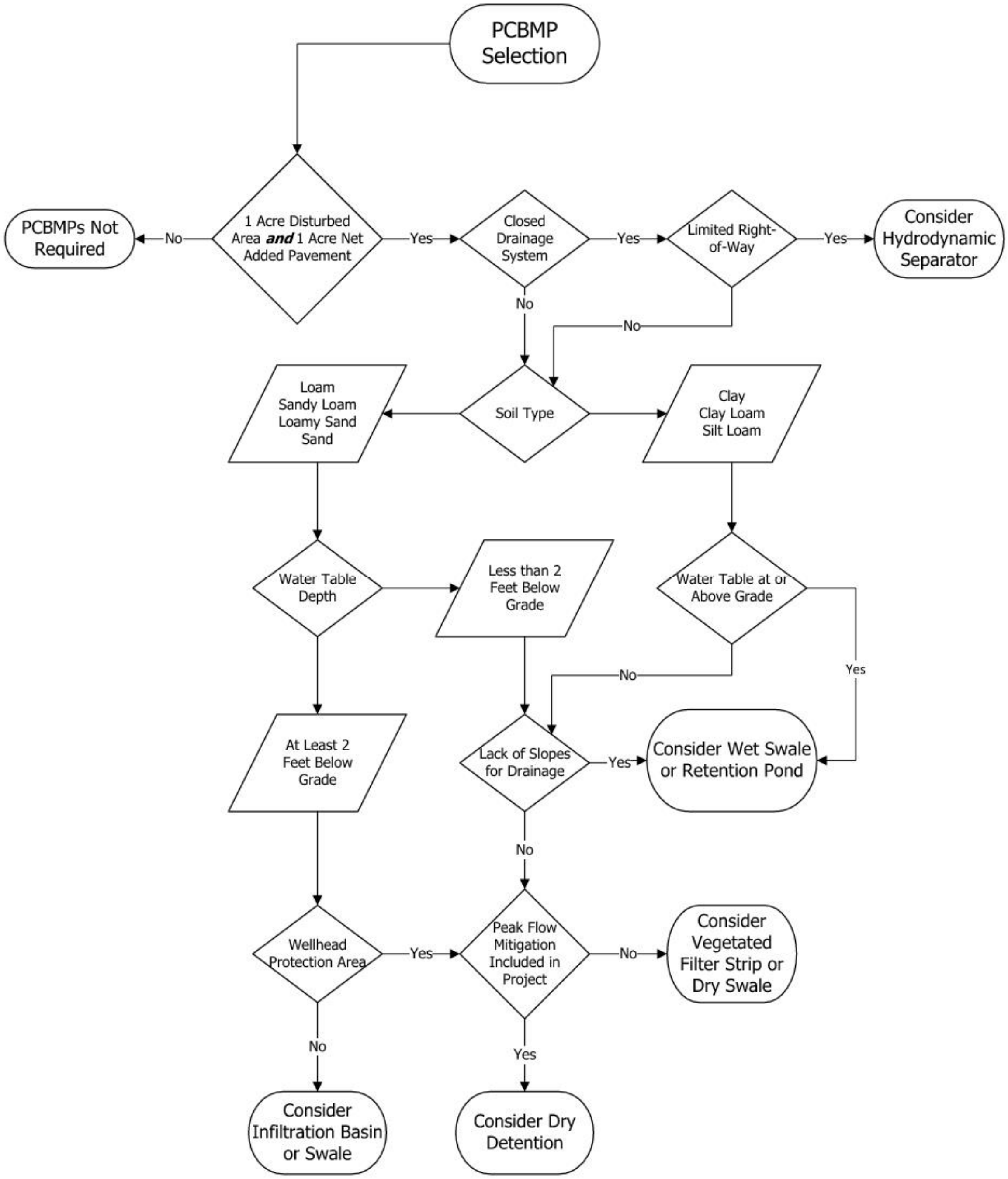
FIGURES

Structural BMPs	Description	Pollutant Removal Mechanism	Priority
Dry Turf Grass Swale	A broad and shallow channel planted with grass. Fully drains between rainfall events.	Sedimentation, physical filtration, and biofiltration	1
Dry Native Grass Swale	A broad and shallow channel planted with dense specialized plants. Fully drains between rainfall events.	Sedimentation, physical filtration, and biofiltration	1
Filter Strip	A vegetated linear section of land. Also often referred to as a buffer strip.	Physical filtration, sorption, biofiltration	1
Dry Detention	An engineered pond or swale planted with grass. Fully drains between rainfall events. Includes an outlet structure to control flow.	Sedimentation, physical filtration, and biofiltration	1
Wet Swale	A broad and shallow channel planted with grass. Designed with a permanent pool and an elevated outlet structure.	Sedimentation, physical filtration, and biofiltration	2
Wet Retention Pond	Engineered basin designed to permanently store run-off. Designed with a permanent pool and an elevated outlet structure.	Sedimentation, physical filtration, and biofiltration	2
Infiltration Swale	A broad and shallow channel with permeable soil planted with grass. Designed to infiltrate run-off into the underlying soil.	Sedimentation, physical filtration, infiltration, sorption, and biofiltration	3
Infiltration Basin	An engineered basin with permeable soil planted with grass. Designed to infiltrate run-off into the underlying soil.	Sedimentation, physical filtration, infiltration, sorption, and biofiltration	3
Proprietary Device	Hydrodynamic separators.	Sedimentation and physical filtration	4*

*In urban areas where right-of-way is limited, hydrodynamic separators may be preferred.

INDOT PREFERRED POST-CONSTRUCTION STORMWATER BEST MANAGEMENT PRACTICES

FIGURE 3A



BEST MANAGEMENT PRACTICE SELECTION FLOWCHART

FIGURE 3B

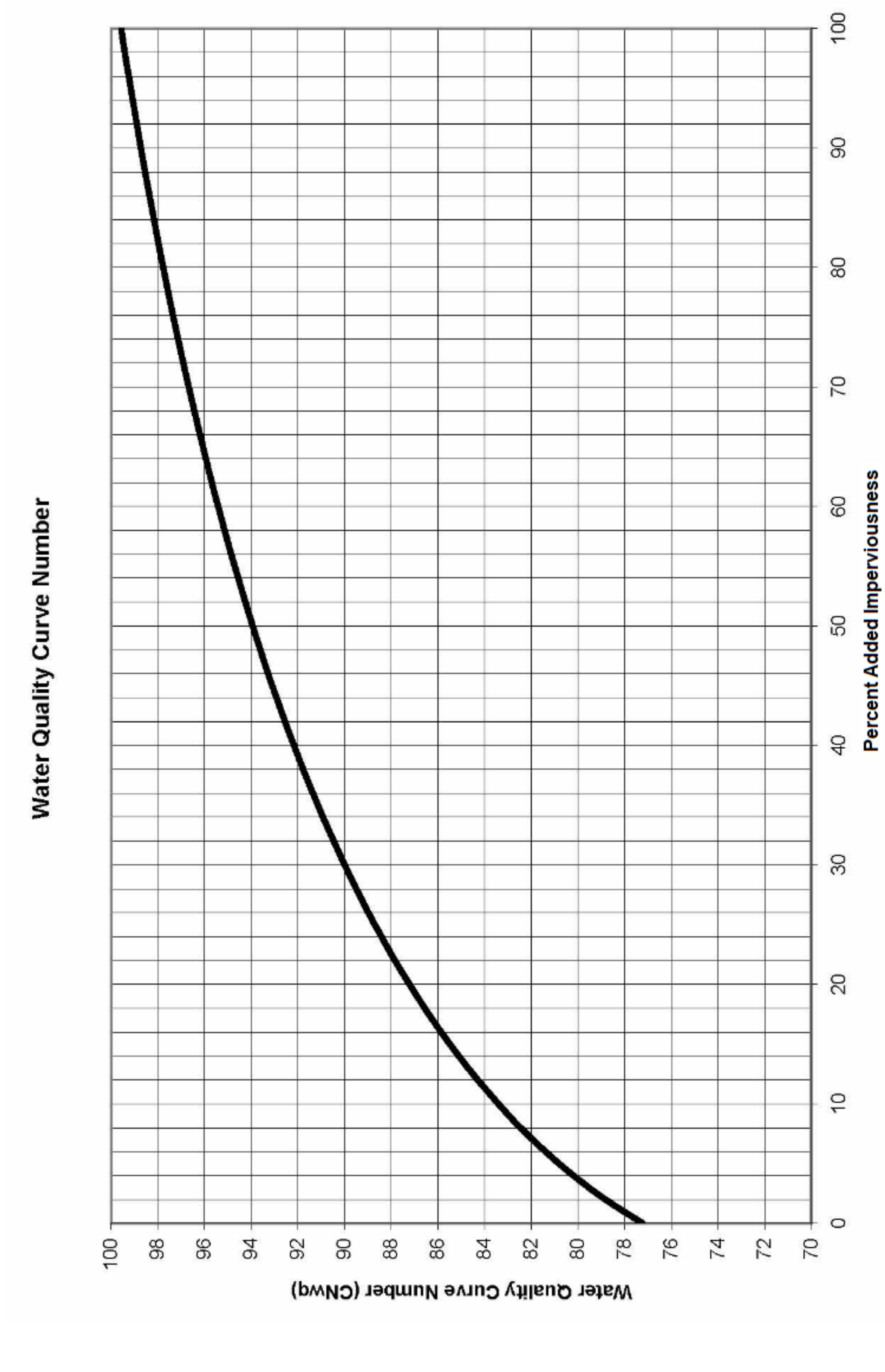
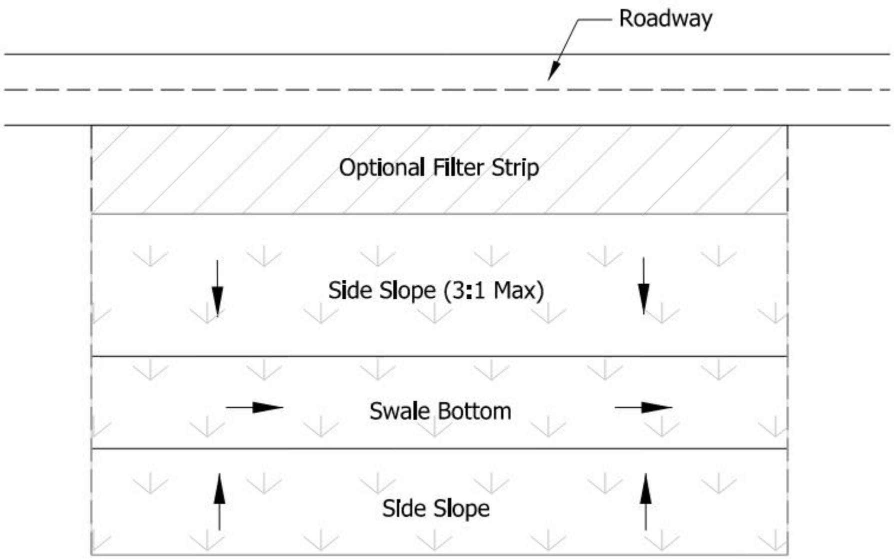
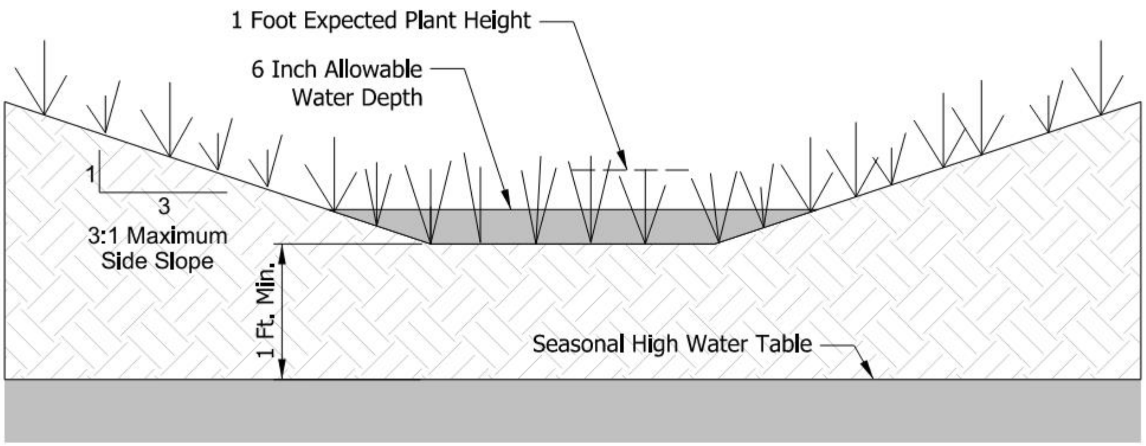

Water Quality Curve Number
Water Quality Curve Number (CNwq)
Percent Added Imperviousness
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
0
10
20
30
40
50
60
70
80
90
100

FIGURE 3C



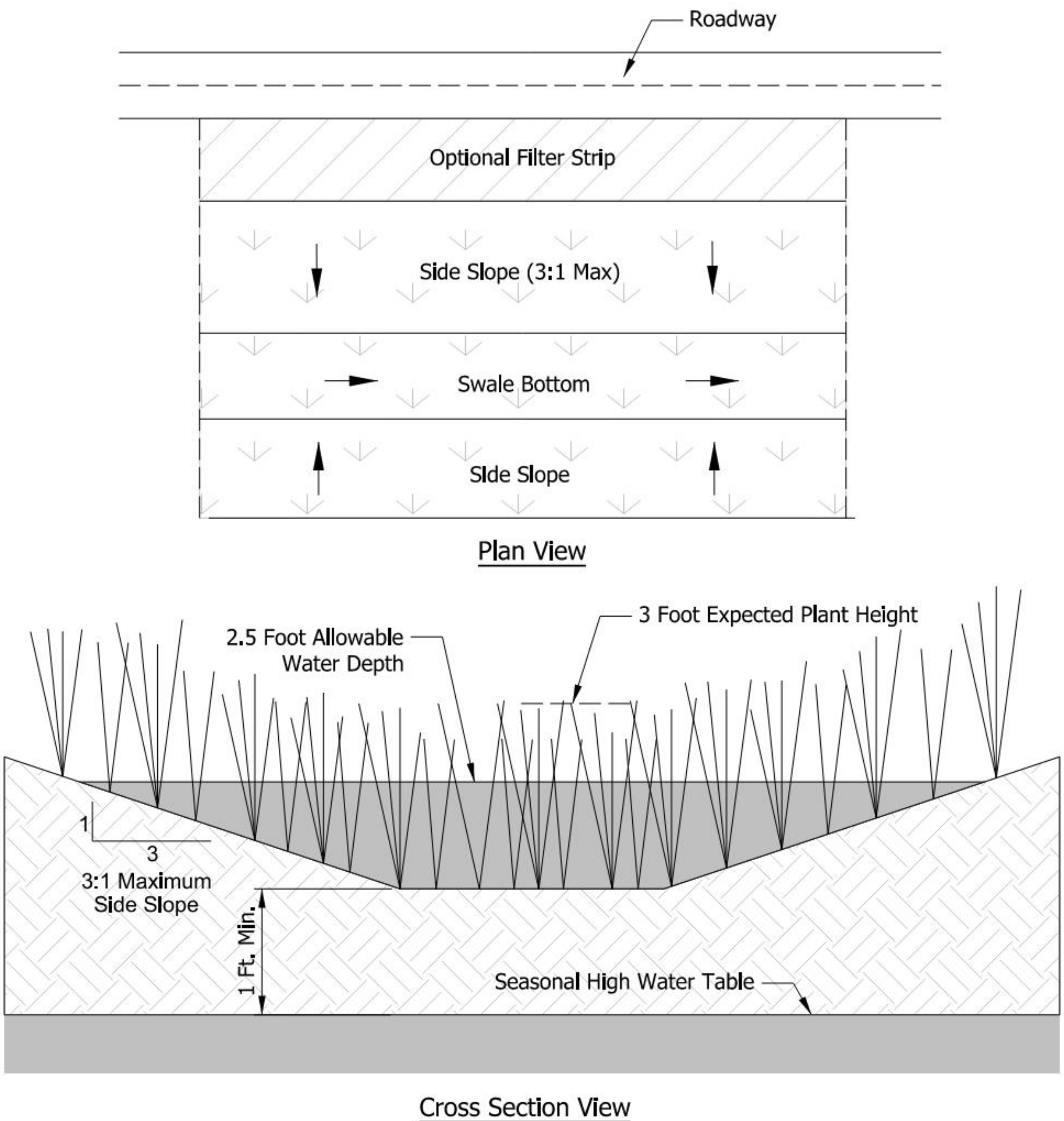
Plan View



Cross Section View

DRY TURF GRASS SWALE DETAILS

FIGURE 4A



DRY NATIVE GRASS SWALE DETAILS

FIGURE 4B

Swale Type	Planting	Expected Plant Height	Maximum Allowable Water Depth at Water Quality Treatment Rate
Dry Turf Grass Swale	Turf Grass	1 foot	6 inches
Dry Native Grass Swale	Native Grass	3 feet	2.5 feet

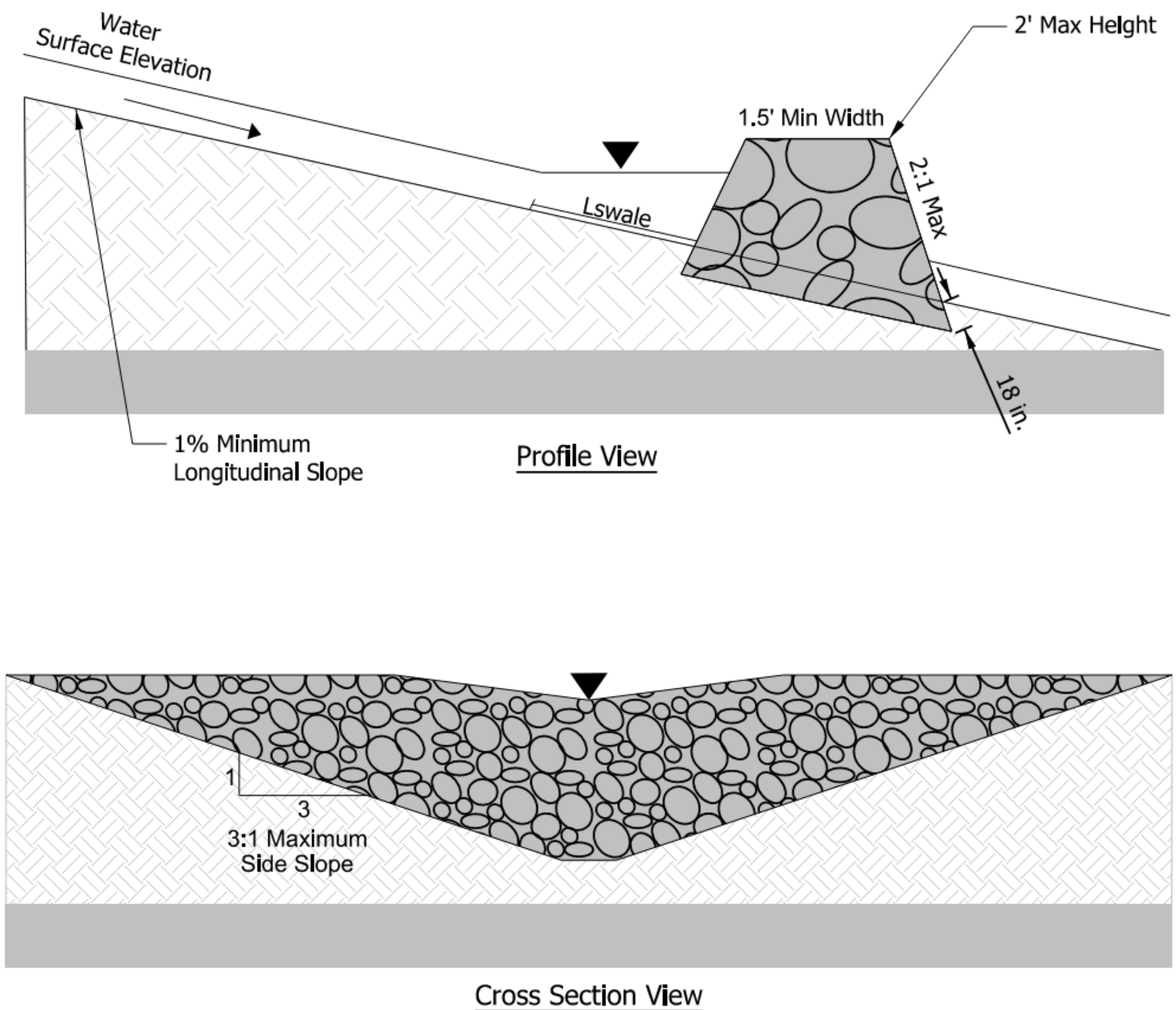
DRY SWALE ALLOWABLE WATER DEPTH

FIGURE 4C

Hydraulic Residence Time (minutes)	% Sediment Removal Achieved
9	80
8	75
7	70
6	65
5	60

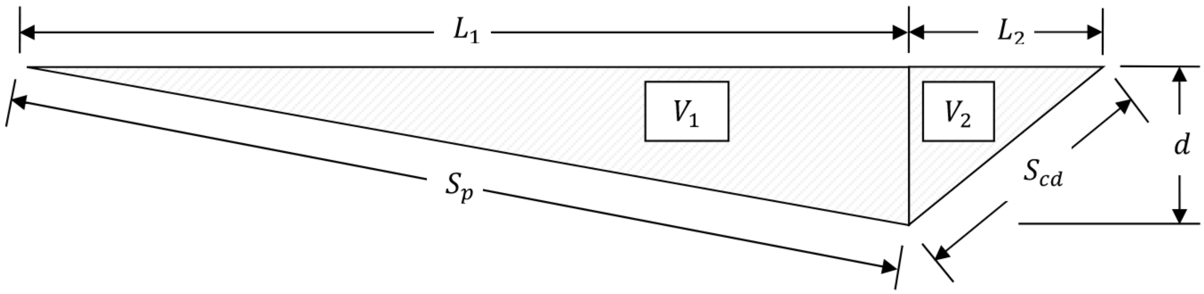
PERCENT SEDIMENT REMOVAL FOR DRY SWALES

FIGURE 4D

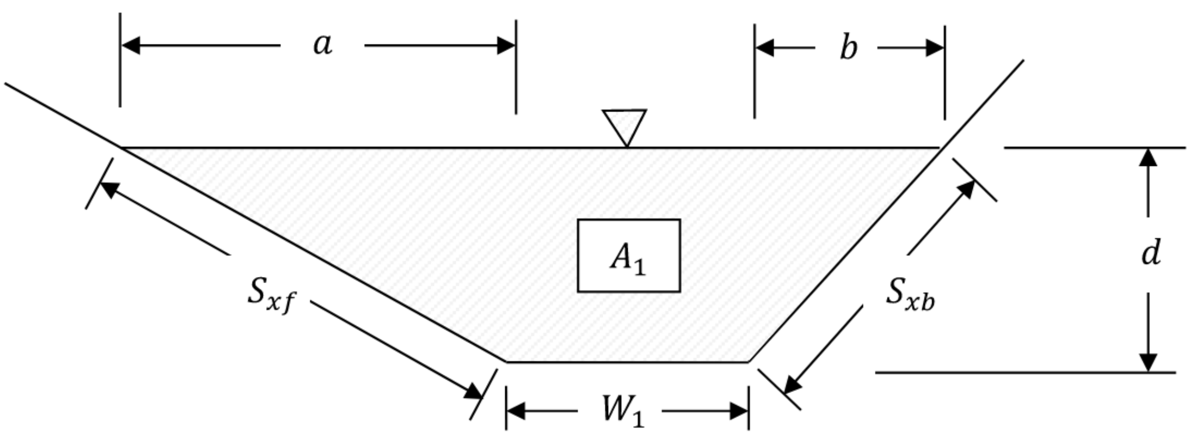


DRY SWALE CHECK DAM

FIGURE 4E



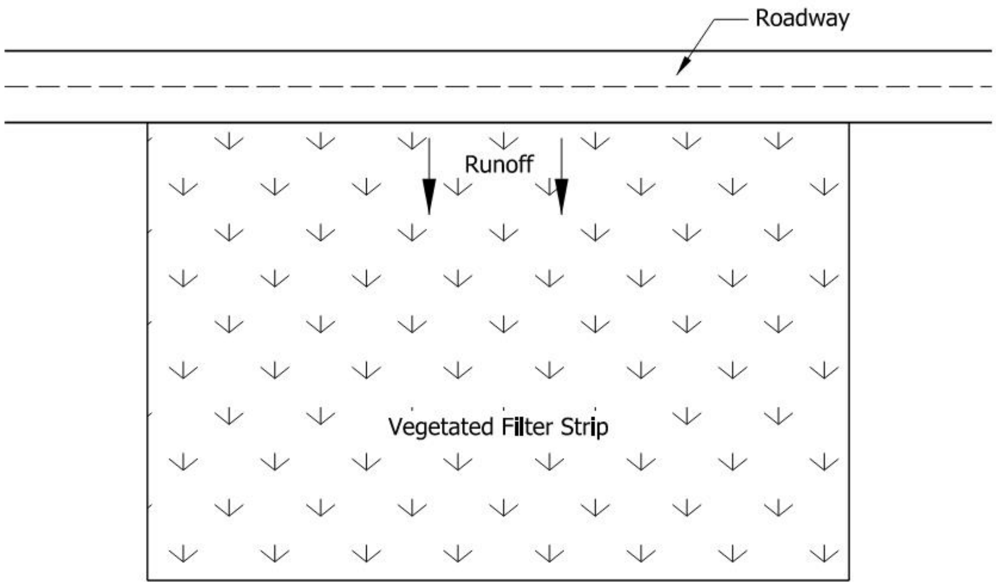
Profile View of Swale and Check Dam



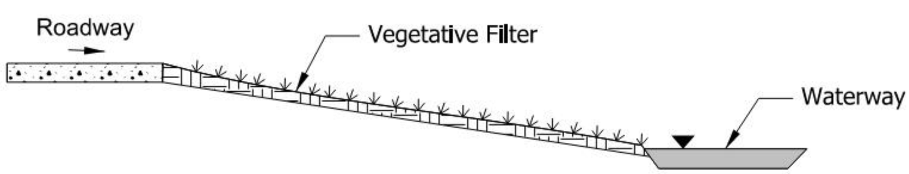
Cross Section View of Swale and Check Dam

CHECK DAM DESIGN PARAMETERS

FIGURE 4F



Plan View



Profile View

VEGETATED FILTER STRIP DETAILS

FIGURE 5A

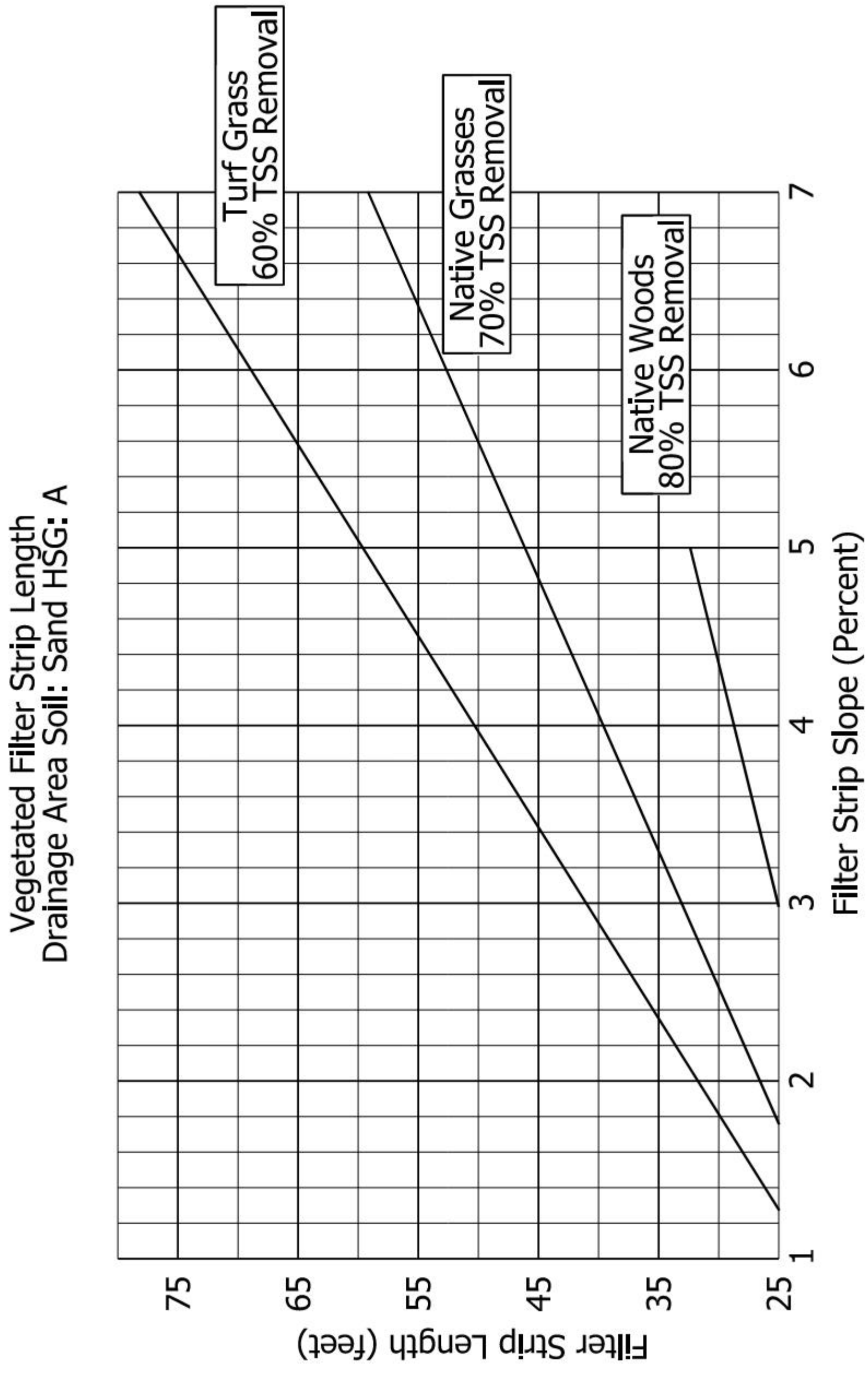
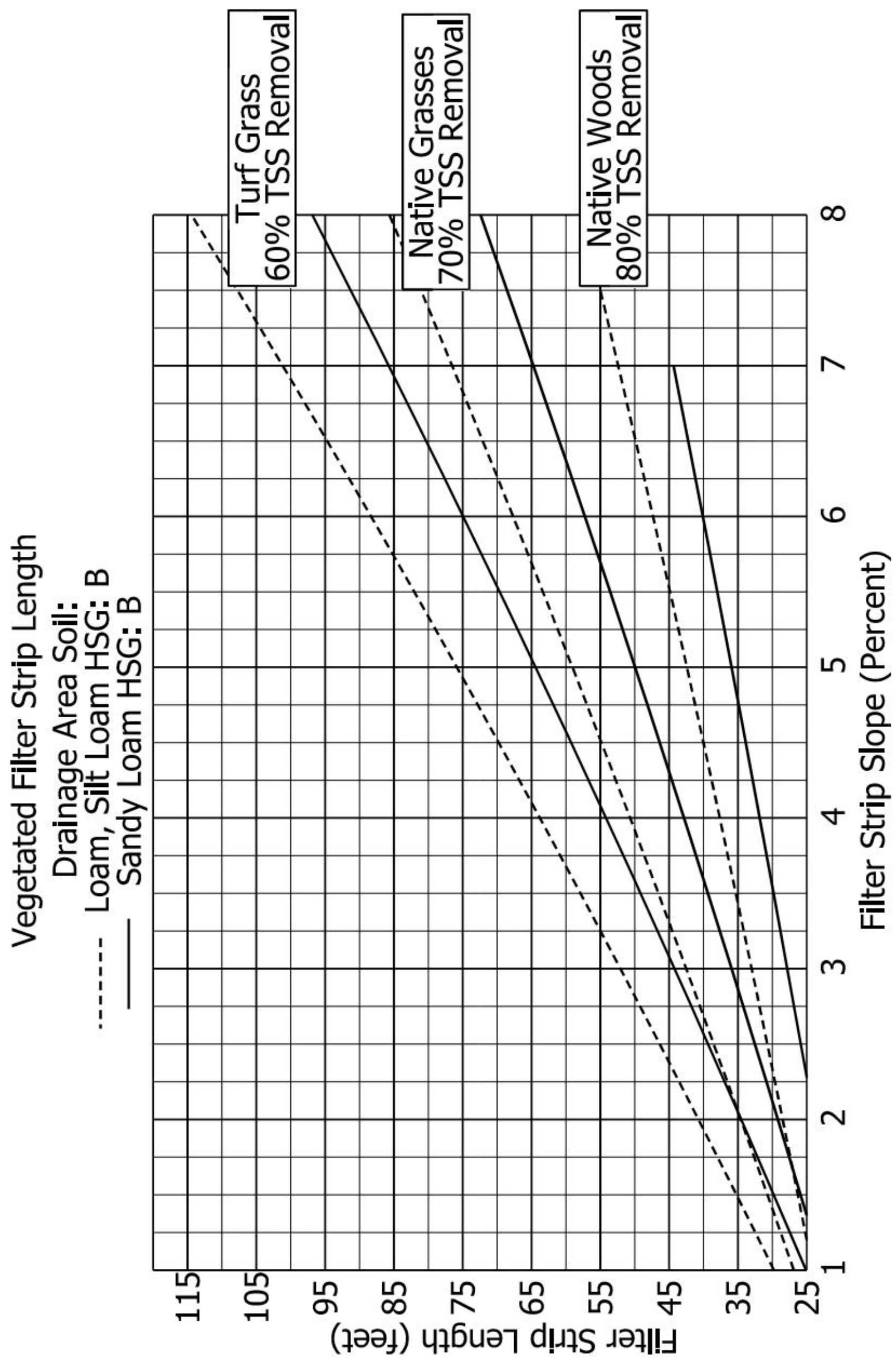

Vegetated Filter Strip Length
Drainage Area Soil: Sand HSG: A
Turf Grass
60% TSS Removal
Native Grasses
70% TSS Removal
Native Woods
80% TSS Removal
Filter Strip Length (feet)
25
35
45
55
65
75
1
2
3
4
5
6
7
Filter Strip Slope (Percent)

FIGURE 5B



Vegetated Filter Strip Length
Drainage Area Soil:
Loam, Silt Loam HSG: B
Sandy Loam HSG: B
Turf Grass
60% TSS Removal
Native Grasses
70% TSS Removal
Native Woods
80% TSS Removal
Filter Strip Length (feet)
115
105
95
85
75
65
55
45
35
25
Filter Strip Slope (Percent)
1
2
3
4
5
6
7
8

FIGURE 5C

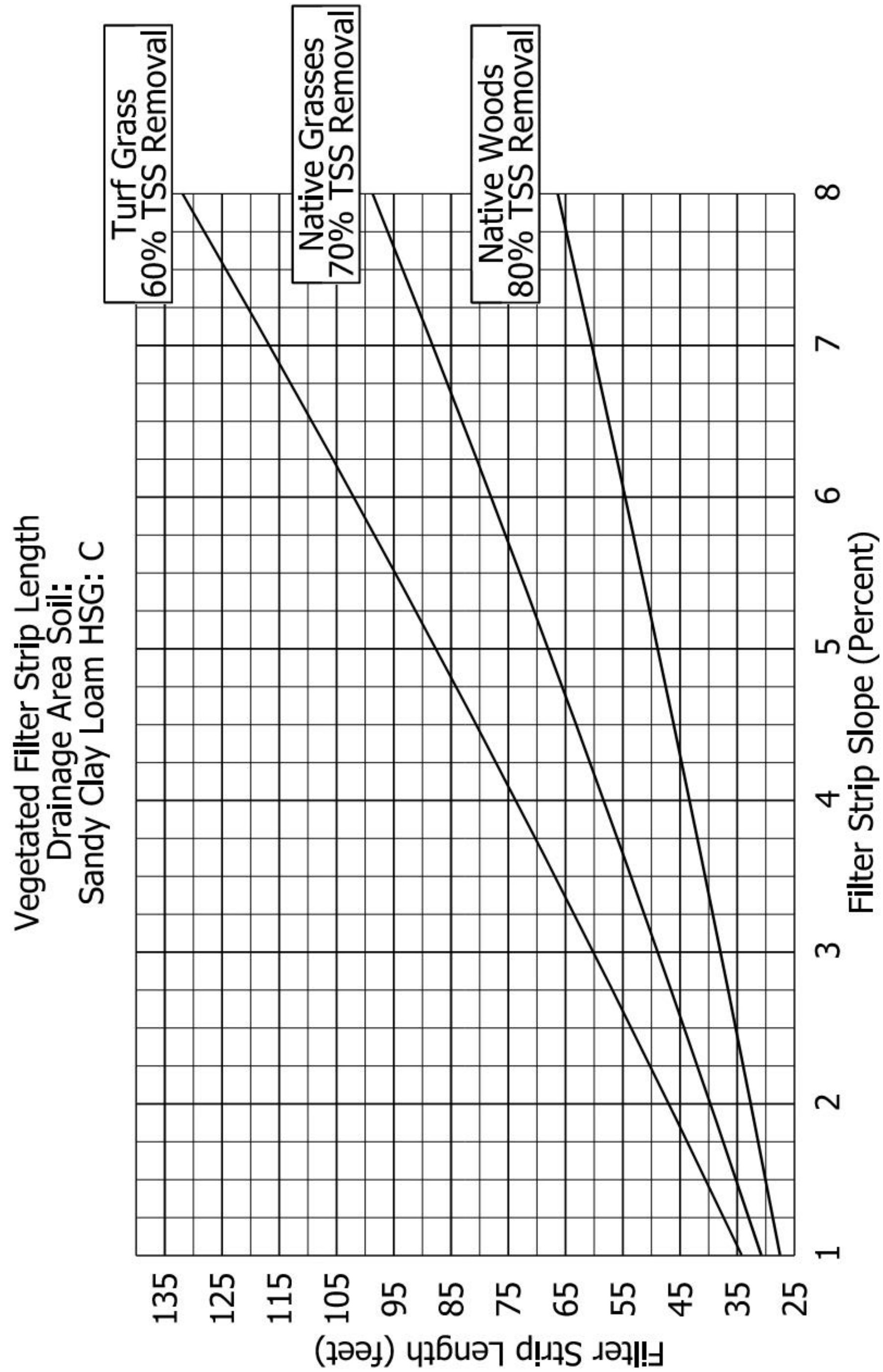
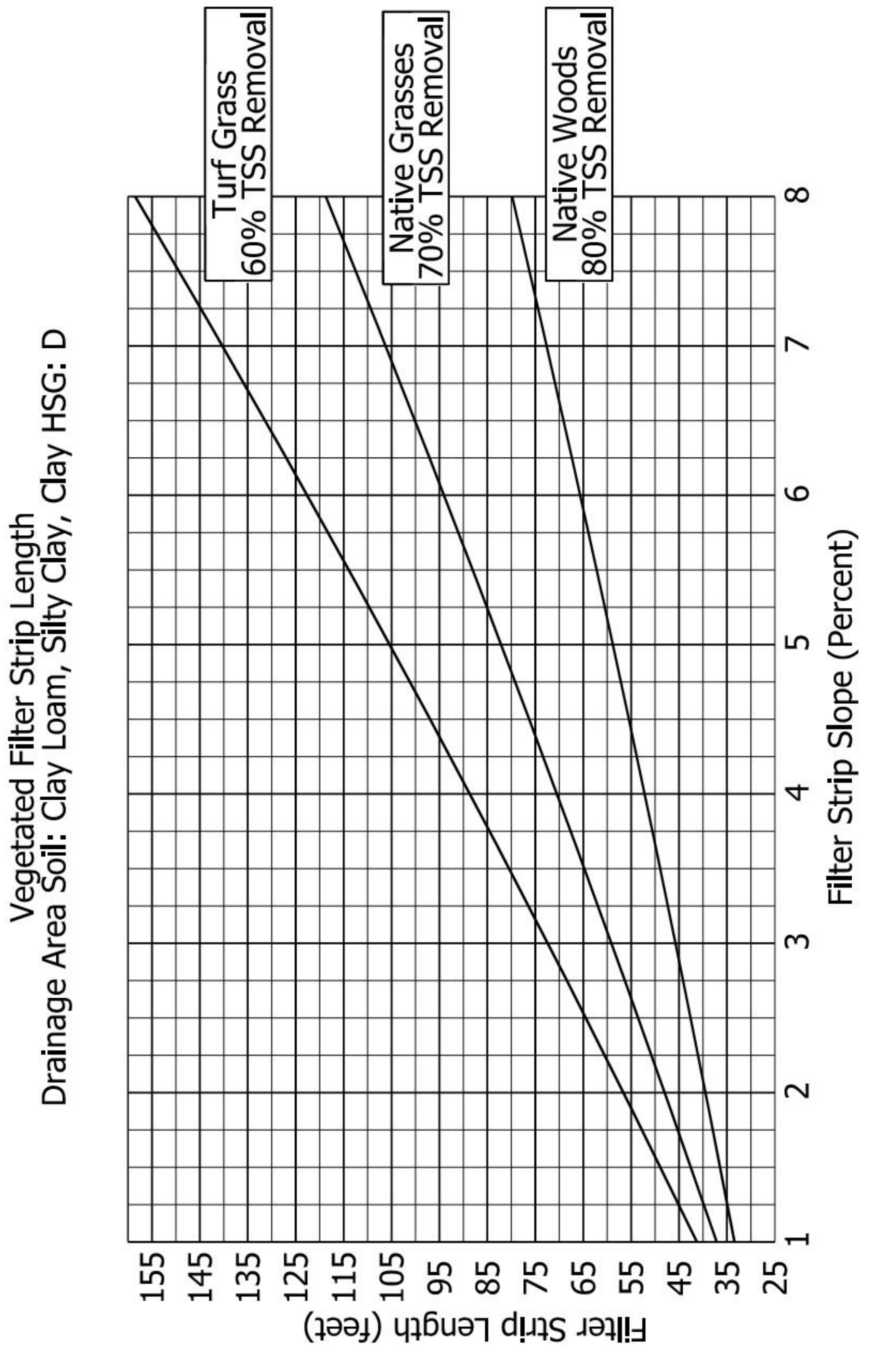
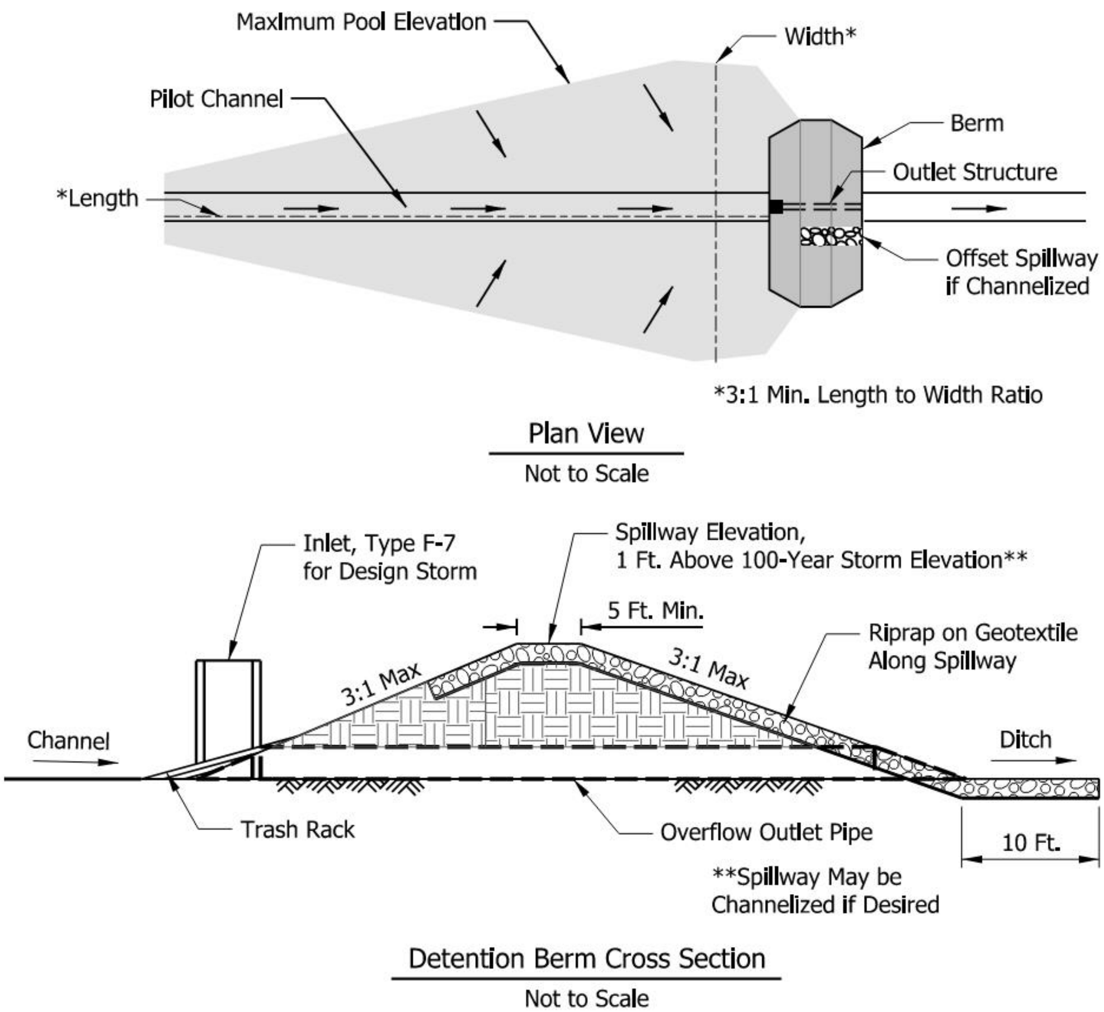

Vegetated Filter Strip Length
Drainage Area Soil:
Sandy Clay Loam HSG: C
Turf Grass
60% TSS Removal
Native Grasses
70% TSS Removal
Native Woods
80% TSS Removal
Filter Strip Length (feet)
135
125
115
105
95
85
75
65
55
45
35
25
Filter Strip Slope (Percent)
1
2
3
4
5
6
7
8

FIGURE 5D



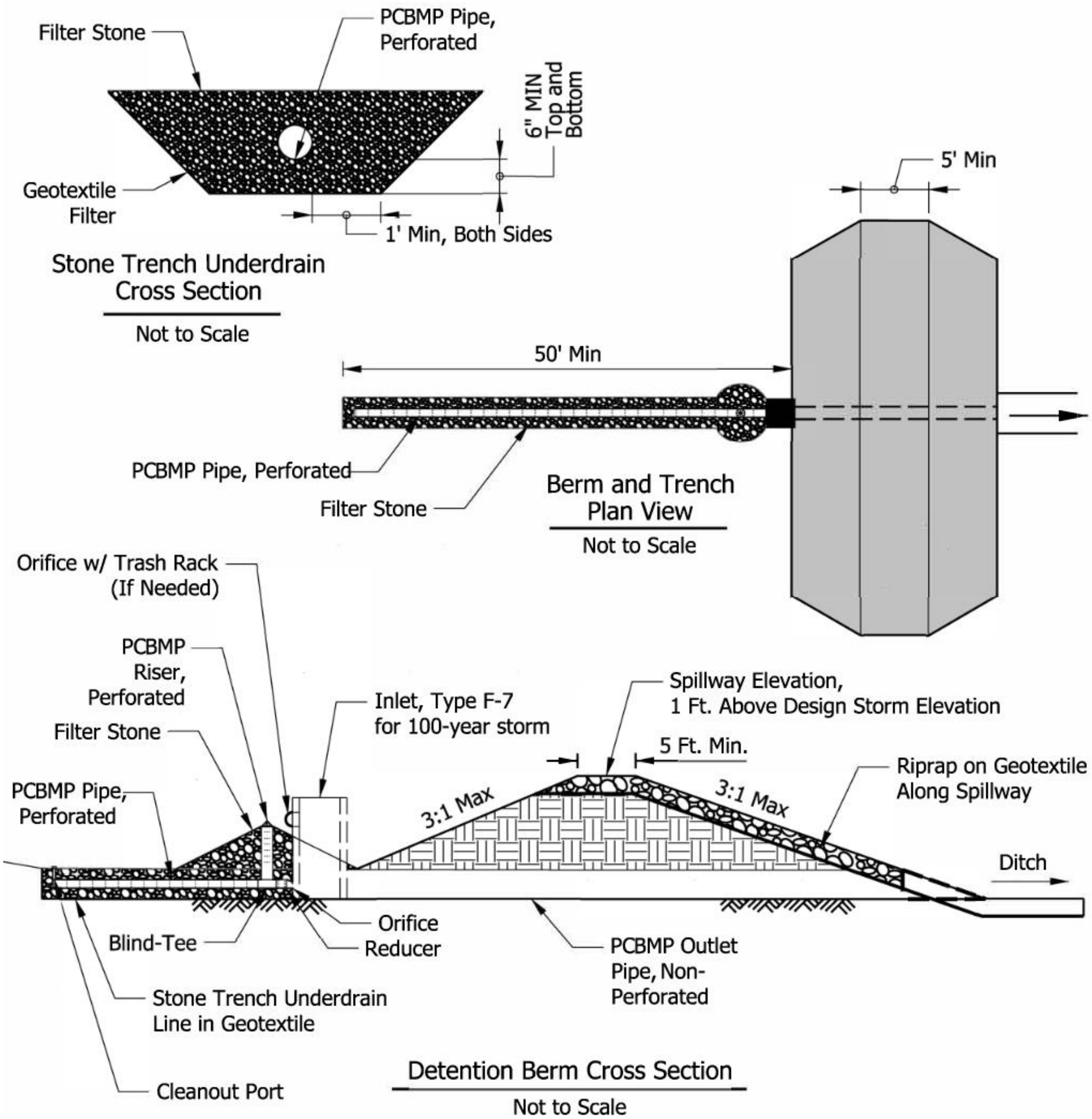
Vegetated Filter Strip Length
Drainage Area Soil: Clay Loam, Silty Clay, Clay HSG: D
Turf Grass
60% TSS Removal
Native Grasses
70% TSS Removal
Native Woods
80% TSS Removal
Filter Strip Length (feet)
155
145
135
125
115
105
95
85
75
65
55
45
35
25
1
2
3
4
5
6
7
8
Filter Strip Slope (Percent)

FIGURE 5E



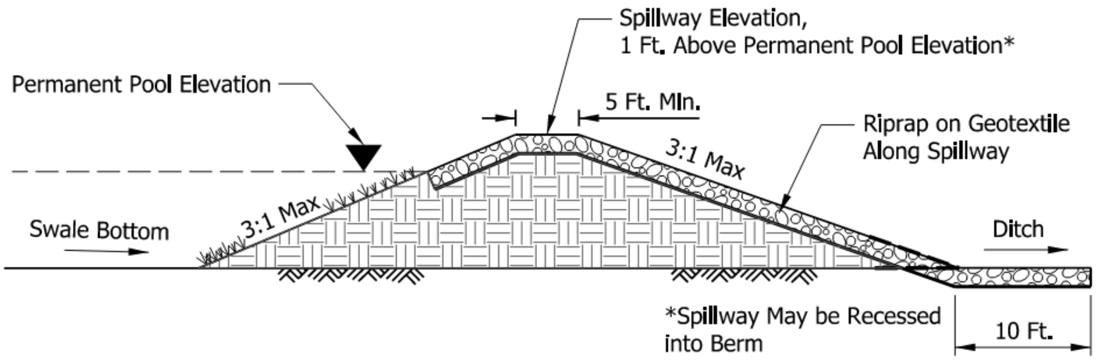
DRY DETENTION DETAILS

FIGURE 6A

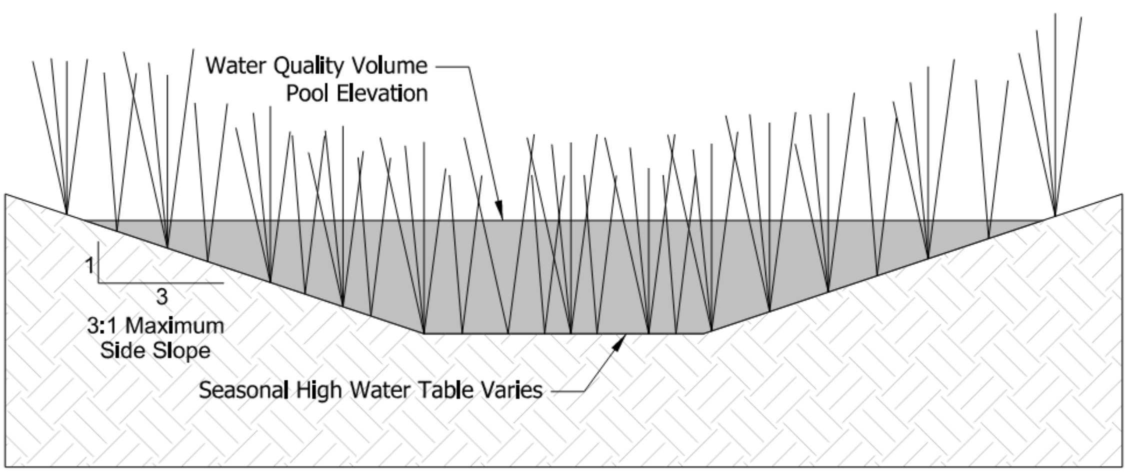


DRY DETENTION WITH UNDERDRAIN DETAILS

FIGURE 6B



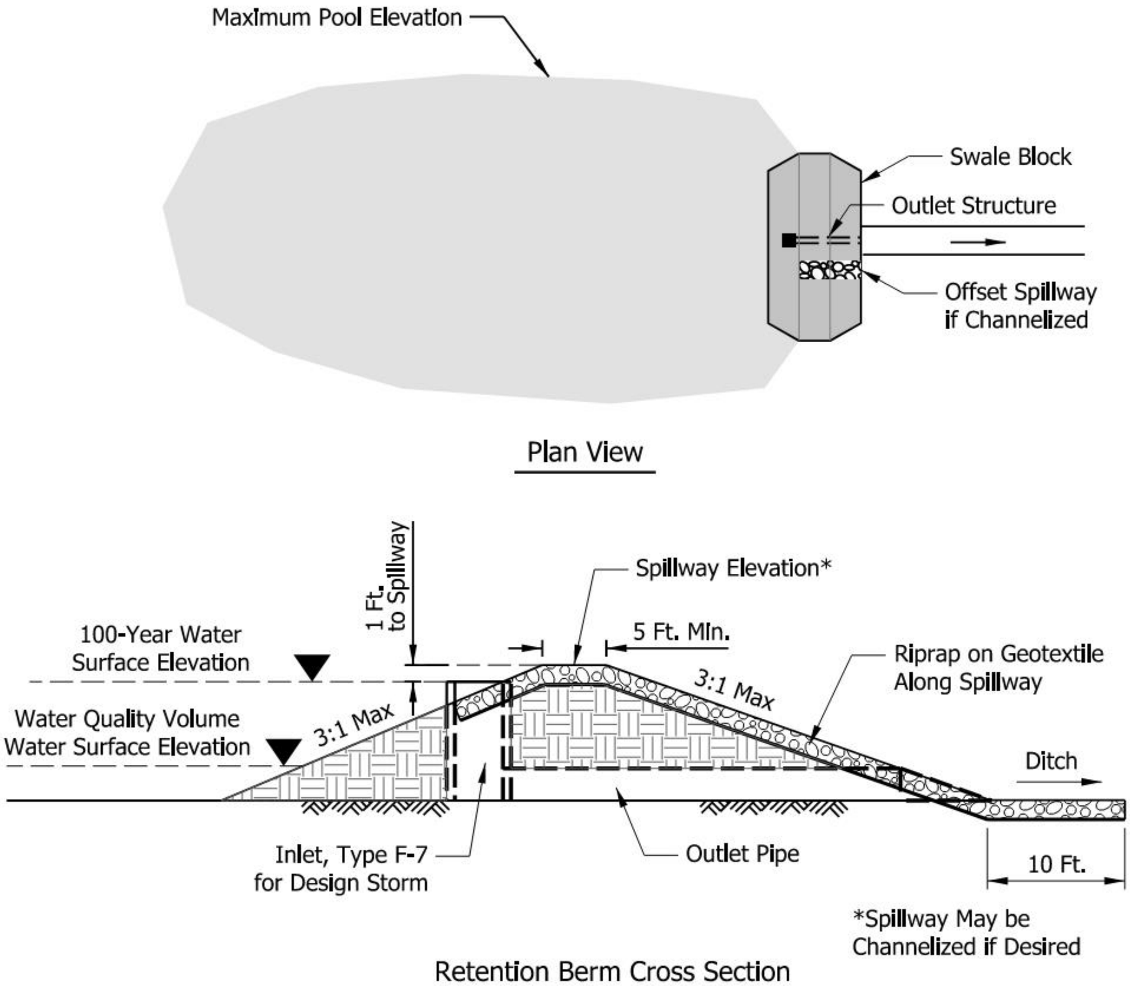
Berm Cross Section



Cross Section View

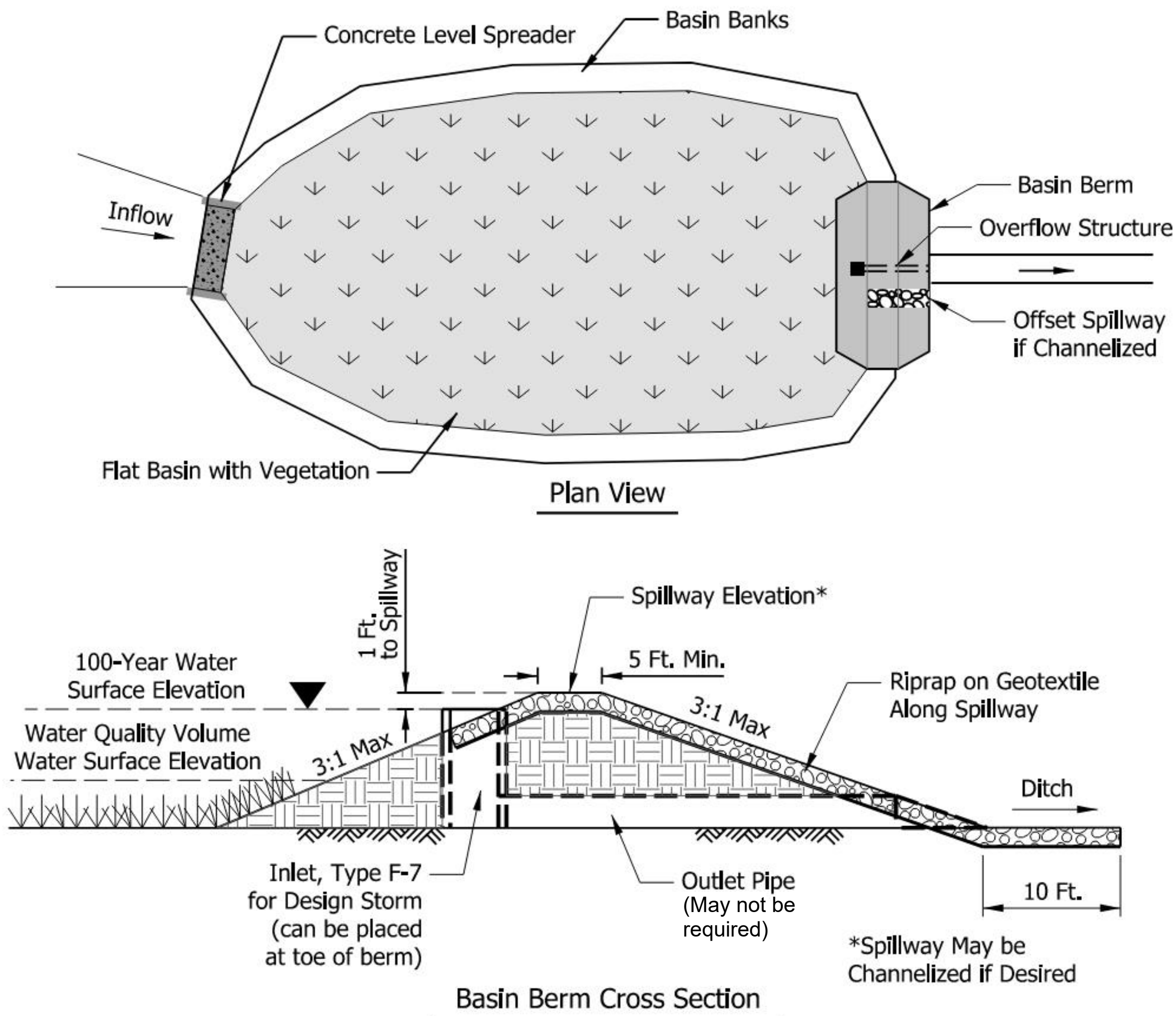
WET SWALE DETAILS

FIGURE 7A



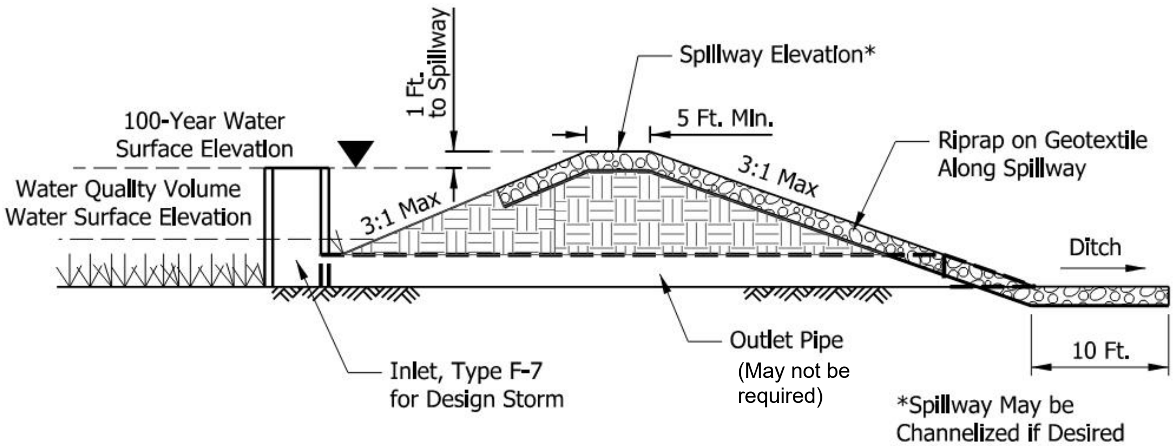
WET RETENTION POND DETAILS

FIGURE 8A

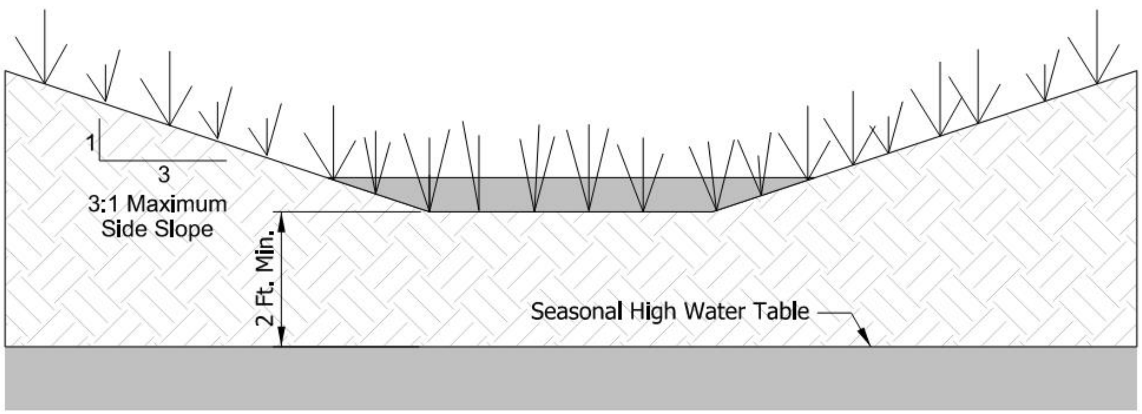


INFILTRATION BASIN DETAILS

FIGURE 9A



Berm Cross Section



Cross Section View

INFILTRATION SWALE DETAILS

FIGURE 9B