The Vermont Stormwater Management Manual
Volume I – Stormwater Treatment Standards

Vermont Agency of Natural Resources
DRAFT March 1, 2016

Acknowledgements

The information contained in this DRAFT manual was developed for the Vermont Agency of Natural Resources by a project team consisting of Stone Environmental, Inc., Horsley Witten Group, Inc., and Adamant Accord. Additional information and manual format was developed by the Vermont Agency of Natural Resources in consideration of internal and external stakeholder comments and stormwater designer participation.

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1.0 INTRODUCTION AND OVERVIEW

Effective stormwater management must include both water quality and water quantity controls. Since the Vermont Stormwater Management Manual (VSMM) was first published in 2002, substantial advances in the design and range of stormwater treatment practices and site design approaches available to meet these goals have occurred. New methodologies – variously referred to as low impact development (LID), environmental site design (ESD) and green stormwater infrastructure (GSI) – have been developed for managing stormwater runoff, including an emphasis on the application of small-scale management practices that minimize stormwater runoff, disperse runoff across multiple locations, and utilize a more naturalized system approach to runoff management.

This manual more fully integrates approaches for designing and sizing stormwater standards for channel protection and groundwater recharge under the umbrella of hydrologic conditions to ensure runoff volumes delivered to local receiving waters after site development more closely mimic predevelopment conditions. In addition, this manual makes explicit the applicability of a range of site planning and green stormwater infrastructure (GSI) design practices for minimizing the generation of runoff from the developed portions of Vermont's landscape.

In the sections that follow, this manual expands and retools the unified approach for designing and sizing stormwater treatment practices (STPs) that was presented in the 2002 Vermont Stormwater Management Manual, incorporating current best practices for stormwater management in a suite of treatment standards that are protective of water quality, hydrologic conditions including channel stability and groundwater recharge, overbank flood protection, and extreme flood control.

The purpose of this manual is threefold:

- To protect the waters of the State of Vermont from the adverse impacts of stormwater runoff.
- To provide design guidance on the most effective stormwater treatment practices (STPs) for new development sites, and to improve the quality of STPs that are constructed in the State, specifically in regard to their performance, longevity, safety, ease of maintenance, community acceptance, and environmental benefit.
- To foster a comprehensive stormwater management approach that integrates site design and nonstructural practices with the implementation of structural STPs.

1.1. Regulatory Authority, Applicability, and Review

This manual was produced to provide technical analysis and design guidance for the Vermont Agency of Natural Resources Stormwater Management Program. This program is authorized under 10 V.S. A. §1264, with specific regulatory guidance provided by the Stormwater Management Rules, and the applicable Stormwater Discharge - General Permits.

This manual has been prepared to assist developers, engineers, consultants, contractors, municipal staff, property owners, and others in planning, designing, and implementing effective stormwater best management practices for the development and redevelopment of properties in Vermont. The Vermont Department of Environmental Conservation (DEC) currently administers a number of programs that require stormwater management. Readers are advised to refer to specific permit requirements to determine if a given project is regulated and whether this manual is applicable. Applicants should consult this manual for guidance on required and recommended elements to achieve stormwater management goals for their projects.

Municipal officials may also use this manual to support local storm water management programs by incorporating or referencing the manual into local ordinances. A number of Vermont's more urban municipalities are regulated under the Municipal Separate Storm Sewer System (MS4) program. Because MS4 program requirements vary somewhat and are subject to change, users of this manual who are applying for local permits are encouraged to consult local MS4 ordinances or procedures as part of developing a stormwater management plan for their project.

The design practices described in this manual shall be implemented by an individual with a demonstrated level of professional competence. Designers, as well as those accountable for operation and maintenance, are ultimately responsible for the long-term performance and success of these practices. However, this manual is also meant to provide guidance for non-technical individuals interested in implementing or recommending specific stormwater management practices at their homes or in their communities.

Designers are required to adhere to the stormwater management standards and performance criteria in this manual. Various words are used to indicate the importance of a particular design standard or criterion in meeting the objectives in this manual. These terms and their meanings in this context are as follows:

- **Must, shall, required**: The design standard or criterion is essential; it is not optional. A written technical justification that is acceptable to the Agency must be provided if the standard or criterion is not used or achieved.
- **Should**: A well-accepted practice; a satisfactory and advisable option or method. It is optional, but subject to review and consent by the Agency.
- **May**: It is recommended for consideration by the designer; it is optional.

Designers should be aware that the figures and photographs included as part of the suite of practice standards presented in Chapters 3.0, 4.0, and 5.0 are schematic graphics only. Design plans should be consistent with the schematic figures when using the method or practice described, but must be completely detailed by the designer for site-specific conditions and construction purposes. In addition, the practice standards present technical guidance that supports the design, construction, and maintenance of effective BMPs. Readers can rely on the information to provide recommended approaches, but reliance on this guidance shall not relieve the reader from compliance with sound engineering judgment or compliance with the required criteria listed elsewhere, nor shall the authors be liable for the use or misuse of this information.

2.0 SITE DESIGN AND STORMWATER TREATMENT PRACTICE SIZING CRITERIA

This section leads designers through a predictable site design process that seeks to minimize impervious surfaces, ensure adequate soil depth and quality post-construction, and preferentially treat runoff from impervious surfaces with distributed practices.

2.1. Site Planning and Design

For the purposes of this Manual, "site" is defined as either the drainage area that includes all portions of a project contributing stormwater runoff to one or more discharge points; or, the area that includes all portions of disturbed area within a project contributing stormwater runoff to one or more discharge points. In cases where there are multiple discharges to one or more waters, "site" shall mean the total area of the sub-watersheds. For linear projects, including but not limited to highways, roads and streets, the term "site" includes the entire right of way within the limits of the proposed work, or all portions of disturbed area within the right of way associated with the project.

During initial site layout, the designer should carefully consider the locations of existing drainage features, forest blocks, stream buffers, wetland, floodplain, recharge areas, habitat, steep slopes, zero-order streams, and other natural areas present on the site. Working to minimize impervious cover and mass grading and to maximize retention of forest cover, natural areas, and undisturbed soils, will reduce the generation of stormwater runoff from the site that will ultimately need to be managed. Further, all disturbed areas of the site will be subject to a post-construction soil depth and quality standard (see Section 3.0), whereas undisturbed areas are presumed to comply with the standard without additional interventions.

In the 2002 Vermont Stormwater Management Manual, several of the site-design approaches described below were offered as optional "credits" that could be applied to reduce the required water quality and recharge storage volumes. In this manual, site planning and design practices are not credited as explicitly. Rather, the strategies for site planning and design discussed below will generally result in smaller development footprints that will reduce the need for building and maintaining stormwater treatment practices in order to meet the treatment standards in Section 2-2.

Natural Area Conservation

- Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants.
- Prevent the discharge of unmanaged stormwater from new stormwater outfalls into wetlands, sole-source aquifers, or ecologically sensitive areas.

Natural Drainage, Buffer and Floodplain Protection

- Establish and protect a naturally vegetated buffer system along all perennial streams and other water features that encompass critical environmental features such as the 100-year floodplain, steep slopes (in excess of 15%), and wetlands.
- Preserve or restore riparian stream buffers with native vegetation.
- Maximize the protection of natural drainage areas, streams, surface waters, and wetlands.

Limit Site Clearing/Grading

- Limit clearing and grading of forests and native vegetation at a site to the minimum area needed to build lots, allow access, and provide fire protection.
- Avoid clearing and grading areas susceptible to erosion and sediment loss.
- Manage a fixed portion of any community open space as protected green space in a consolidated manner.
- Protect as much undisturbed open space as possible to maintain pre-development hydrology and allow precipitation to naturally infiltrate into the ground.

Minimize Impervious Cover

- Cluster development using conservation design principles, reduce the area of impervious surfaces required and promote the use of shared driveways.
- Reduce standard roadway widths whenever possible. Use curvilinear designs on roads and trails to promote sheet flow of runoff.
- Incorporate vegetated swales for drainage instead of concrete curbs and gutters.
- Consider options to "go vertical" reducing the area of land required for parking with multi-story parking structures or underground parking.

2.2. Treatment Standards

After applying appropriate site planning and design strategies, and complying with the requirements for Post-Construction Soil Depth and Quality outlined in Section 3.1, the designer will select one or more stormwater treatment practices (STPs) presented in Chapter 4.0 to meet the specified treatment standards for recharge, water quality, channel protection, overbank flood protection, and extreme flood control. Each of these standards and their exemptions are discussed in more detail in the following sections.

Table 2-1: Treatment Standard Summary

Treatment Standard	Treatment Requirement
Soil Depth and Quality Standard	Maintain or restore on-site soils
Groundwater Recharge Standard	Infiltrate a portion of the post developed runoff based on hydrologic soil group
Water Quality Treatment Standard	Reduce or treat the runoff from the 90th percentile (1.0 inch) storm
Channel Protection Standard	Control the post-developed runoff from the 1-year 24 hour storm by one of two methods: • Hydrologic Condition Method – Match the post-development runoff to the pre development runoff volume from the 1 year storm. • Extended Detention Method – Provide 12 or 24 hour detention of the 1 year storm.
Overbank Flood Protection Standard	Control the post-developed peak discharge from the 10-year storm to 10-year pre-development rates
Extreme Flood Protection Standard	Control the peak discharge from the 100-year storm to the 100-year pre development rates

Under this manual, practices that use disconnection and infiltration shall be first considered to meet the Groundwater Recharge, Water Quality, and Channel Protection Standard by the Hydrologic Condition Method as described in Section 2.2.5.1. Recognizing that site conditions may limit the ability of designers to fully comply with these treatment standards using only the STPs presented in Chapter 4.0, STPs that have limited applicability either because they only provide water quantity control capabilities or because they have limited water quality treatment capabilities are included in Chapter 5.0.

Taken together, these treatment standards are intended to manage the entire range of storms anticipated over the life of the stormwater management system and the associated development. These include storms ranging from the smallest, most frequent events that produce little (or no) runoff, but make up the majority of individual storm events up to the largest, very infrequent storm events that can cause catastrophic damage (see Figure 2-1).

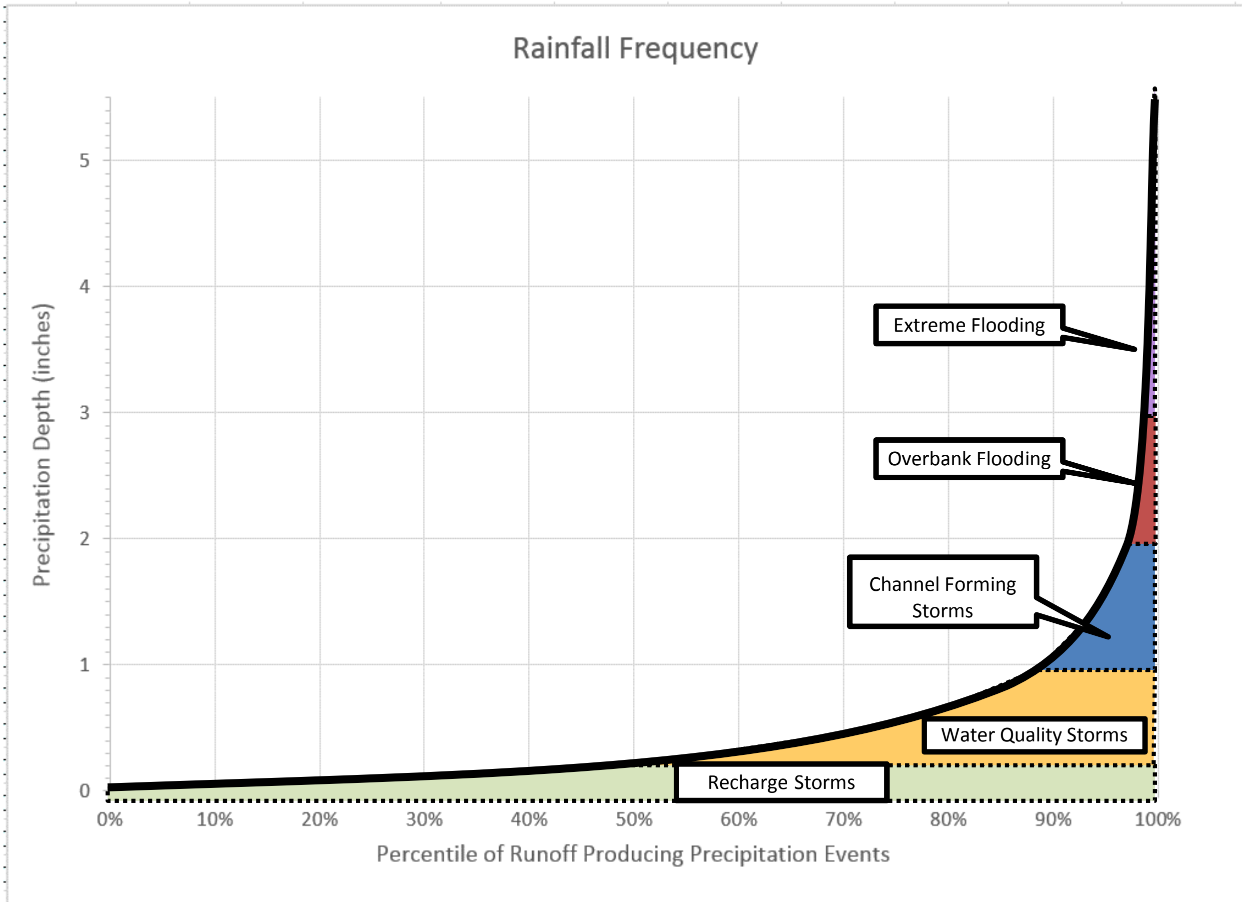


Figure 2-1. Approximate Ranges for Storms Comprising Treatment Standards Sizing Criteria

In the event that an exact numerical criterion specified within the various required design elements cannot be complied with precisely due to site constraints, the designer may use their best professional judgment to specify minor variations from numerical design criteria. However, these variations must be certified by the designer as being equivalent in performance to the required design element, and any such variation must be specifically identified in the Notice of Intent (NOI) letter to the Agency. The Agency will then have the option of either approving the variation on a case specific basis and allowing coverage under the general permit, or requiring the system to be considered as an 'alternative system' as described in Section 4.4.

2.2.1. Post-Construction Soil Quality and Depth

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions including: water infiltration; nutrient and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions can be lost when development removes native vegetation, removes or compacts native soil, and replaces it with minimal topsoil and sod. Not only can these important stormwater functions be diminished, but such landscapes may themselves become pollution generating pervious surfaces due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

In recognition of the important role that soil quality plays in water quality issues, this Manual establishes a mandatory Post-Construction Soil Quality and Depth standard designed to retain greater stormwater functions in the post-development landscape, provide increased treatment of pollutants and sediments that result from development and habitation, and minimize the need for some landscaping chemicals, thus reducing pollution through prevention. This standard applies to all disturbed areas within the limits of the site which are not covered by an impervious surface, incorporated into a structural stormwater treatment practice, or engineered as structural fill or slope once development is complete. A post-construction inspection will be required to verify compliance with the standard. More information on the Post-Construction Soil Quality and Depth Standard is presented in Section 3.1.

2.2.2. Runoff Reduction Framework

Each of the treatment standards described in this manual may be met wholly or partially by runoff reduction. Runoff reduction is a strategy for stormwater management focused on preventing increases in pollutant export, peak flows, and runoff volumes from development through practices that promote infiltration, reuse, or evapotranspiration of runoff.

The attainment of the treatment standards can be assessed in terms of the treatment volume (T_v) credit that can be calculated for each STP that provides runoff reduction. T_v credit can generally be applied to all treatment standards. Table 2-2 lists the STPs that can receive T_v credit.

Table 2-2. Stormwater Treatment Practices that Reduce Runoff

Runoff Reduction STPs	
Practice	**Manual Section**
Reforestation	4.2.1
Simple Disconnection	4.2.2
Disconnection to Filter Strip or Vegetated Buffer	4.2.3
Bioretention Areas (unlined)	4.3.1
Dry Swales	4.3.2
Infiltration Trenches and Basins	4.3.3
Filtering Systems (unlined)	4.3.4
Green Roofs[1]	4.3.7
Permeable Pavement[1]	4.3.8
Rainwater Harvesting[1]	4.3.9

1. Practice provides limited credit towards runoff reduction. See individual practice standards in Section 4.3

Practices that do not reduce runoff volume do not receive a T_V credit and cannot be used to meet the recharge standard. These practices may be able to meet the some or all of the remaining standards through alternative methods. The methods for meeting each treatment standard are described in the sections below. Methods for calculating the credit of each practice is described in Chapter 4.

2.2.3. Groundwater Recharge Treatment Standard (Re_v)

The average annual recharge rate for the prevailing hydrologic soil group(s) (HSG) shall be maintained in order to preserve existing water table elevations. Recharge treatment volume (Re_v) is determined as a function of annual predevelopment recharge for a given soil group, average annual rainfall volume, and amount of impervious cover at a site.

A list of practices acceptable for meeting the recharge requirement is presented in Table 2-3; all practices are described in detail in Chapter 4.0 of this manual. All STPs that meet the groundwater recharge standard may be credited towards subsequent standards through the runoff reduction framework.

Table 2-3. List of Practices Acceptable for Meeting the Groundwater Recharge Standard

Type	Practice
Non-Structural	Simple Disconnection
	Disconnection to Filter Strips and Vegetated Buffers
	Reforestation
Structural	Infiltration Trenches/Basins
	Permeable Pavements
	Sand Filter (unlined)
	Bioretention (unlined)
	Dry Swales (unlined)

The recharge treatment volume is calculated as follows:

$$Re_v = \frac{(F)(A)(I)}{12}$$

where:

Re_v = Recharge volume (acre-feet)

F = Recharge factor (dimensionless), see Table 2-4.

A = Site area (in acres)

I = Site imperviousness (expressed as a decimal percent)

Table 2-4. Recharge Factors Based on Hydrologic Soil Group (HSG)

HSG	Recharge Factor (F)
A	0.60
B	0.35
C	0.25
D	waived

Recharge shall be calculated separately for each drainage area. Re_v can be credited toward the water quality volume and provides credit toward other treatment standards.

The groundwater recharge standard shall be waived for stormwater runoff from hotspot land uses (as described in Section 2.3).

Stormwater recharge may be prohibited or otherwise restricted within groundwater recharge areas, source protection areas, or where features may exist such as karst topographic areas or areas of documented slope failure. Further, no infiltration of stormwater using a structural infiltration system will be allowed within 500′ of a public community water supply or non-transient non-community water supply.

In evaluating STPs for the groundwater recharge treatment standard, the following criteria shall be applied:

- Identify all drinking water supplies and groundwater source protection areas within 500 feet of drainage structural infiltration system on a site plan.
- Locating a structural infiltration system within 100 feet of a drinking water source located in bedrock or a confined unconsolidated aquifer is prohibited, or as otherwise specified in the Vermont Wastewater and Potable Water Supply Rules (or their replacement).
- Locating a structural infiltration system within 150 feet of a drinking water source located in an unconfined aquifer is prohibited, or as otherwise specified in the Vermont Wastewater and Potable Water Supply Rules (or their replacement).
- Identify distance from bottom of structural infiltration system to the seasonal high groundwater table (SHGWT).

2.2.4. Water Quality Treatment Standard (WQTS)

The objective of the Water Quality Treatment Standard (WQTS) is to capture and treat the portion of runoff containing the majority of pollutants. The water quality volume (WQ_v) is the volume of runoff resulting from the 90th percentile rainfall event, which is equivalent to the first inch of rainfall. Achievement of the WQTS with approved practices is designed to remove 85% of the average annual, post-development total suspended solids (TSS) load, and 50% of the total phosphorus (TP) load.

The following equation shall be used to determine the treatment volume needed to comply with the WQTS in acre-feet of storage:

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

where:

WQ_v = water quality treatment volume (acre-feet)

P = 1.0 inch across Vermont

R_v = volumetric runoff coefficient, equal to: [0.05 + 0.009(I)]

I = whole number percent impervious of the site

A = site area (in acres)

In association with the 90% rule, a minimum WQ_v of 0.2 watershed inches is required to treat the runoff from pervious surfaces on sites with low impervious cover.

In evaluating STPs for water quality treatment, the following criteria shall be applied:

- The WQ_v should be treated by reducing the first inch of runoff using the runoff reduction practices listed in Table 2-2.
- If not achieved through runoff reduction, then the final WQ_v shall be treated by an acceptable STP or suite of STPs selected from those presented in Chapters 4.0 or 5.0 of this manual, consistent with the feasibility requirements contained in the individual practice standards, unless an alternative STP design is accepted by the Agency as described in Section 4.4.

- The sizing of water quality practices shall be based on the drainage area to the practices providing treatment. Runoff from off-site areas shall either be diverted away from or bypass water quality practices or be sized to treat all on-site and off-site pervious and impervious areas draining to them.
- If off-site runoff is rerouted, the designer must ensure that such rerouting will not cause channel erosion or flooding problems in the area where the water is discharged.

2.2.4.1. Water Quality Peak Flow Calculation

The peak rate of discharge for the water quality design storm is needed for the sizing of rate based treatment practices and off-line diversion structures. Conventional Natural Resource Conservation Service (NRCS) methods for calculating runoff have been found to underestimate the volume and rate of runoff for rainfall events less than 2".

In order to adapt NRCS methods for the water quality storm, a modified Curve Number (CN) shall be calculated using the water quality volume (WQ_v) and the following equation:

$$CN = \frac{1000}{[10 + 5P + 10Q_a - 10(Q_a^2 + 1.25Q_aP)^{1/2}]}$$

where:

P = rainfall, in inches (use the Water Quality Storm depth, 1”)
Q_a = runoff volume, in inches (equal to WQ_V ÷ area)

The calculated CN can be used to estimate the peak discharge rate of the water quality storm using a computer aided hydrologic model (TR-55, TR-20, or an approved equivalent).

2.2.5. Channel Protection Standard

It is not only the pollutant load transported by stormwater runoff from the developed landscape that has a deleterious impact on receiving streams. Management of the one-year, 24 hour storm event is required for the protection of stream channels from the changes in timing, runoff volume, and peak flow rate of stormwater runoff that occurs as the result of development activities.

The Channel Protection Standard shall be waived for:

- A site where the pre-routed, post-development discharge is less than 2 cubic feet per second. Pre-routed post development flow is the runoff after development including post-development conveyance, but without STPs. When examining whether or not the site qualifies for this waiver, off-site runoff does not need to be considered.
- A site that directly discharges to a waterbody with a drainage area equal to or greater than 10 square miles, and that is less than 5% of the watershed area at the site’s upstream boundary. “Directly discharges” means that the runoff from the project does not reach any water of the State before discharging to the waterbody.

Waiver eligibility shall be determined on a “per receiving water” basis. Receiving waters are considered separate if the drainage area at their downstream point of confluence is greater than 10 sq. mi. The Channel Protection Standard shall be satisfied using the Hydrologic Condition Method, the Extended Detention Method, or a combination of both. The Hydrologic Condition Method and the Extended Detention Method are described in the following subsections.

2.2.5.1. Hydrologic Condition Method

The Hydrologic Condition Method is intended to determine a suite of practices, including the mandatory post-construction soil quality and depth standard, which, when implemented, will approximate runoff characteristics of "woods in good condition" for the one-year, 24-hour storm event.

In Vermont the one-year, 24-hour rainfall ranges between 1.8 and 3.0 inches (NOAA, Atlas 14, 2015). Rainfall depths for the one-year, 24-hour storm event can be obtained from NOAA Atlas 14, Volume 10, available at http://hdsc.nws.noaa.gov/hdsc/pfds/. Rainfall values from Atlas 14 shall be used unless specific data are available for a particular site location and prior approval has been obtained from the Agency.

The Hydrologic Condition Method is based on the curve number (CN) hydrology method developed by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). HC_V is the difference between the pre-development and post-development site runoff for the 1-year, 24-hour storm. The following equation shall be used to determine the treatment volume needed to comply with the HCM in acre-feet:

$$HC_V = \frac{(Q_{1Post} - Q_{1Pre}) * A}{12}$$

Where:

HC_V = hydrologic conditions treatment volume (acre-feet)

Q_{1Post} = post-construction runoff depth for the 1-year, 24-hour storm (inches)

Q_{1Pre} = pre-construction runoff depth for the 1-year, 24-hour storm (inches)

A = post-construction site area (acres)

Runoff depth (Q) shall be calculated by the NRCS Runoff methods or approved equivalent pre and post-development condition.

$$Q = \frac{(P - 0.2 * S)^2}{P + 0.8 * S}$$

where:

Q = runoff depth in inches

P = precipitation in inches

$S = 1000/CN - 10$

The standard for characterizing the pre-development land use shall be woods in good calculation. CN values for woods in good condition are presented on Table 2-4. Existing impervious not subject to jurisdiction may be modeled as impervious.

Table 2-5. Runoff Curve Numbers for Woods in Good Condition

Cover Type	HSG A	HSG B	HSG C	HSG D
Open Space in Good Condition	30	55	70	77

When a site area is composed of multiple land uses, the runoff from each curve number shall be calculated separately and summed. Use of area-weighted curve numbers is not allowed without Agency approval.

The Hydrologic Condition Method is met when the total T_v provided on the site is equal to or greater than the HC_v. A list of practices acceptable for meeting the Channel Protection Standard by the Hydrologic Condition Method is presented in Table 2-5; all practices are described in detail in Chapter 4.0 of this manual.

Table 2-6. List of Practices Acceptable for Meeting Channel Protection through Hydrologic Condition Method.

Type	Practice	Crediting Notes
Non-Structural	Reforestation	
	Simple (Rooftop) Disconnection	
	Disconnection to Vegetated Buffer or Filter Strip	
Structural	Infiltration Trenches/Basins	
	Permeable Pavements	
	Sand Filter	The full depth of the filter counts toward HCM only when unlined so that stormwater is infiltrated into underlying soils or substratum; if the filter includes an underdrain, only the volume stored in a sump beneath the underdrain will count toward HCM.
	Bioretention	The full depth counts toward HCM only when unlined so that stormwater is infiltrated into underlying soils or substratum; if the bioretention practice includes an underdrain, only the volume stored in a sump beneath the underdrain will count toward HCM.
	Green Roofs	Only the volume stored in the void spaces counts toward HCM.
	Dry Swales	Only counts toward HCM when unlined so that stormwater is infiltrated into underlying soils or substratum; if the dry swale includes an underdrain, only the volume stored in a sump beneath the underdrain will count toward HCM
	Rainwater Harvesting	

More information on how practices are credited toward the HCS is provided in the individual practice standards presented in Chapter 4.0.

2.2.5.2. Extended Detention Method

For those sites where the practice or suite of practices is insufficient to achieve the HCS, additional STPs may need to be implemented to protect stream channels from degradation. Storage of the channel protection volume (CP_v) shall be provided by means of extended detention storage (ED) for the one-year, 24-hour rainfall event. As noted previously, the channel protection rainfall depths will vary depending on project location. If a stormwater discharge is to a cold water fish habitat, 12 hours of extended detention is required and if a stormwater discharge is to a warm water fish habitat, 24 hours of extended detention is required. Cold water fish habitats and warm water fish habitat designations are listed in the Vermont Water Quality Standards.

In evaluating a site for channel protection by the Extended Detention Method, the following criteria shall be applied:

- Extended detention shall be demonstrated by center of mass detention time and released at a roughly uniform rate over the required release period.
- The models TR-20 or approved equivalent shall be used for determining peak discharge rates and runoff volumes.

- Adjusted curve numbers should be used when runoff volumes have been reduced through runoff reduction STPs by the process described in Section 2.2.5.3.
- Extended detention shall be provided for the on-site and off-site runoff that drains to the detention structure.
- If off-site runoff is rerouted, the designer must ensure that such rerouting will not cause channel erosion or flooding problems in the area where the water is discharged.
- Off-site areas shall be modeled as "present condition" for the one-year storm event.
- Orifices less than three inches shall be protected from clogging. The minimum allowable orifice size is one inch.

2.2.5.3. Calculating Adjusted Curve Numbers

When the channel protection standard is partially met by the hydrologic condition method, an adjusted CN will need to be calculated for the project site. The adjusted CN (CN_{adj}) is then used to demonstrate compliance with the channel protection standard by extended detention and flood protection (Q_{P10} and Q_{P100}), where required, using the following procedure:

The cumulative treated volume is equal to the sum of the T_v for the individual runoff reduction practices provided on the site:

$$HC_{Vact} = \sum T_V$$

where:

HC_{Vact} = the cumulative runoff reduction provided on the site, in acre-ft

T_V = the runoff reduction volume credit provided by a single treatment practices, in acre-ft

The cumulative treated volume should be converted into a runoff depth in watershed inches (Q_{Act}):

$$Q_{Act} = \left(\frac{HC_{Vact} * 12}{A}\right)$$

where:

Q_{Act} = the volume of runoff reduced in watershed inches

A = the site area, in acres

The remaining untreated watershed inches (Q_{Rem}) is then calculated as:

$$Q_{Rem} = Q_{1Post} - Q_{Act}$$

Ab adjusted CN for the impervious area can then be calculated as follows:

$$CN_{adj} = \left(\frac{200}{(P + 2 * (Q_{Rem}) + 2) - \sqrt{(5 * P * Q_{Rem} + 4 * (Q_{Rem})^2)}}\right)$$

where:

P = depth of the target storm.

For the channel protection standard, the precipitation event is the one-year, 24-hour storm. For Q_{P10} and Q_{P100}, the ten-year and 100-year, 24-hour storms must be used to calculate a separate CN_{adj} for each applicable storm.

Once CN_{adj} is computed, CN_{adj} shall be used for areas treated by STPs that reduce runoff in demonstrating compliance with CP_v, Q_{P10} and Q_{P100}, as discussed in more detail in the following subsections.

2.2.5.4. Alternative Extended Detention Method

For projects that will use distributed and non-structural treatment for the majority of a site without the use of large structural detention practices, a designer may elect to use the Alternative Extended Detention Method to satisfy the channel protection standard. In this case, the designer shall demonstrate that the one-year storm post-developed peak discharge from the site after providing distributed and non-structural treatment is no greater than the peak discharge from the site when modeled as if 12-hour detention were provided.

For the purpose of this alternative demonstration of compliance, the designer shall route all site impervious to a hypothetical dry detention basin. Proposed water quality treatment practices throughout the site should not be included in the hypothetical model. The dry detention basin shall be sized to provide 12 hours of extended detention on a center of mass basis using the following design constraints:

- All outflow shall be routed through a single vertical bottom orifice, sized to provide 12 hours of center of mass detention time.
- Peak storage depth within the hypothetical pond for the 1 year storm shall submerge the outlet orifice, but shall not exceed a depth of 8′.
- Pond side slopes shall be 3:1 or flatter.

The peak outflow rate from this hypothetical pond shall be the site wide post-treatment one-year storm standard. By demonstrating that the post-development site with all proposed treatment produces a peak one-year flow rate that is less than this hypothetical pond peak outflow rate, the site will be presumed to meet the channel protection standard.

2.2.5.5. Time of Concentration

In order to calculate peak rates for compliance with the Extended Detention and flow attenuation standards, the time of concentration must be determined for use with each modeled subcatchment. Time of concentration shall be determined using the Watershed Lag Method (Lag/CN Method) as described by NRCS and shown below:

$$T_c = \frac{(l)^{0.8}\left[\left(\frac{1000}{CN'} - 10\right) + 1\right]^{0.7}}{1140Y^{0.5}}$$

where:

Tc = time of concentration (hr)

l = hydraulic length (ft)

CN′ = retardance factor

Y = average catchment slope (%)

The hydraulic length (l) is defined as the longest flow path in the catchment and can be calculated using the empirical relation presented by NRCS:

$$l = 209A^{0.6}$$

where:

A = subcatchment area (ac)

Or by determining the longest flowpath length by direct measurement from a plan sheet.

Retardance factor (CN') is used to describe the land cover of the catchment of interest, and shall be approximated by the adjusted or flow weighted composite curve number used to describe the catchment.

Average catchment slope (Y) can be determined a number of ways, including in AutoCAD, ArcGIS, or by the following relation:

$$Y = 100\frac{CI}{A}$$

where:

C = contour length (ft)

I = contour interval (ft)

Contour length (C) is the total length of all contour lines within the catchment, including all closed contours.

The Watershed Lag Method incorporates average catchment slope and the composite land cover characteristics of a catchment, and is therefore preferred to spatially explicit methods, such as the NRCS Velocity Method (TR-55 Method), which represent time of concentration for a catchment with varying slopes and land cover characteristics using the characteristics of a single flow path.

The Watershed Lag Method shall be used for determination of peak rates for existing and proposed condition modeling, proposed condition modeling with treatment volume credit and an associated adjusted curve number, and water quality storm modeling.

Other time of concentration calculation methods may be considered on a case by case basis, but will require pre-application discussion and subsequent Agency approval. Any spatially explicit time of concentration methods proposed under this framework (TR-55/Velocity Method) shall include no more than 100 ft. of sheet flow in the total flow path length.

Reference: U.S. Department of Agriculture, Natural Resources Conservation Service. 2010. National Engineering Handbook. Part 630 Hydrology. Washington, DC.

2.2.6. Overbank Flood Protection Standard

The post-development peak discharge rate shall not exceed the pre-development peak discharge rate for the 10-year, 24-hour storm event. It is recommended that a downstream analysis be conducted as described in Section 2.5. The Agency may require a downstream analysis as described in Section 2.5 when there are known drainage problems or known flooding conditions, or as otherwise deemed appropriate for large projects. The Agency will waive the requirement to control the 10-year, 24 hour storm event on a case-by-case basis where it is demonstrated that there will be no increase in flood threat downstream to the point of the so-called 10% rule (see Section 2.5 for the requirements of a downstream analysis). This will always require that an applicant perform downstream hydrologic/hydraulic analyses.

In evaluating overbank flood protection and related STPs, the following criteria shall be applied:

- An adjusted curve number (CN_{adj}), consistent with the analysis performed in Section 2.2.5.3, should be applied to post-development conditions in order to determine the required volume of overbank flood control storage.
- For expansions of previously non-permitted projects, the site shall mean the expanded portion of the site including all areas within the limits of construction.
- The models TR-55 and TR-20 (or approved equivalent) will be used for determining peak discharge rates, and for routing detention ponds.
- The standard for characterizing pervious pre-development land use for on-site areas shall be woods, meadow, or pasture in good condition. Existing impervious may be characterized as impervious in the pre-development condition. For agricultural land, a curve number representing pasture in good condition should be used.
- Off-site areas should be modeled as "existing condition."
- For safe passage of the 100-year, 24 hour storm event, off-site areas that drain to the STP that will be used for overbank flood control shall be modeled as "ultimate condition." Ultimate condition reflects full build-out based on zoning. Where zoning has not been established, ultimate conditions shall reflect reasonable professional judgment that considers the likely nature of land use for the subject lands projected into the future over a 30- to 40-year planning period. Review authorities should be consulted where zoning has not been established.

Rainfall depths for the 10-year, 24-hour storm event can be obtained from NOAA Atlas 14, Volume 10, available at http://hdsc.nws.noaa.gov/hdsc/pfds/. Site designers shall use rainfall values from Atlas 14, or its replacement, unless specific data are available for a particular site location and prior approval has been obtained from the Agency.

The treatment standard for overbank flood protection shall be waived if:

- A site discharges directly to a large reservoir, lake, or stream with a drainage area greater than or equal to 10 square miles. “Directly discharges” means that the runoff from the project does not reach any water of the State before discharging to the waterbody; or
- The site is smaller than five (5) acres and the channel has adequate capacity to convey the post-development 10-year discharge downstream to the point of the so-called 10% rule; and downstream conveyance systems have adequate capacity to convey the 10-year storm.

2.2.7. Extreme Flood Protection Standard

The post-development peak discharge rate shall not exceed the pre-development peak discharge rate for the 100-year, 24-hour storm event. The purpose of this treatment standard is to prevent flood damage from infrequent but very large storm events, maintain the boundaries of the pre-development 100-year floodplain, and protect the physical integrity of a STP. It is recommended that a downstream analysis be conducted as described in Section 2.5. The Agency may require a downstream analysis as described in Section 2.5 when there are known drainage problems or known flooding conditions, or as otherwise deemed appropriate for large projects.

In evaluating extreme flood control and related STPs, the following criteria shall be applied:

- An adjusted curve number (CN_{adj}), consistent with the analysis performed in Section 2.2.5.3, shall be applied to post-development conditions in order to determine the required volume of extreme flood control storage.
- For expansions of previously non-permitted projects, the site shall mean the expanded portion of the site including all areas within the limits of construction.
- The models TR-55 and TR-20 (or approved local equivalent) will be used for determining peak discharge rates, and for routing detention ponds.
- The standard for characterizing pre-development land use for on-site areas shall be woods, meadow, or pasture in good condition. For agricultural land, a curve number representing pasture should be used.
- Off-site areas should be modeled as "existing condition."
- For safe passage of the 100-year event, off-site areas that drain to the STP should be modeled as "ultimate condition".

Rainfall depths for the 100-year, 24-hour storm event can be obtained from NOAA Atlas 14, Volume 10, available at http://hdsc.nws.noaa.gov/hdsc/pfds/. Site designers shall use rainfall values from Atlas 14, or its replacement, unless specific data are available for a particular site location and prior approval has been obtained from the Agency.

The treatment standard for extreme flood control shall be waived if the following conditions exist:

- A site that directly discharges to a waterbody with a drainage area equal to or greater than 10 square miles, and that is less than 5% of the watershed area at the site's upstream boundary. "Directly discharges" means that the runoff from the project does not reach any water of the State before discharging to the waterbody.; or
- The impervious area on site or otherwise associated with a common plan of development (constructed after 2002) is less than 10 acres; or
- A downstream analysis is conducted (See Section 2.5) that indicates extreme flood control is not necessary for the site.

2.3. Stormwater Hotspots

A stormwater hotspot is defined as a land use or activity that generates higher concentrations of hydrocarbons, trace metals or toxicants than are found in typical stormwater runoff, based on monitoring studies. If a site, or a specific discharge point at a site, is designated as a hotspot, it has important implications for how stormwater is managed. First and foremost, stormwater runoff from hotspot discharges shall not utilize a structural or non-structural stormwater treatment practice (STP) designed to all for infiltration to meet applicable stormwater treatment and control standards.

The infiltration prohibition at hotspots applies only to stormwater discharges that come into contact with the area or activity on the site that may generate the higher potential pollutant load. In addition, infiltration practices should not be deployed on sites where subsurface contamination is present from prior land use, due to the increased threat of pollutant migration associated with increased hydraulic loading from infiltration systems, unless the contamination is removed and the site has been remediated, or if approved by the Agency on a case-by-case basis. In areas where infiltration is not appropriate, the structural treatment practices described in Section 4.3 can be used as long as they are lined (e.g., lined bioretention areas). The intent of this standard is to prevent, to the maximum extent practicable, pollution from entering groundwater resources.

Many industrial sites subject to NPDES (National Pollutant Discharge Elimination System) Stormwater Multi-Sector General Permit (MSGP) coverage include hotspot land uses and activities that area considered to generate higher potential pollutant loads and therefore may not be allowed to infiltrate stormwater runoff from these areas.

In addition, other sites not subject to the MSGP may be identified as a hotspot land use or activity where stormwater infiltration is prohibited, such as vehicle fueling stations. Sites where stormwater runoff is demonstrated not to present a risk to groundwater quality may be authorized to infiltrate stormwater runoff as necessary to meet applicable stormwater treatment standards., provided infiltration is allowable under other applicable local, state, or federal regulation, including but not limited to the Vermont Underground Injection Control (UIC) Rule. Prior to incorporating stormwater infiltration into a project stormwater management plan, designer's shall review a site's current or proposed use, and consult with the Agency as to whether the site and/or site area would be identified as a hotspot land use or activity.

The following land uses and activities may generate higher potential pollutant loads that present a risk to groundwater quality and in those cases would be considered stormwater hotspots. For these sites, design shall consider site areas and specific site activities that present a risk to groundwater quality prior to utilizing structural or non-structural infiltration for meeting applicable stormwater treatment standards:

- Paper products (i.e. paperboard mills); Chemical products; food products (i.e. grain mills);
- Asphalt, cement, concrete, and gypsum products (i.e. asphalt or concrete batch plants);
- Metal or coal mining; Non-metallic mineral mining/dressing (i.e. sand, gravel, dimensional and crushed stone extraction/processing);
- Oil and gas extraction;
- Hazardous waste treatment, storage, disposal facilities
- Landfills, open dumps, vehicle salvage yards, and recycling facilities;
- Vehicle fueling facilities (i.e., gas stations);
- Vehicle service and maintenance facilities, and equipment cleaning areas;
- Road salt storage and loading areas, including public works equipment or material storage areas;
- Marinas or ship and boat building facilities (outdoor service, maintenance, cleaning areas, and building activities);
- Aircraft fueling, maintenance, or deicing areas;
- Other manufacturing, processing, material storage, or additional land uses or activities as determined by the Agency on a case-by-case basis.

The following land uses and activities are not considered hotspots:

- Residential, institutional, office development;
- Non-industrial rooftops; and
- Pervious areas, except golf courses, garden centers, and nurseries (which may need stormwater pollution prevention plans and/or integrated pest management (IPM) plans).

2.4. Redevelopment

This section establishes alternative requirements for projects or portions of projects where existing impervious areas will be redeveloped. Because redevelopment may present a wide range of constraints and limitations, this manual affords redevelopment projects additional flexibility in implementing stormwater management practices.

Redevelopment is defined in the Chapter 18 and Chapter 22 Stormwater Rules, and is included in the glossary of this Manual. Applicable jurisdictional thresholds for redevelopment are set forth in the Chapters 18 and Chapter 22 Stormwater Rules. For areas of jurisdictional redevelopment, only the Water Quality Treatment Standard applies, whereby either:

- The existing impervious surface shall be reduced by 25% and restored to meet the Soil Depth and Quality Standard (Section 3.1) where applicable; or
- A STP shall be designed to capture and treat 50% of the WQv from the redeveloped impervious area; or
- A combination of water quality treatment and impervious surface reduction proportional to the above options is provided.

If none of the above options are practical, a designer may propose alternatives that would achieve an equivalent pollutant reduction. For example, a site may use a combination of STPs and strategies to treat more than 50% of the redevelopment area with STPs not included in this Manual, including those with a lesser pollutant removal efficiency than stipulated in Chapter 4.0. In such cases, it will be the responsibility of the designer to document the expected pollutant removal.

Alternate STPs used solely for redevelopment need not meet the full documentation requirements for Alternative Design STPs (Section 4.4), and as a result must include an adequate margin of safety. The redevelopment alternate STP documentation must also include construction, inspection and maintenance requirements commensurate with the level of detail provided for the STPs included in Chapter 4.0, with all documentation subject to Agency review. In no case will a higher pollutant removal rate be assigned to a redevelopment alternative STP than is stipulated for the Water Quality Treatment Practices in Chapter 4.0, unless a practice goes through the full documentation requirements for Alternative Design Practices (see Section 4.4), subject to Agency approval.

2.5. Downstream Analysis for Qp10 and Qp100

Depending on the shape and land use of a watershed, it is possible that upstream peak discharge may arrive at the same time a downstream structure is releasing its peak discharge, thus increasing the cumulative peak discharge (Figure 2-2). As a result of this “coincident peaks” problem, it is often necessary to evaluate conditions downstream from a site to ensure that effective out-of-bank control is being provided.

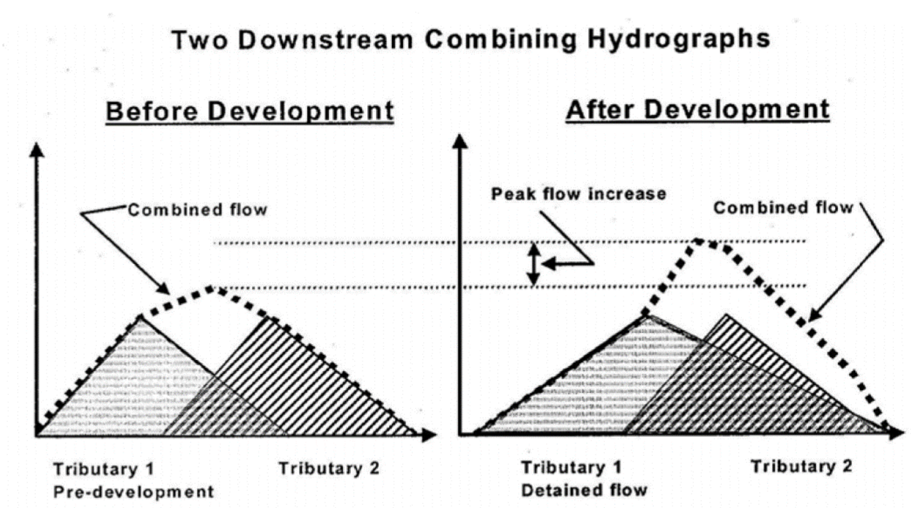


Figure 2: Graphical Depiction of Coincident Peak Phenomena (ARC, 2001)

A downstream analysis is required when deemed appropriate by the Agency (e.g., known drainage problems known flooding conditions or large projects) or as required by the Overbank Flood Protection Standard (Section 2.2.6) or by the Extreme Flood Protection Standard (Section 2.2.7). The criteria used for the downstream analysis is referred to as the "10% rule". Under the 10% rule, a hydrologic and hydraulic analysis is extended downstream to the point where the site represents 10% of the total drainage area. For example, a 60-acre site would be analyzed to the point downstream where the total drainage area reaches 600 acres. In cases where the site area is already less than 10% of the drainage area at the point of discharge, the downstream analysis allowable increase shall be scaled according to Table 2-6 below, which reduces allowable increases as the percentage of the site area relative to contributing drainage area decreases. In addition, in these cases, the analysis may need to be extended downstream to the first structure (e.g. bridge, culvert) if the structure is reasonably expected to be affected by the project.

Table 2-7. Allowable Increases for Downstream Analysis

Site Area Relative to Drainage Area of Receiving Water at Discharge Point	Allowable Flow Rate and Velocity Increase at Analysis Point
10%	5% allowable increase
5 to <10%	2.5% allowable increase
2.5% to <5%	1.25% allowable increase
1.25% to <2.5%	0.63% allowable increase
<1.25%	0.31% allowable increase

At a minimum, the analysis should include the hydrologic and hydraulic effects of all culverts and/or obstructions within the downstream channel, and should assess whether an increase in water surface elevations will adversely impact existing buildings or structures, or adversely impact existing land uses. The analysis should compute flow rates and velocities (for the overbank and extreme flood control storms) downstream to the location of the 10% rule for present conditions and proposed conditions (i.e., before and after development of the applicable site). If flow rates and velocities (for Qp10 and Qp100) without detention increase by less than 5% from the present condition, or as otherwise required by Table 2-6 above, and no existing structures are adversely impacted, then no additional analysis is necessary and no detention is required. If the flow rates and velocities increase by more than 5%, or as otherwise required by Table 2-6 above, the designer must either redesign the project with a detention structure and complete the analysis with detention, propose corrective actions to the impacted downstream areas, or utilize some combination of the above. The Agency may require the designer to complete additional investigations on a case-by-case basis depending on the magnitude of the project, the sensitivity of the receiving water resources, or other issues such as past drainage or flooding complaints. The Agency may require an applicant and/or designer to retain an additional third-party expert to provide the downstream analysis and consult with the Agency's Rivers Program for additional review as necessary.

Special caution should be employed where the analysis shows that no detention structure is required. Stormwater designers must be able to demonstrate that runoff will not cause downstream flooding within the stream reach to the location of the 10% rule. The absence of on-site detention shall not be perceived to waive or eliminate other treatment standards requirements.

A typical downstream analysis will require a hydrologic investigation of the site area draining to a proposed detention facility and of the contributing watershed to the location of the 10% rule for the 10- and possibly 100-year storms. A hydraulic analysis of the stream channel below the facility to the location of the 10% rule will also be necessary (e.g., a HECRAS water surface profile analysis or approved equivalent). Depending on the magnitude of the impact and the specific conditions of the analysis, additional information and data may be necessary. Additional information may include collecting field run topography, establishing building elevations and culvert sizes, investigating specific drainage concerns or complaints, and identification of all culverts, control, conveyance, and stormwater treatment and control contributing to the point of analysis.

Typical Downstream Analysis Steps

1. Calculation of Pre- and Post-Development Runoff at the Point of the 10% rule.

    a. Locate the downstream analysis study point downstream of the project discharge point where site area is 10% of the total contributing drainage area (i.e. where the drainage area is 10 times the project site area). NOTE: In cases where the site area is already less than 10% of the drainage area at the point of discharge, the downstream analysis allowable increase shall be scaled according to Table 2-6 above, which reduces allowable increases as the percentage of the site area relative to contributing drainage area decreases. In addition, in these cases, the downstream analysis may need to be extended downstream to the first structure (e.g. bridge, culvert) if the structure is reasonably expected to be affected by the project.

    b. Model the existing condition runoff from the entire contributing off-site drainage area to the identified analysis point. As a separate component to the model, model the project site for both existing conditions and post-development. The project site model should then be linked to the remainder of the contributing drainage area model to calculate the existing and post-development flow rates and velocities to the identified analysis point.

2. Comparison of Existing Condition and Post-Development Runoff at Point of the 10% rule.

    a. **If flows and velocities increase by less than 5%** at the analysis point, or as otherwise required by Table 2-6 above, then no detention facility may be required if and only if the following is confirmed via hydraulic analyses:

        i) Verify the stream channel and all structures downstream to the identified analysis point, and all conveyances to the discharge point (off-site and project site) have adequate capacity to safely convey the increased runoff, such that no structures, buildings, or existing land uses are adversely impacted. A simple channel model may be used in limited cases to demonstrate that the post development peak volume will not exceed channel capacity. In most scenarios, a more in depth hydraulic water surface profile analysis may be required to satisfy the analysis (e.g. HECRAS). If peak flow conditions are predicted to access the flood plain during peak flow conditions, then pre- and post- inundation mapping may be required to demonstrate that proposed conditions will not create or exacerbate adverse impacts to structures, buildings, or existing land uses. More rigorous and detailed hydraulic analyses may be required for evaluation of the 100-year 24-hour design storm.

    b. **If flows and velocities increase by 5% or greater** at the analysis point, or as otherwise required by Table 2-6 above, then the designer must provide enough stormwater detention on the project site so that flows and velocities do not increase by 5% or greater at the analysis point, or as otherwise required by above, AND satisfy Step 2.a. above.

3.0 POST-CONSTRUCTION SOIL DEPTH AND QUALITY

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions including: water infiltration; nutrient and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are largely lost when development removes native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions diminished, but such landscapes may themselves become pollution generating pervious surfaces due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

Establishing soil quality and depth regains greater stormwater functions in the post-development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes the need for some landscaping chemicals, thus reducing pollution through prevention.

3.1. Post-Construction Soil Depth and Quality Design Summary

Criteria	Element	Requirements
Feasibility	Slope	Less than 33%
	Contributing Drainage Area	Applies to all site areas not covered by impervious surface, incorporated into a structural stormwater treatment practice, or engineered as structural fill or slope,
Conveyance		Not applicable
Pre-Treatment		Not applicable
Treatment	Soil Retention	Retain duff layer and native topsoil undisturbed to the maximum extent practicable. Where grading is required, the duff layer and topsoil shall be removed and stockpiled on site and reapplied to other portions of the site,
	Soil Quality	Topsoil layer with minimum organic matter content of 10% by dry weight in planting beds and 5% organic matter in turf areas met using the options presented in Table 3-1, and pH of 6.0 - 8.0 or matching pH of undisturbed soil. Topsoil layer minimum depth of 8 inches except where tree roots limit amendment incorporation. Subsoils below topsoil scarified at least 4 inches, with incorporation of upper material. Mulch planting beds with 2 inches of organic material. Compost and other materials shall meet organic content and contaminant limit requirements of the Vermont Solid Waste Management Rules §6-11 and this practice standard. The resulting soil shall be conducive to the type of vegetation to be established.
	Credit Towards Standards	Site areas meeting these required elements may be entered into runoff models as "Open Space in Good Condition" for the soil group underlying the area.
Other	Vegetation and Landscaping	Site specific plan for soil management during construction must be provided. Dense and vigorous vegetative cover shall be established over turf areas. Planting beds shall be covered with 2 inches of organic mulch.
	Construction Sequence	Soil preparation options shall be implemented that best suit each area of the site, as identified on the site-specific soil management plan (Table 3-1). Post-construction inspection shall be completed prior to planting.
	Maintenance	General landscaping maintenance and annual inspections.

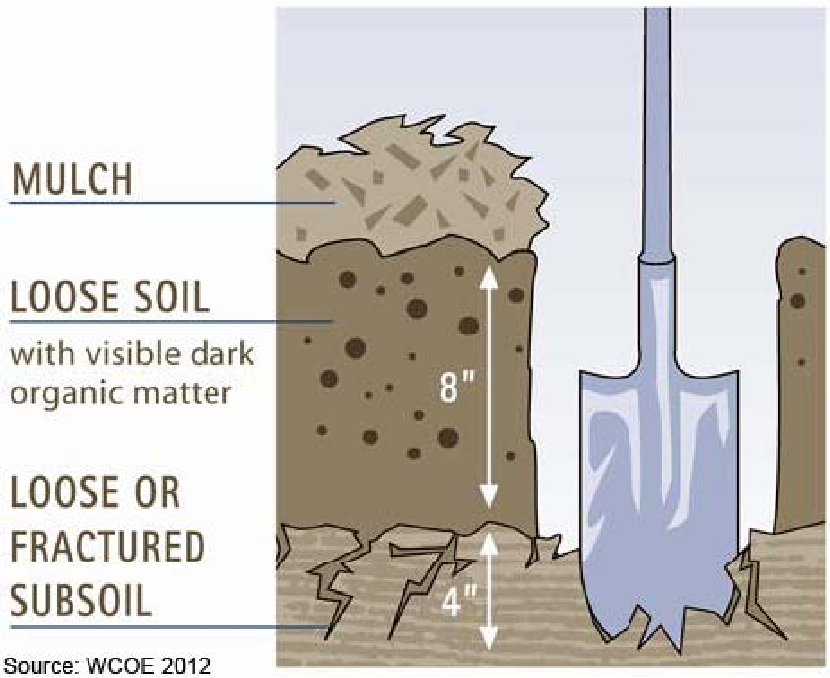


Figure 3-1. Typical Section, Verifying Post-Construction Soil Depth and Quality Using a Test Hole. Test holes should be about one foot deep (after first scraping away any mulch) and about one foot square.

3.2. Post-Construction Soil Depth and Quality Feasibility

Required Elements

- The Post-Construction Soil Depth and Quality Standard shall apply to all disturbed areas within the limits of the site which are not covered by an impervious surface, incorporated into a structural stormwater treatment practice, or engineered as structural fill or slope once development is complete.
- Undisturbed areas where the duff layer and native topsoil are retained meet the intent of this standard and shall not be subject to disturbance solely for the purpose of soil amendment.
- This practice shall not be required on soil slopes greater than 33 percent.

Design Guidance

- Establishing a minimum soil quality and depth will provide improved on-site management of stormwater flow and water quality where soils are disturbed during construction activities. Meeting a minimum soil quality and depth standard is, however, not the same as preservation of naturally occurring soil and vegetation.
- Soil organic matter can be improved or increased through numerous materials such as compost, composted woody material, and forest product residuals. It is important that the materials used to meet the soil quality and depth standard be appropriate and beneficial to the plant cover to be established. Likewise, it is important that imported topsoils improve soil conditions and do not have an excessive percent of clay fines

3.3. Post-Construction Soil Depth and Quality Treatment

Required Elements

Soil retention. Retain, in an undisturbed state, the duff layer and native topsoil to the maximum extent practicable. In any areas requiring grading, the duff layer and topsoil shall be removed and stockpiled on site in a designated, controlled area, at least 50 ft. from surface waters, wetlands, floodplains, or other critical resource areas, to be reapplied to other portions of the site where feasible.

Soil quality. All areas subject to clearing and grading that have not been covered by impervious surface, incorporated into a drainage facility or engineered as structural fill or slope shall, at project completion, demonstrate the following:

- A topsoil layer with a minimum organic matter content of 10% dry weight in planting beds, and 5% organic matter content in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the undisturbed soil. The topsoil layer shall have a minimum depth of eight inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer shall be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.
- Mulch planting beds with 2 inches of organic material.
- Compost and other materials shall be used that meet these organic content requirements:
    - The organic content for "pre-approved" amendment rates can be met only using compost that meets the definition of "compost" in the Vermont Solid Waste Management Rules §6-1102. This rule is available online at: http://www.anr.state.vt.us/dec/wastediv/solid/documents/SWRule.final.pdf.
        - The compost must also have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.
    - Calculated amendment rates may be met through use of composted materials that meet the above requirement; or other organic materials amended to meet the carbon to nitrogen ratio requirements, and meeting the contaminant standards of the Vermont Solid Waste Management Rules §6-1104(g)(6-7), §6-1105(e)(8-9), and §6-1106(e)(8-9).
- The resulting soil shall be conducive to the type of vegetation to be established.
- The soil quality requirements listed above can be met by using one of the following methods:
    - Option 1: Leave undisturbed native vegetation and soil, and protect from compaction during construction. **Failure to establish and maintain exclusionary controls around these areas during the construction phase may trigger the requirement to restore soils per one of the following options.**
    - Option 2: Amend existing site topsoil or subsoil either at default "pre-approved" rates, or at custom calculated rates based on tests of the soil and amendment, subject to Agency review.
    - Option 3: Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements, either at default "pre-approved" rates or at a custom calculated rate, subject to Agency review.
    - Option 4: Import topsoil mix of sufficient organic content and depth to meet the requirements.
- More than one method may be used on different portions of the same site. Soil that already meets the depth and quality standard, and has not been compacted during construction, does not need to be amended.

3.4. Post-Construction Soil Depth and Quality Vegetation and Landscaping

Required Elements

- A site specific plan for soil management must be provided, including:
    - A scale drawing identifying areas where native soil and vegetation will be retained undisturbed, and which soil treatments will be applied in landscape areas.
    - A completed worksheet identifying treatments and products to be used to meet the soil depth and organic content requirements for each site area.
    - Computations of compost or topsoil volumes to be imported (and/or site soil to be stockpiled) to meet "pre-approved" amendment rates; or calculations by a qualified professional to meet organic content requirements if using custom calculated rates.
- A dense and vigorous vegetative cover shall be established over turf areas, and planting beds shall be covered with 2 inches of organic mulch.

3.5. Post-Construction Soil Depth and Quality Construction Sequencing

- Required Elements Establish soil depth and quality toward the end of construction and once established, protect from compaction, such as from large machinery use, and from erosion.
- Soil preparation options shall be implemented that best suit each area of the site, as identified on the site-specific soil management plan. Construction steps for each option are outlined in Table 3-1.
- A post-construction inspection shall be completed, preferably prior to planting, so that omissions can easily be corrected:
    - Verify that compost, mulch, topsoil and amendment delivery tickets match volumes, types, and sources approved in the site specific plan. If materials other than those approved in the plan were delivered, submissions by the supplier shall verify that they are equivalent to approved products.
    - Check soil for compaction, scarification and amendment incorporation by digging at least nine 12 inch deep test holes per acre of land subject to the standard (Figure 3-1). Test holes must be excavated using only a garden spade driven solely by inspector's weight and shall be at least 50 feet apart from each other and on areas of land subject to the standard
    - Verify placement of two inches of organic mulch material on all planting beds.

    If a test cannot be performed in the location designated on the approved sampling scheme, a written explanation shall be provided and the alternative location identified on the post-construction certification plan sheet.
- If inspection indicates that an installation does not fulfill the soil depth and quality standard additional tests shall be performed to determine the extent of unsuitable material present. All unsuitable material shall be removed and replaced or amended to the point where it meets the standard. Soil amendment and additional testing shall be completed before certification. When results are unclear or disputed, an independent consultant should conduct sampling for analytical testing of organic matter as described in the project specifications.
- Plant vegetation and mulch the amended soil areas after installation is complete and inspection verifies the standard is met.

Table 3-1. Construction Sequence Options for Meeting the Post Construction Soil Depth and Quality Standards

<table>
<tr><th>Option</th><th colspan="2">Construction Sequence</th></tr>
<tr><td colspan="3">OPTION 1: Leave native vegetation and soil undisturbed, and protect from compaction during construction.</td></tr>
<tr><td></td><td colspan="2">Identify areas of the site that will not be stripped, logged, graded or driven on, and fence off those areas to prevent impacts during construction. If neither soils nor vegetation are disturbed, these areas do not require amendment. Failure to establish and maintain exclusionary controls around these areas during the construction phase may trigger the requirement to restore soils per one of the following options.</td></tr>
<tr><td colspan="3">OPTION 2: Amend existing site topsoil or subsoil either at default “pre-approved” rates, or at custom calculated rates based on designer's tests of the soil and amendment.</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Scarification. Scarify or till subgrade to 8 inches depth (or to depth needed to achieve a total depth of 12 inches of uncompacted soil after calculated amount of amendment is added). Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained. Amend soil to meet required organic content.</td></tr>
<tr><td>A. Planting Beds
1. PRE-APPROVED RATE: Place 3 inches of composted material and rototill into 5 inches of soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of soil needed to achieve 8 inches of settled soil at 10% organic content.
Rake beds to smooth and remove surface rocks larger than 2 inches diameter.
Mulch planting beds with 2 inches of organic mulch.</td><td>B. Turf Areas
1. PRE-APPROVED RATE: Place 2 inches of composted material and rototill into 6 inches of soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of soil needed to achieve 8 inches of settled soil at 5% organic content.
Water or roll to compact to 85% of maximum dry density.
Rake to level, and remove surface woody debris and rocks larger than 1 inch diameter.</td></tr>
<tr><td colspan="3">OPTION 3: Stockpile existing topsoil during grading. Replace it before planting.
Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements, either at a pre-approved default rate or at a custom calculated rate.</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Scarification. If placed topsoil plus compost or other organic material will amount to less than 12 inches: Scarify or till subgrade to depth needed to achieve 12 inches of loosened soil after topsoil and amendment are placed. Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.
Stockpile and cover soil with weed barrier material that sheds moisture yet allows air transmission, in approved location, prior to grading.
Replace stockpiled topsoil prior to planting. Amend if needed to meet required organic content.</td></tr>
<tr><td>A. Planting Beds
1. PRE-APPROVED RATE: Place 3 inches of composted material and rototill into 5 inches of replaced soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of replaced soil needed to achieve 8 inches of settled soil at 10% organic content.
Rake beds to smooth and remove surface rocks larger than 2 inches diameter.
Mulch planting beds with 2 inches of organic mulch or stockpiled duff.</td><td>B. Turf Areas
1. PRE-APPROVED RATE: Place 2 inches of composted material and rototill into 6 inches of replaced soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of replaced soil needed to achieve 8 inches of settled soil at 5% organic content.
Water or roll to compact soil to 85% of maximum dry density.
Rake to level, and remove surface rocks larger than 1 inch diameter.</td></tr>
</table>

<table>
<tr><th>Option</th><th colspan="2">Construction Sequence</th></tr>
<tr><td colspan="3">OPTION 4: Import topsoil mix of sufficient organic content and depth to meet the requirements.</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Scarification. Scarify or till subgrade in two directions to 6 inches depth.
Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.</td></tr>
<tr><td>A. Planting Beds
Use imported topsoil mix containing 10% organic matter (typically around 40% compost). Soil portion must be sand or sandy loam as defined by the USDA.
Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil.
Place second lift of 3 inches topsoil mix on surface.
Rake beds to smooth, and remove surface rocks over 2 inches diameter.
Mulch planting beds with 2 inches of organic mulch.</td><td>B. Turf Areas
Use imported topsoil mix containing 5% organic matter (typically around 25% compost). Soil portion must be sand or sandy loam as defined by the USDA.
Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil.
Place second lift of 3 inches topsoil mix on surface.
Water or roll to compact soil to 85% of maximum dry density.
Rake to level, and remove surface rocks larger than 1 inch diameter.</td></tr>
</table>

3.6. Post-Construction Soil Depth and Quality Maintenance – Year 1

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- After construction, the site shall be inspected following the first two precipitation events of at least 1.0 inch to ensure that appropriate vegetative cover has been established and erosion is not occurring. Thereafter, inspections shall be conducted on an annual basis.

3.7. Post-Construction Soil Depth and Quality Maintenance – Annual

Required Elements

- Inspect practice for consistency with annotated design plan provided with permit, including any narrative inspection and maintenance requirements.

Design Guidance

- Leave grass clippings, plant debris or its equivalent on the soil surface to replenish organic matter.
- Reduce and adjust, where possible, the use of irrigation, fertilizers, herbicides and pesticides, to the minimum necessary needed to ensure robust vegetated cover.

3.8. Post-Construction Soil Depth and Quality References

Metro Water Services (Nashville, TN). 2012. Metropolitan Nashville – Davidson County Stormwater Management Manual Volume 5: Low Impact Development Stormwater Management Manual. Effective June 2012. Accessed at https://www.nashville.gov/portals/0/SiteContent/WaterServices/Stormwater/docs/SWMM/vol5/SWMM_Vol5LIDManual_2012.pdf on June 11, 2014.

New York Department of Environmental Conservation (NY DEC). August 2010. *New York State Stormwater Management Design Manual*. Accessed at http://www.dec.ny.gov/docs/water_pdf/swdm2010entire.pdf on August 7, 2014.

Vermont Department of Environmental Conservation, Waste Management Division. 2012. Solid Waste Management Rules. Rule 11P-03, effective March 15, 2012. Accessed at http://www.anr.state.vt.us/dec/wastediv/solid/documents/SWRule.final.pdf on February 6, 2015.

Virginia Department of Conservation and Recreation (VA DCR). January 2013. *Virginia DCR Stormwater Design Specification No. 2, Sheetflow to Vegetated Filter Strip or Conserved Open Space, Version 2.0.* Accessed at http://www.deq.virginia.gov/fileshare/wps/2013_DRAFT_BMP_Specs/ on August 27, 2014.

Washington Organics Recycling Council. 2012. Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington. Third edition, released 2012. Accessed at http://www.soilsforsalmon.org/pdf/Soil_BMP_Manual.pdf on February 5, 2015.

Washington State Department of Ecology. 2014. 2012 Stormwater Management Manual for Western Washington, as amended December 2014. Accessed at http://www.ecy.wa.gov/programs/wq/stormwater/manual.html on February 5, 2015.

4.0 ACCEPTABLE STORMWATER TREATMENT PRACTICES

This section presents detailed practice standards for the suite of STPs that will receive credit toward one or more of the treatment requirements identified in Section 2.0 of this Manual.

- Section 4.1 identifies a range of pre-treatment practices that will both improve water quality and enhance the effective design life of the STPs. Designers are encouraged to consider which pre-treatment practice is best suited to the STPs selected for the site.
- Section 4.2 presents a suite of non-structural STPs that are intended to shift stormwater design away from centralized management and focus instead on infiltrating runoff close to the source. Practices discussed include reforestation and disconnections. Designers are encouraged to exhaust opportunities to incorporate non-structural practices into site design before considering structural STPs.
- Section 4.3 presents structural STPs that are intended to augment treatment provided by non-structural STPs in order to fully achieve the requirements identified in Section 2.0. Practices discussed include: green roofs, permeable pavement, rainwater harvesting, bioretention, swales, infiltration trenches, filtering systems, treatment wetlands and wet ponds. Designers are encouraged to consider practices in the order presented, maximizing opportunities for infiltration before considering more traditional detention practices such as treatment wetlands and wet ponds.

Sites that meet that do not **fully meet** Channel Protection Standard using the Hydrologic Condition Method in **Section 2.2.5.1** will be required to submit a feasibility analysis justifying the use of practices that are not credited under the Hydrologic Condition Method.

Each practice standard includes two sets of criteria—required elements and design guidelines. **Required elements** are features that shall be used in all applications. If required design criteria for a particular practice cannot be met at a site, an alternative pretreatment BMP or STP must be selected, or adequate justification must be provided to the approving agency why the particular criteria is not practicable, subject to regulatory approval. **Design guidance** includes features that enhance practice performance, and are therefore optional and might not be necessary for all applications.

Each practice standard in also includes a “Design Summary” table near the beginning of the practice. The design summary is meant as a quick reference guide for frequent users of the manual. The criteria and guidance featured within the summaries are not exhaustive, and important design considerations may be contained in the text that are not detailed on the tables.

The figures included in this chapter are schematic graphics only. Design plans should be consistent with the schematic figures when using the method or practice described, but must be completely detailed by the designer for site-specific conditions and construction purposes.

4.1. Pre-Treatment Practices

Pre-treatment practices are designed to improve water quality and enhance the effective design life of practices by consolidating the maintenance to a specific location. However, they do not meet pollutant removal targets or stormwater volume reduction standards on their own.

Pretreatment shall be provided for the entire WQ_v, except for roof runoff that does not commingle with other runoff prior to treatment. Pre-treatment practices must be combined with acceptable volume reduction, water quality, or storage practices to meet applicable criteria. Examples of pre-treatment practices include:

- Pre-Treatment Swales (Grass Channels)
- Vegetated Filter Strips
- Sediment Forebays
- Deep Sump Catch Basins
- Proprietary Devices

In cases where the practice is a proprietary product, specifications and design criteria can typically be obtained from vendors.

4.1.1. Pre-Treatment Swale

Pre-treatment swales (or "grass channels") are shallow, vegetated, earthen channels designed to convey flows, while capturing a limited amount of sediment and associated pollutants. They are similar to conventional drainage ditches, with the major differences being flatter side and longitudinal slopes, as well as a slower design velocity for small storm events. A pre-treatment swale differs from a treatment swale in that it is not intended to provide sufficient contact time for pollutant removal processes other than those associated with larger sediment particles.

4.1.1.1. Design Summary

Design Parameter	**Requirements**
Minimum Length	≥ 50 feet (not including portions in a roadside ditch)
Bottom Width	2 to 8 feet
Longitudinal Slope	0.5% - 2% without check dams >2% - 6% with check dams
Maximum Side Slopes	3:1 or flatter
Design Discharge Capacity	10-year, 24-hour storm event with minimum 6" freeboard
Vegetation and Landscaping	Dense and vigorous vegetative cover required Salt-tolerant grasses recommended

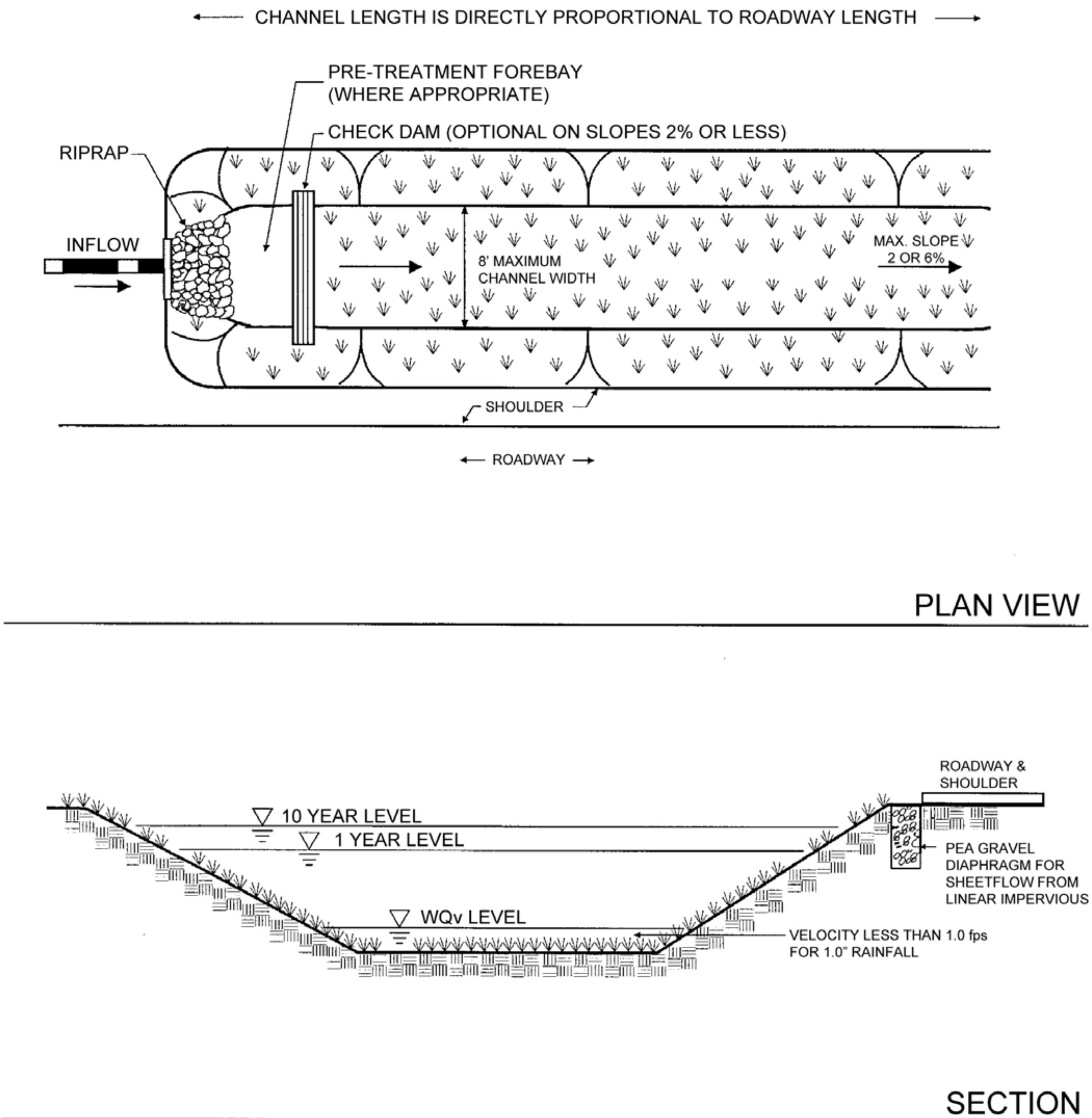


Figure 4-1. Pre-Treatment Swale

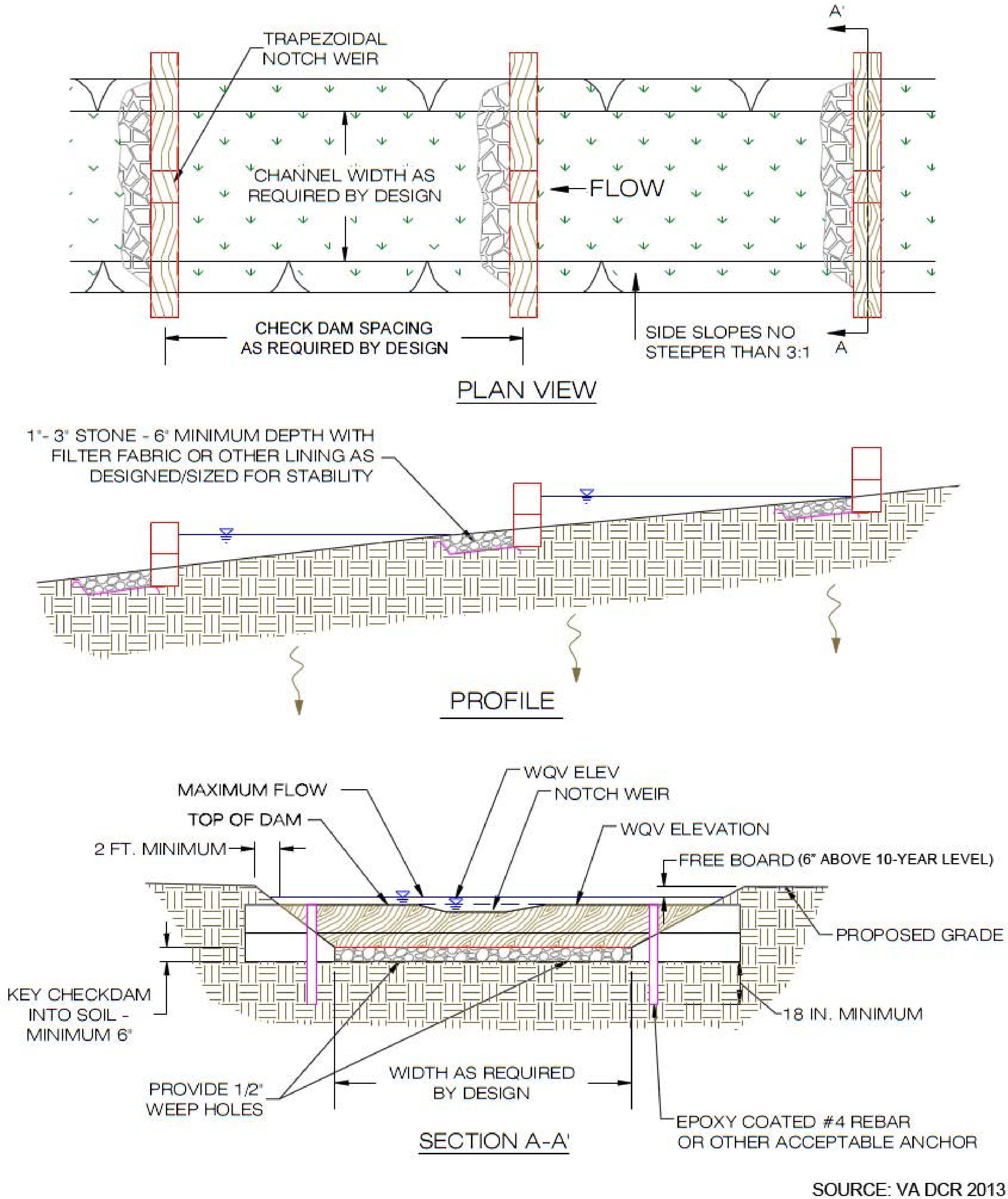


Figure 4-2. Pre-treatment Swale with Check Dams Shown for Swales >2%

4.1.1.2. Pre-Treatment Swale Feasibility

Required Elements

- Pre-treatment swales constructed without check dams shall have a maximum longitudinal slope of 2%. Pre-treatment swales constructed on steeper slopes, to a maximum longitudinal slope of 6%, shall include check dams, step pools, or other grade controls.

Design Guidance

- Pre-treatment swales can be applied in most development situations with few restrictions, and may be well-suited for pre-treatment of some highway or residential road runoff due to their linear nature.

4.1.1.3. Pre-Treatment Swale Design

Required Elements

- Sizing of the pre-treatment swale length is based on the peak flow rate from the water quality storm (WQ_v, see Section 2.6.2) and shall be designed to ensure a minimum residence time of ten (10) minutes at peak velocity for flow from the inlet to the outlet of the swale. For linear projects with no defined primary inflow location, adherence to the minimum 10 minute residence time based on the peak flow rate from the water quality storm is considered sufficient for meeting pre-treatment swale design requirements.
- The peak velocity for the 1-year storm must be non-erosive (see Appendix C7, Vermont Stormwater Management Manual, Vol. 2, Technical Guidance).
- The bottom of the swale shall be between two and eight feet wide. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, the formation of small channels within the channel bottom.
- Pre-treatment swales shall have a trapezoidal or parabolic cross section with relatively mild side slopes (i.e., 3H:1V or flatter).
- Pre-treatment swales shall not intercept groundwater.
- **Check Dams:** Check dams or weirs shall be used to increase hydraulic residence time in the swale in steeper applications (Figure 4-2). Plunge pools or other energy dissipation may also be required where the elevation difference between the tops of weirs to the downstream channel invert is a concern. Design requirements for check dams are as follows:
    - The maximum check dam height shall be 12 inches.
    - Check dams shall be composed of wood, concrete, stone, or other non-erodible material. The check dam should be designed to facilitate easy maintenance and periodic mowing (gravel check dams are discouraged).
    - Check dams must be firmly anchored into the side-slopes to prevent outflanking; check dams must also be anchored into the channel bottom a minimum of 6 inches.
    - Check dams must be designed with a center weir sized to pass the channel design storm peak flow (10-year storm event if an on-line practice).
    - Pre-treatment swales shall have the capacity to convey larger storms (typically 10-year storm event) safely with 6” of freeboard.
    - Armoring may be needed at the downstream toe of the check dam to prevent erosion.

  - Check dams shall be spaced based on channel slope, as needed to increase residence time, provide storage volume, or meet volume attenuation requirements. The ponded water at a downhill check dam should not touch the toe of the upstream check dam.
  - Each check dam should have a weep hole or similar drainage feature so it can dewater after storms.

Design Guidance

- During construction, it is important to stabilize the swale until its turf cover has been established, either with a temporary grass cover, or by using natural or synthetic erosion control products.

4.1.1.4. Pre-Treatment Swale Maintenance

The lifetime of pre-treatment swales is directly proportional to maintenance frequency. Maintenance objectives for this practice include preserving or retaining the hydraulic and sediment removal efficiencies of the swale and maintaining a dense, healthy grass cover.

Required Elements

- The following activities shall be performed on an annual basis or more frequently as needed:
  - Sediment removal from the channels and from behind check dams;
  - Repair check dams as necessary to design specifications;
  - Periodic mowing during the growing season to maintain grass heights in the 4 to 6 inch range;
  - Litter and debris removal; and
  - Repair of eroded areas, removal of invasive species, and reseeding as warranted by inspection.

Design Guidance

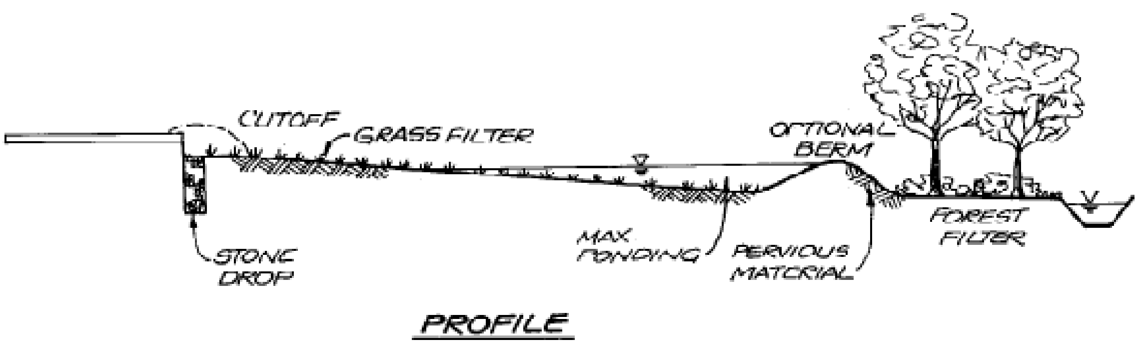
- When sediment accumulates to a depth of approximately ¼ of the original design depth, it should be removed, and the channel should be reconfigured to its original dimensions.
- Sediment testing may be required prior to sediment disposal when a hotspot land use is present.
- If the surface of the swale becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the bottom should be rototilled or cultivated to break up any hard-packed sediment, and then reseeded

4.1.2. Pre-Treatment Filter Strip

Filter strips (i.e., vegetated filter strips, grass filter strips, and grassed filters) are vegetated areas that are intended to treat sheet flow from adjacent impervious areas. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some limited infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice, and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide effective pre-treatment. One challenge associated with filter strips, however, is that it is difficult to maintain sheet flow. Consequently, urban filter strips can be "short circuited" by concentrated flows if sheet flow is not maintained. Proper grading to ensure sheet flow throughout the length of the practice is necessary for a properly functioning filter strip.

4.1.2.1. Design Summary

Parameter	Requirements			
Maximum Impervious Contributing Flow Path Length	35 feet		75 feet	
Filter Strip Slope (maximum 6%)	<2%	>2%	<2%	>2%
Filter Strip Minimum Length (feet)	10	15	20	25



Source: Claytor and Schueler, 1996

Figure 4-3. Filter Strip

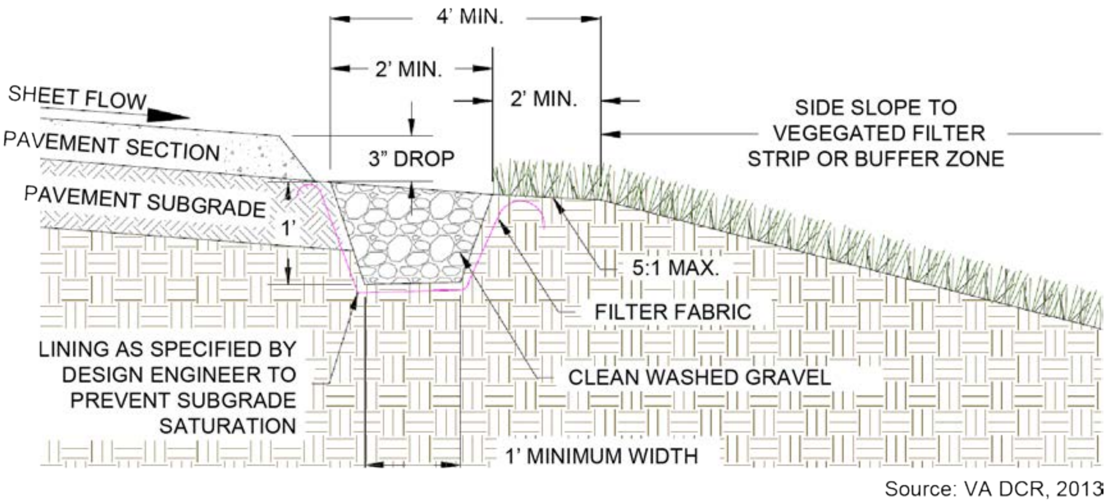


Figure 4-4. Stone Diaphragm

4.1.2.2. Filter Strip Feasibility

Required Elements

- Filter strips designed for pre-treatment shall have a maximum average slope of 6%. The first 5 feet of the filter strip must have a slope of 2% or less while maintaining positive grading toward the remainder of the filter strip.
- The soils underlying the filter strip must, at minimum, meet the criteria included in the Post-Construction Soil Depth and Quality standard (Section 3.1).

Design Guidance

- Filter strips are best suited to pre-treating runoff from roads and highways, roof downspouts, and small parking lots.

4.1.2.3. Filter Strip Design

Required Elements

- The filter strip must abut the entire length of the contributing area to ensure that runoff from all portions of the site are treated.
- The side slopes of pre-treatment or treatment swales shall not be counted as filter strip pre-treatment.
- To limit the occurrence of concentration flow conditions, the maximum impervious contributing flow path length to a filter strip shall be limited to 75 for impervious surfaces and 150 feet for pervious surfaces and the filter strip shall be graded in such a way as to prevent the concentration of flow.
- A pavement drop, depressed trench with concrete curb at uniform height, or other hardened level edge shall be provided to ensure sheet flow from impervious contributing drainage areas into the filter strip pre-treatment.
- A roughly uniform clean stone diaphragm at the top of the slope is required for filter strips providing pre-treatment for contributing impervious surfaces with slopes greater than 4% (Figure 4-4).

- The roughly uniform clean stone diaphragm is created by excavating a 2-foot wide and 1-foot deep trench that runs on the same contour at the top of the filter strip.
- Flow shall travel over the impervious area and to the practice as sheet flow, and then drop at least 2 inches onto the clean stone diaphragm.
- A layer of filter fabric should be placed between the stone and the underlying soil trench.
- If the contributing drainage area is steep (6% slope or greater), then larger stone (e.g clean bank-run gravel) shall be used in the diaphragm.

Design Guidance

- Filter strips should be designed on slopes between 2% and 4%. Steeper slopes encourage concentrated flow; slopes flatter than 2% may result in ponding and other nuisance problems. Slopes may be between 4 and 6%, but such slopes will require erosion control matting and a detailed engineering evaluation.
- Designers should choose a grass that can withstand relatively high velocity flows, and both wet and dry periods. See Appendices B8 and C7, VSMM, Vol. 2 for appropriate plantings/grasses for open channels and filter strips.

4.1.2.4. Filter Strip Maintenance

Filter strip maintenance is important for maintaining healthy vegetative cover and ensuring that flow does not become concentrated or short circuit the practice.

Required Elements

- Filter strips, or areas proposed as such, must be protected by proper soil erosion and sediment control techniques (e.g., silt fences) during all phases of construction. These measures must be properly maintained until final site stabilization and subsequent removal of all trapped sediments has occurred.
- Ensure that grass has vigorously established before flow is directed to the filter strip.
- Filter strips shall be planted at such a density to achieve a 90% grass/herbaceous cover after the second growing season. The filter strip vegetation may consist of turf grasses, meadow grasses, or other herbaceous plants, as long as at least 90% coverage with grasses and/or other herbaceous plants is achieved.
- Filter strips shall be inspected at least quarterly during the first year of operation and annually thereafter. Evidence of erosion and concentrated flows within the filter strip must be corrected immediately. Eroded spots must be reseeded and mulched.
- The bulk of accumulated sediments will be trapped at the initial entry point of the filter strip. These deposited sediments shall be removed manually at least once per year, or when accumulating sediments cause a change in the grade elevation. Reseeding may be necessary to repair areas damaged during the sediment removal process.

Design Guidance

- Grass filter strips should be mowed approximately 2 to 4 times a year, leaving vegetation a minimum of 4 inches in height. Mowing operations are to be conducted during the growing season, but preferably after mid-August. This management technique maintains a tall vigorous growth.

- Filter strips provide a convenient area for snow storage and treatment. If used for this purpose, vegetation in the filter strip should be salt tolerant, (e.g., creeping bentgrass), and a maintenance schedule should include the removal of sand built up at the bottom of the slope.

4.1.3. Sediment Forebay

A sediment forebay is a separate cell within the facility formed by a barrier such as an earthen berm, concrete weir, or gabion baskets. Forebays can be used as a pre-treatment practice to minimize maintenance needs for nearly any stormwater treatment practice. The purpose of the forebay is to provide pre-treatment by settling out sediment particles. This can enhance treatment performance, reduce maintenance, and increase the longevity of a stormwater facility.

4.1.3.1. Design Summary

Design Parameter	Requirements
Forebay Volume	10% of the WQ_v, at minimum. See treatment practice for specific volume requirement.
Minimum Depth	2 feet
Maximum Depth	6 feet
Safety	Bench required when peak design storm depth is greater than 4' and forebay side slopes are steeper than 4:1.
Maximum Side Slopes	2:1 or flatter

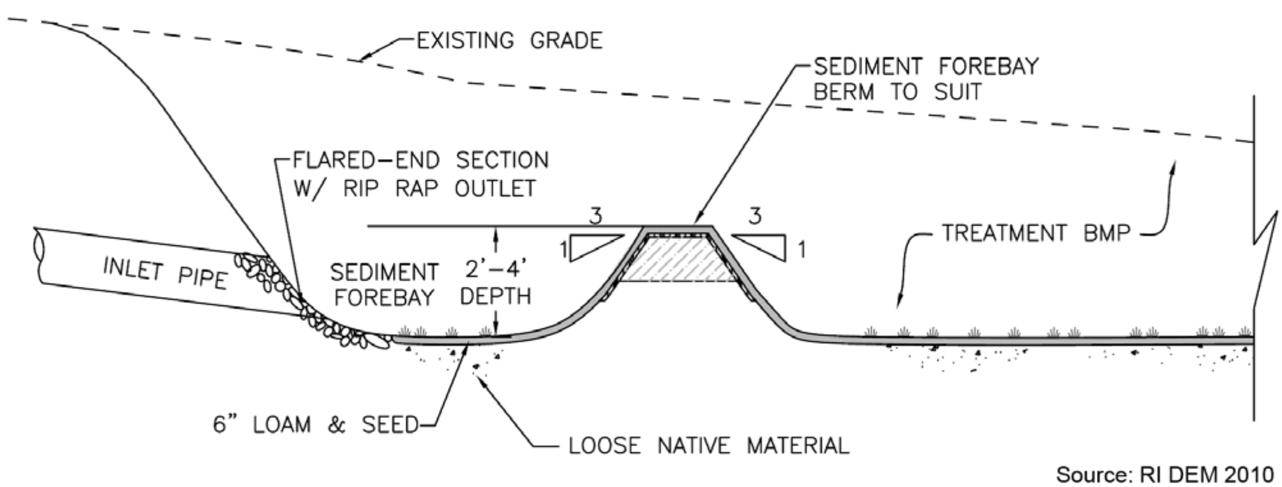


Figure 4-5. Sediment Forebay

4.1.3.2. Sediment Forebay Design

<u>**Required Elements**</u>

- The forebay shall be sized to contain a minimum of 10% of the WQ_v (greater than 10% may be required depending on the downstream treatment practice) and be of an adequate depth to prevent re-suspension of collected sediments during the design storm, often 4 to 6 ft deep. Shallower depths shall be designed such that flow-through velocities do not exceed 2 ft./sec. for all design storms up to the 100-year storm. The goal of the forebay is to, at a minimum, remove particles consistent with the size of medium sand.

- The forebay shall have side slopes no steeper than 2:1.
- The forebay shall have a minimum length to width ratio of 1:1 and a preferred minimum length to width ratio of 2:1 or greater. When riprap is used, designers shall appropriately size riprap to effectively dissipate erosive velocities.
- The forebay shall consist of a separate cell, formed by an acceptable barrier such as an earthen berm, gabion baskets, or a concrete weir. If a channel is used to convey flows from the forebay to the primary treatment facility, the bed and side slopes of the channel must be armored.
- The perimeter of all deep pool areas (four feet or greater in depth at peak design flow) shall be surrounded by a safety bench that generally extends 15 ft outward (a 10 ft minimum bench is allowable on sites with extreme space limitations at the discretion of the approving agency) from the normal water edge to the toe of the side slope. The maximum slope of the safety bench shall be 6%. This requirement shall be waived where forebay side slopes are 4:1 or flatter.
- The outlet from the forebay must be designed in a manner to prevent erosion of the embankment and primary pool.
- The outlet invert must be elevated in a manner such that a minimum of 10% of the WQ_v can be stored below it. This outlet can be configured in a number of ways, such as a culvert, weir, or spillway channel. The outlet should be designed to convey the same design flow proposed to enter the structure.

Design Guidance

- The sediment forebay may be designed with a permanent pool.

4.1.3.3. Sediment Forebay Maintenance

Required Elements

- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition.
- Direct access for appropriate maintenance equipment must be provided to the forebay, and may include a ramp to the bottom of the embankment if equipment cannot reach all points within the forebay from the top of the embankment.
- Sediment removal from the forebay shall occur after 50% of total forebay capacity has been lost. Annual inspections shall note the depth of sediment in the forebay, and whether sediment was removed as part of annual maintenance.

Design Guidance

- The bottom of the forebay may be hardened (i.e., concrete, asphalt, grouted riprap) to make sediment removal easier and minimize the possibility of excavating subsurface soils or undercutting embankments during routine maintenance. This shall not be considered to be jurisdictional impervious.
- Sediment testing may be required prior to sediment disposal when a hotspot land use is present.

4.1.4. Deep Sump Catch Basins

Deep sump catch basins are modified inlet structures that can be installed in a piped stormwater conveyance system to remove coarse sediment, trash, and debris. They can also serve as temporary spill containment devices for floatables such as oils and greases.

4.1.4.1. Design Summary

Design Parameter	Requirements
Maximum Drainage Area	≤0.25 acres of impervious area
Minimum Catch Basin Diameter	4 feet
Depth from Outlet Invert to Sump Bottom	4 feet deep below the lowest pipe invert or four times the diameter of the outlet pipe, whichever value is greater
Hooded Outlet	Horizontal hood opening ≥1 foot below outlet invert

Figure 4-6. Deep Sump Catch Basin

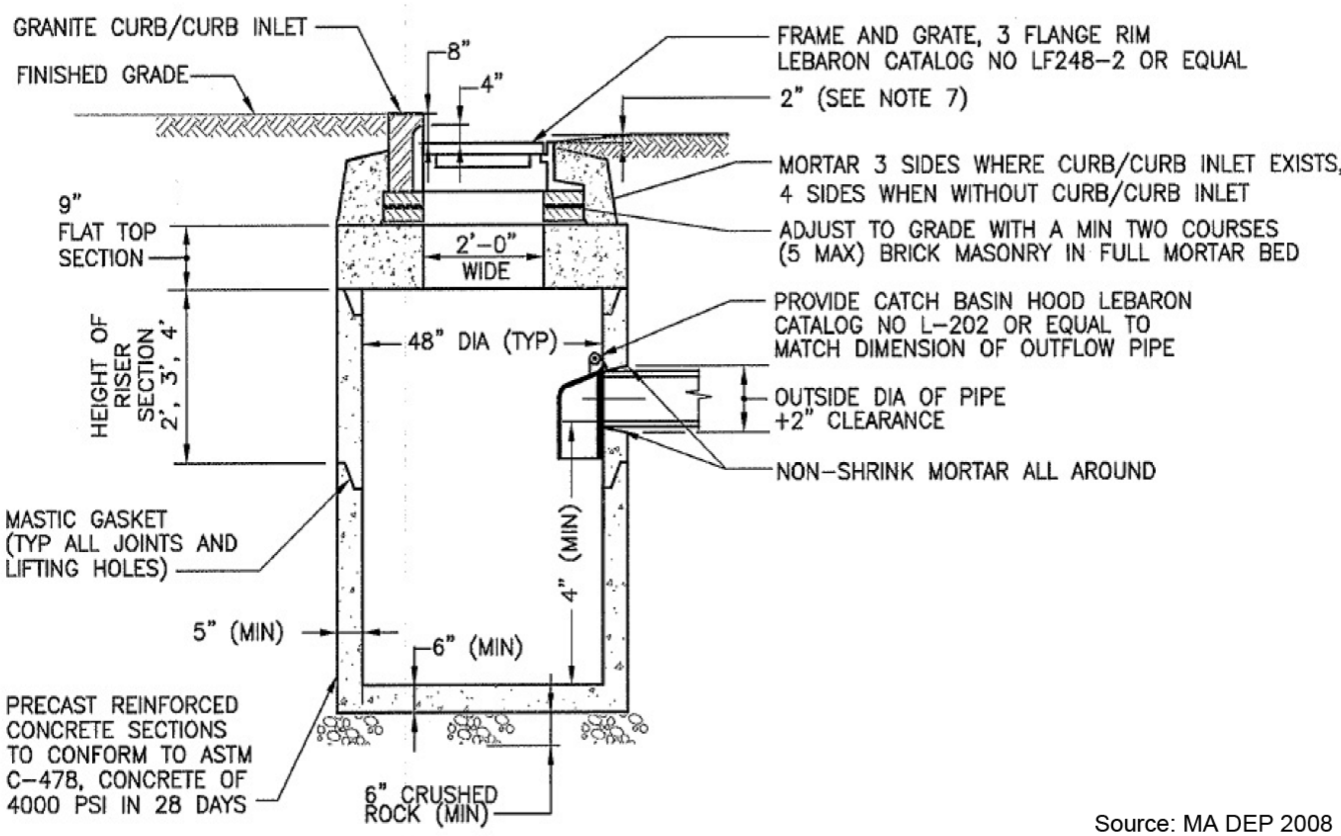
4.1.4.2. Deep Sump Catch Basin Feasibility

Required Elements

- Deep sump catch basins used as pretreatment devices must be located "off-line" – designed in a catch basin-to-manhole configuration with no inlet pipes (Figure 4-6) (NOT in a catch basin-to-catch basin configuration) to be used as pretreatment for other practices. Catch basin-to-catch basin or inlet-to-inlet configurations are acceptable for conveyance, but they cannot be counted as a pre-treatment practice.
- The contributing drainage area to each deep sump catch basin shall not exceed 0.25 acres of impervious cover.

Design Guidance

- Potential site constraints include the presence of utilities, bedrock, and high groundwater elevations.
- Hoods may be susceptible to displacement or damage from cleaning activities. This should be considered in the configuration of the tops of structures (e.g., use of eccentric cones or flat tops with the inlet offset from alignment with the hood) to minimize risk of damage from cleaning equipment. However, the configuration should also permit access for repositioning or replacing the hood.



Source: MA DEP 2008

4.1.4.3. Deep Sump Catch Basin Design

Required Elements

- The deep sump shall be a minimum of 4 feet deep below the lowest pipe invert, or four times the diameter of the outlet pipe, whichever value is greater.
- The inlet grate shall be sized based on the contributing drainage area, to ensure that the flow rate does not exceed the capacity of the grate. The grate shall not allow flow rates greater than 3 cfs for 10-year storm event to enter the sump.
- Inlet grates designed with curb cuts must reach the back of the curb cut to prevent flow bypass.
- Hooded outlets shall be used.

Design Guidance

- The inlet grate should have openings not more than 4 square inches, to prevent large debris from collecting in the sump.

4.1.4.4. Deep Sump Catch Basin Maintenance

Required Elements

- Inspections shall be performed a minimum of 2 times a year (spring/fall). Units shall be cleaned annually, and whenever the depth of sediment is greater than or equal to half the sump depth.

- The inlet grate shall not be welded to the frame so that the sump can be easily inspected and maintained.
- Sufficient maintenance access shall be provided when designing the geometry of deep sump catch basins.
- Damaged hoods shall be replaced when noted during inspections.

Design Guidance

- Sediment testing may be required prior to sediment disposal when a hotspot land use is present.
- Cleaning may require a vacuum-truck instead of “clam-shell” to avoid damage to the hood.

4.1.5. Proprietary Devices

Proprietary devices are manufactured systems that use proprietary settling, filtration, absorption/adsorption, vortex principles, vegetation, and other processes to provide stormwater treatment. Three general types of proprietary devices are most often considered for stormwater applications: oil/grit separators, hydrodynamic devices, and filtering systems. Often, these proprietary devices are not capable of achieving the level of water quality performance required by this manual (Schueler, 2000; Claytor, 2000; UNHSC, 2007). They may, however, provide pre-treatment for stormwater before it is directed to a downstream practice if an independent third-party monitoring program (e.g., ETV, TARP, TAPE) verifies that it removes a minimum of 50% TSS for the WQ_v including during the maximum flow during the water quality event (Q_{wq}).

While proprietary devices must be designed and installed per the manufacturer's recommendations, the following design requirements and guidance generally apply.

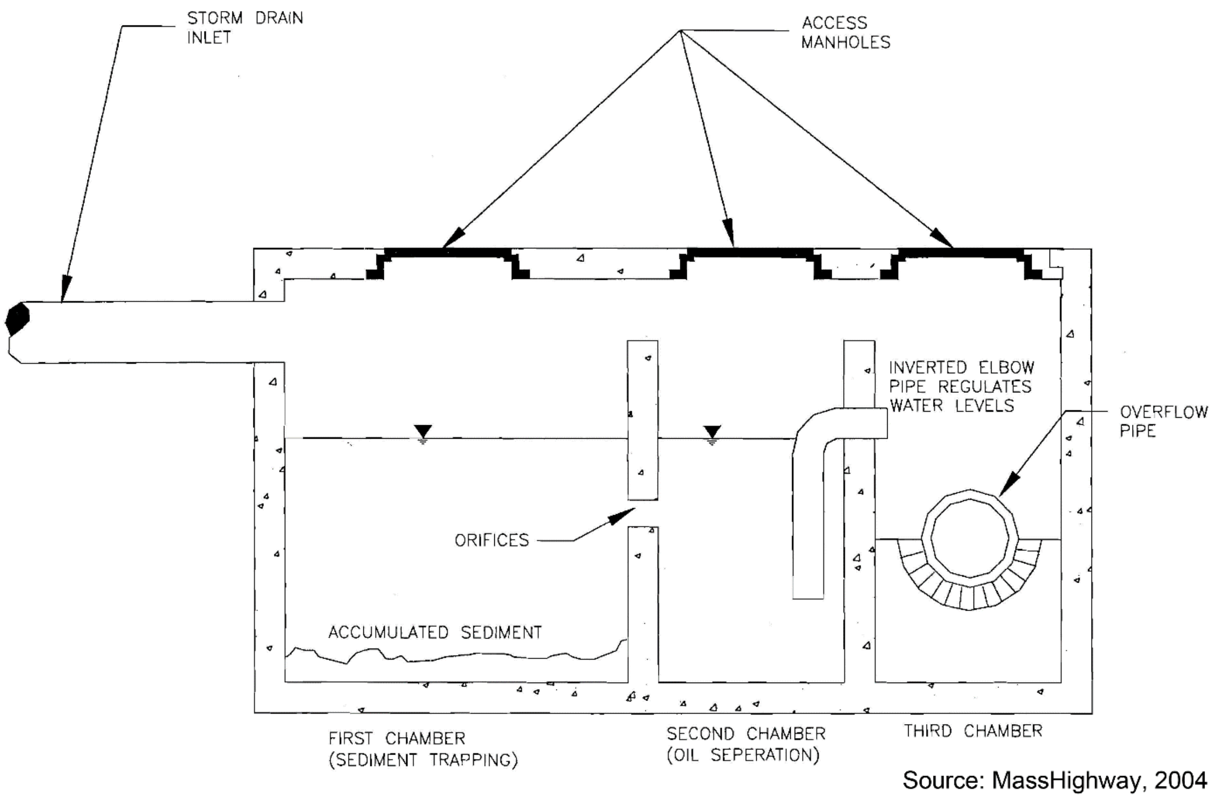


Figure 4-7. Oil and Grit Separator

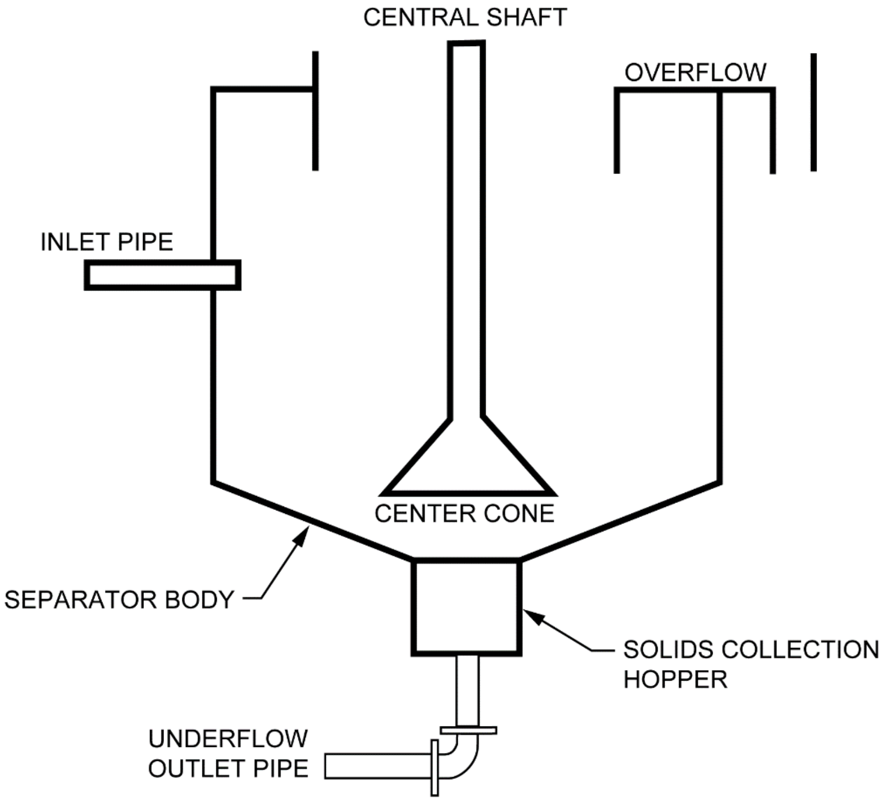


Figure 4-8. Hydrodynamic Device

4.1.5.1. Proprietary Devices Feasibility

Required Elements

- Proprietary devices shall be designed and installed per the manufacturer's recommendations.
- Proprietary devices must be designed as off-line systems, or have an internal bypass to avoid large flows and re-suspension of pollutants, in order to be used as pre-treatment for other practices.

Design Guidance

- The contributing drainage area to each proprietary device should generally not exceed 1 acre of impervious cover.
- Potential site constraints that should be considered in evaluating potential proprietary devices include the presence of utilities, bedrock, and high water tables.

4.1.5.2. Proprietary Devices Design

Required Elements

- Flow-through proprietary devices shall be designed to pass the entire WQ_v. To qualify as an acceptable pre-treatment device, proprietary devices shall remove a minimum of 50% TSS, as verified by an independent third-party monitoring group. In certain retrofit cases and other cases where higher pre-treatment standards may be appropriate, higher removal efficiency may be required in order to achieve stormwater treatment goals for the project.

- A proprietary storage device shall be sized based on the required pre-treatment volume, which is expressed as a percentage of the WQ_v).
- Flows higher than the design flow or that exceed the pretreatment storage volume shall be configured to bypass the system.
- For proprietary devices such as oil/grit separators, all baffles shall be tightly sealed at sidewalls and at the roof to prevent the escape of oil.

Design Guidance

- Roof drains should bypass proprietary pre-treatment devices.

4.1.5.3. Proprietary Devices Maintenance

Required Elements

- Proprietary devices shall be maintained in accordance with manufacturers' guidelines.
- Proprietary devices shall be located such that they are accessible for maintenance and emergency removal of oil and/or chemical spills.
- Inspections shall be performed a minimum of 2 times a year. Devices shall be cleaned when pollutant removal capacity is reduced by 50% or more, or where 50% or more of the pollutant storage capacity is filled or displaced. Hazardous debris removed shall be disposed of in accordance with state and federal regulations by a properly licensed contractor.

4.1.6. References

Claytor, R. and T. Schueler. 1996. *Design of Stormwater Filtering Systems*. Center for Watershed Protection. Ellicott City, MD.

Claytor, R. 2000. Performance of a Proprietary Stormwater Treatment Device: The Stormceptor. *The Practice of Watershed Protection*, editors Thomas R. Schueler and Heather K. Holland. Center for Watershed Protection, Ellicott City, MD.

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4.2. Non-Structural Practices

4.2.1. Reforestation

Trees act as natural reservoirs by intercepting and storing rainfall, which can reduce runoff volume and mitigate its effects. Tree canopies intercept rainfall before it becomes stormwater, and the uncompacted soil into which trees are ideally planted can also be used to capture and treat runoff. Trees may also provide a host of wildlife and habitat benefits along with social and health benefits.

For the purposes of this manual, site reforestation is considered to involve planting a stand or block of trees at a project site with the explicit goal of establishing a mature forest canopy that will intercept rainfall, increase evapotranspiration rates, and enhance soil infiltration rates. Reforestation may be considered in urban and suburban areas, as well as in rural situations where unforested areas are proposed for development, to provide shade and stormwater retention and to add aesthetic and natural habitat value.

4.2.2. Design Summary

Criteria	Element	Requirements
Feasibility	Minimum Required Area	Minimum contiguous area of 10,000 ft^2 Minimum width of 50 ft.
	Slope	Slope requirements not applicable for stand-alone reforestation. When reforested area is used in combination with disconnections the following restriction applies: 15% or less for credit under Simple Disconnection (Section 4.2.2) 8% or less for credit under Disconnection to Filter Strips or Vegetated Buffers (Section 4.2.3)
	Soils	Shall not be applied in jurisdictional wetlands or jurisdictional wetland buffers
Flow Control and Treatment	Conveyance	Impervious surfaces are not required to drain to reforested areas, however when reforestation is used in combination with disconnection, impervious surfaces must drain to reforested areas via sheetflow and/or consistent with Simple Disconnection or Disconnection to Filter Strip / Vegetated Buffer
	Pre-Treatment	Shall be provided for any contributing impervious surfaces consistent with Simple Disconnection and/or Disconnection to Filter Strip / Vegetated Buffer
	Treatment	Soils must meet Post-Construction Soil Depth and Quality standard Planting densities, species diversity, canopy cover specifications must be followed If area is receiving additional credit through a disconnection practice, required treatment elements of that practice must also be satisfied
	Credit Towards Standards	Credited 0.1 watershed inches per square foot reforested toward the HC_V, and therefore CN_{adj} that is applied to CP_v, Q_{P10} and Q_{P100}. (i.e. A reforested area of 1 acre equates to a HC_v credit of 363 cubic feet).
Other	Vegetation and Landscaping	Planting plan required Planting densities: 300 large canopy trees/acre (overall height at maturity of thirty feet or more) Two thirds of selected trees must be large canopy 2 small canopy trees may substitute for 1 large canopy tree 10 shrubs may substitute for 1 large canopy tree Tree species selected shall be well-suited to the site with consideration of natural species composition and diversity of forests in the immediate or local area. Minimum planting sizes: Minimum tree height: 6-8 ft in height Minimum shrub height: 18-24 inches or 3 gallon container New trees planted following appropriate procedures Entire area covered with approved native seed mix

	Maintenance	First year maintenance includes inspection after initial storm events; spot reseeding; watering; control of noxious weeds and invasive plants, and removal and replacement of dead plantings. Nuisance plants that present a physical hazard may be removed with written Agency approval (i.e. poison ivy). Annual inspection for consistency with approved design plan Watering; stabilization of bare soil or sediment sources; trash/debris removal; removal and replanting of dead and damaged trees and shrubs; control of noxious weeds and invasive plants; address areas of standing water if required to comply with disconnection requirements.

4.2.2.1. Reforestation Feasibility

Required Elements

- The minimum contiguous area of reforestation shall be a minimum of 10,000 square feet.
- The minimum width for reforested areas shall be 50 feet.
- To receive credit towards HC_V, the reforested area must be within the site as defined in Section 2.1 or may be contiguous with the site, provided that in either case, the reforested area is under same ownership/control as the site and protected from development and disturbance.
- For reforested areas that are intended to receive runoff from impervious surfaces, slope limitations shall be consistent with the requirements of Simple Disconnection (Section 4.2.22) or Disconnection to Filter Strips and Vegetated Buffers (Section 4.2.33).
- Reforestation shall not be applied within jurisdictional wetlands or jurisdictional wetland buffers.
- Tree species selection shall be appropriate to the soil and site conditions of the area to be reforested.

Design Guidance

- The use of this practice should be limited to areas where there is sufficient space for fully grown trees, space for nearby utilities, and a separation distance from structures.
- Consulting an arborist, forester, or landscape architect early in the reforestation design process is highly recommended.
- Reforestation areas may require temporary or permanent demarcation (e.g. split-rail fence, boulders, etc.) to restrict or limit unnecessary access and to protect plantings following establishment.
- Designers may consider designated foot traffic access to reforested areas by use of path or trail. Impervious surface areas located within or across reforested areas do not count toward reforestation credit requirements.

4.2.2.2. Reforestation Conveyance

Required Elements

- Pervious, un-reforested areas shall drain to reforested areas via sheet flow.
- If the reforested area will accept rooftop or non-rooftop runoff, conveyance shall be designed consistent with the required elements of the applicable practice.

4.2.2.3. Reforestation Pre-Treatment

Required Elements

- If the reforested area will accept rooftop or non-rooftop runoff, pre-treatment shall be provided in a manner consistent with the required elements of the applicable practice.

4.2.2.4. Reforestation Treatment

Required Elements

- Reforestation involves using soil types currently on a site, whether preserved from disturbance and compaction during construction or restored through specified soil amendments during construction. The soil within the area to be reforested must meet the Post-Construction Soil Depth and Quality standard (Section 3.1).
- A planting plan consistent with required tree planting densities, native species diversity, and canopy cover specifications must be followed in order to claim credit for utilizing this practice.
- Planting densities requirements:
  300 large canopy trees/acre (overall height at maturity of thirty feet or more)
  Two thirds of selected trees must be large canopy
  2 small canopy trees may substitute for 1 large canopy tree
  10 shrubs may substitute for 1 large canopy tree
- Tree species selected shall be well-suited to the site with consideration for natural species composition and diversity of forests in the immediate or local area.
- If the reforestation area is serving as a vegetated filter strip to receive additional credit through Disconnection to Filter Strips and Vegetated Buffers (Section 4.2.3), the required elements of that practice must also be satisfied, taking steps necessary to insure that additional routed runoff does not cause erosion or degrade the quality of ground cover.
- T_V credit for reforestation shall be equal to 0.1 inches multiplied by the reforested area (i.e. A reforested area of 1 acre equates to a HC_v credit of 363 cubic feet).

4.2.2.5. Reforestation Vegetation and Landscaping

Required Elements

- A planting plan for the reforestation area shall be prepared to indicate how the area will be stabilized and established with vegetation. Minimum elements of a plan include: delineation of the reforestation area, selection of corresponding plant species, plant locations, sequence for preparing the reforestation area (including soil amendments, if needed), and sources of plant material. Landscaping plans shall clearly specify how vegetation within the reforested area will be established and managed. These plans shall include trees and shrubs that are native or adapted to Vermont, and procedures for preventing noxious or invasive plants. Managed turf (e.g., playgrounds, regularly mown and maintained open areas) is not an acceptable form of vegetation management within reforested areas.
- The basic required density of plantings is 300 large canopy trees per acre, which corresponds to plantings located approximately 12 feet on center. Examples of large canopy trees include sugar maple, white pine, and Northern red oak. When shrubs are substituted for trees, there must be 10 shrubs per one large canopy tree.

Two small canopy trees, such as crabapple, hawthorn, or eastern red bud, may also be substituted for one large canopy tree. Two thirds of selected trees must be large canopy, and reforestation methods shall be targeted to achieve 75% forest canopy within ten years.

- Selection of tree species for reforestation shall consider the composition of area forests
    - The USGS LANDFIRE map may be consulted for delineation of forest type: http://landfire.cr.usgs.gov/viewer/. The NatureServe Explorer provides descriptions for each ecological system, including descriptions of prevalent tree species within each forest type: http://explorer.natureserve.org/.
    - Additional guidance for appropriate tree selection is available at the Vermont Urban and Community Forestry (UCF) website: http://www.vtcommunityforestry.org/resources/tree-selection. Important relevant resources include the *Vermont Tree Selection Guide* (http://www.vtcommunityforestry.org/sites/default/files/pictures/vttree_guide.pdf) and the UCF Tree Selection Tool (http://www.vtcommunityforestry.org/resources/tree-care/tree-selection).
- The minimum size requirement for trees is saplings 6-8 feet in height. The minimum size requirement for shrubs is 18-24 inches in height, or 3 gallon size.
- New trees shall be planted following appropriate procedures (e.g., the International Society of Arboriculture's *Planting New Trees*, http://www.treesaregood.com/treecare/resources/New_TreePlanting.pdf). Planting details for trees and shrubs under a variety of site conditions are available from the International Society of Arboriculture at http://www.isa-arbor.com/education/onlineResources/cadplanningspecifications.aspx#Planting. Planting shall only be performed when weather and soil conditions are suitable for planting.
- The entire reforestation area shall be covered with an approved native seed mix covered with mulch in order to help retain moisture and provide a beneficial environment for the reforestation.
- Reforestation areas shall not be maintained as landscaped areas. Forest leaf litter, duff, and volunteer sapling and understory growth shall not be removed.

Design Guidance

- The planting plan should be designed to fully occupy the reforestation area with vegetation early on, with the expectation that some trees will be removed or allowed to die to achieve appropriate spacing. This allows the function of the site to be maximized early on, and minimizes the establishment of undesirable plants. One strategy for meeting these goals is to pre-plan the winners and losers. Plant out and invest the most in the trees that will own the site in 10 years, and between them, plant trees and shrubs that are acceptable, but cheaper and likely to be weeded out in favor of the winners.
- The designer should be accountable for fully planting the space to be reforested to the extent that plantings have space to grow, but not that other species have ample space to establish. Opportunistic re-vegetation is typically discouraged, particularly in urban settings where invasive (and likely exotic) plants will be most likely to quickly establish. However, native opportunistic re-vegetation that occurs is allowable in reforested areas to supplement the planting plan, provided noxious or invasive plants are promptly removed.
- The final size of the trees in relation to nearby utilities should be considered when designing the planting plan.

- Soils and mulch play a significant role in pollutant removal and tree health. Selection of soils and mulch intended to improve stormwater controls should allow water to infiltrate into the soil, with planting soil characteristics and volume tailored to meet the needs of a healthy tree.
- A 4-inch layer of undyed organic mulch may be installed around newly planted trees to aid in moisture retention. If mulch is used, no more than 1" of mulch should be installed on top of the root ball, and mulch shall not be installed within 6 inches of trunks or stems.

4.2.2.6. Reforestation Construction Sequencing

Required Elements

- The reforestation area shall be clearly identified on all construction drawings and design plans, and protected by acceptable signage and erosion control measures where possible.
- Construction runoff should be directed away from the reforestation area.
- Areas to be reforested that are within the limits of construction disturbance may require light grading to achieve desired elevations and slopes, and to ensure sheet flow. This shall be completed with tracked vehicles to limit compaction.
- Any soil restoration activity (rototilling, topsoil replacement or amendment, etc.) needed within the area to be reforested in order to meet the Post-Construction Soil Depth and Quality standard (Section 3.1) must be completed before trees are planted. Topsoil and/or compost amendments should be incorporated evenly across the reforested area, stabilized with seed, and protected by mulch and/or biodegradable erosion control matting or blankets.
- New trees shall be planted following appropriate procedures (e.g., the International Society of Arboriculture's *Planting New Trees*, http://www.treesaregood.com/treecare/resources/New_TreePlanting.pdf). Planting shall only be performed when weather and soil conditions are suitable for planting.

Design Guidance

- The construction contract should contain a care and replacement warranty extending for three growing seasons, to ensure adequate growth and survival of the plant community.

4.2.2.7. Reforestation Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- Within the first year of operation, inspect the reforested area after events greater than or equal to 1.0 inches of rainfall to verify that sheet flow is being maintained into and within the reforested area.
- Successful reforestation requires that the following tasks be undertaken in the first year following installation:
    - Spot Reseeding. Bare or eroding areas in the contributing drainage area or within the reforested area should be immediately stabilized with grass cover or mulch.

- Watering. Depending on rainfall, watering may be necessary once a week during the first growing season (April-October). Each tree or shrub shall receive ½ inch to 1 inch of water per week, whether through rainfall or watering.
- Invasive species control. Inspect for, and remove, any noxious or invasive plant species.
- Removal and replacement of dead plants. The typical thresholds below which replacements are required within the first year after planting are 85% survival of plant material, including shrubs, and 100% survival of trees.

4.2.2.8. Reforestation Maintenance – Annual

Required Elements

- Inspect practice for consistency with approved design plan, including any narrative inspection and maintenance requirements.
- Additional maintenance activities include:
    - Depending on rainfall, watering may be necessary once a week during the first two to three growing seasons. Each tree or shrub shall receive ½ inch to 1 inch of water per week, whether through rainfall or watering. Once trees are well established, water as needed during dry periods.
    - Look for bare soil or sediment sources within the reforested area, and stabilize them immediately.
    - Remove trash and debris.
    - Replant trees if overall survivability of the original plantings drops below 80%.
    - Inspect for, and remove, any noxious or invasive (http:// www.vtinvasives.org) plant species.
    - The inspection may address areas of standing water if determined to be necessary.
    - Trees determined to be dead, diseased, or unsafe may be cut within a reforestation area, provided soil and groundcover disturbance is limited, restored as necessary, and stumps are not excavated or removed. Dead, diseased, or unsafe/hazard trees that are removed shall be replaced with comparable species.

4.2.2.9. References

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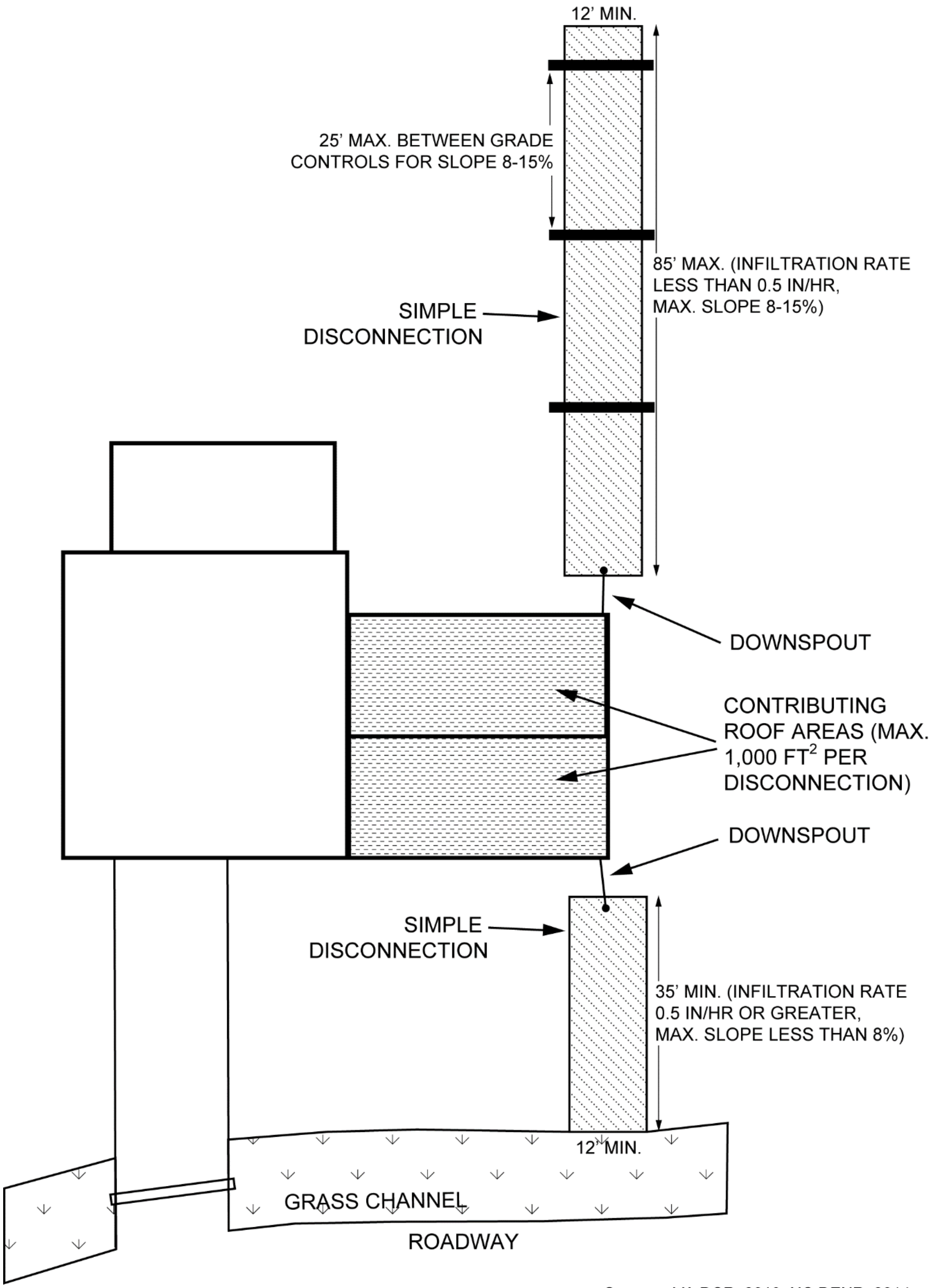
4.2.3. Simple Disconnection

Simple disconnection involves directing flow from residential or small commercial rooftops, sidewalks, and residential driveways to pervious areas, where it can soak into or filter over the ground. This effectively disconnects these surfaces from the storm drain system, reducing both runoff volume and pollutants delivered to receiving waters. In simple disconnection practices, treatment of pollutants and total suspended solids occurs via physical filtering of the runoff through soil and vegetation, as well as chemical and biological activity within the soil.

This practice is dependent on several site conditions (e.g., permeable flow path length, soils, slopes, and vegetative cover) in order to function properly.

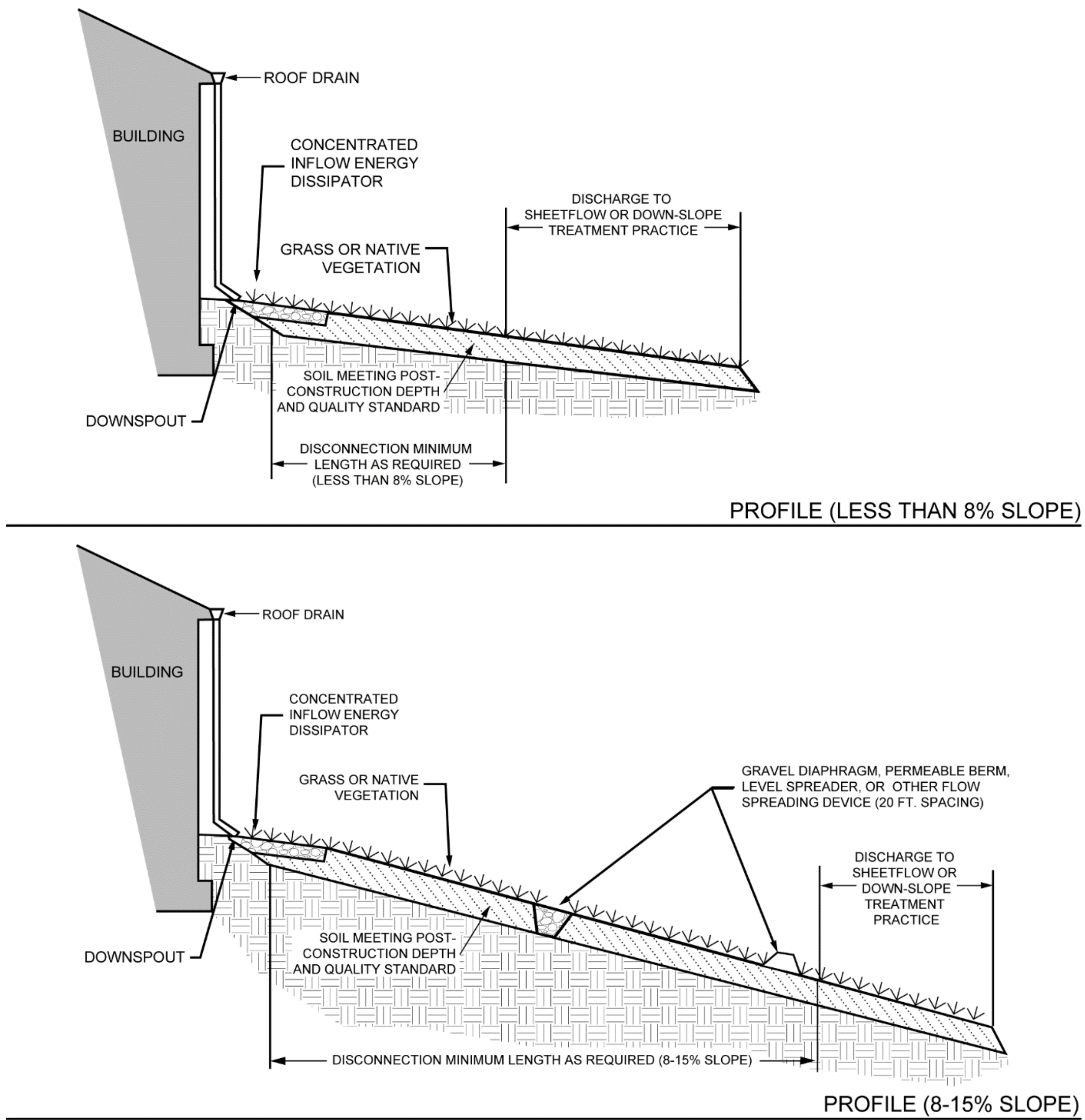
4.2.3.1. Design Summary

Criteria	Element	Requirements
Feasibility	Slope	15% or less (maximum slope in disconnection area) Terraces, berms, or other grade controls required every 20 feet if slope >8%
	Soils	Infiltration rate of 0.5 in/hr (HSG A/B) or greater for shortest disconnection flow path lengths, in less permeable soils (HSG C and D) the disconnection length is longer. Soils in treatment area must meet Post-Construction Soil Depth and Quality standard
	Contributing Drainage Area	Rooftops, sidewalks, recreation paths, and residential driveways only < 1,000 ft^2 draining to each discharge point/ treatment area Maximum contributing impervious length 75 ft.
Conveyance	Flow Regulation	Runoff must enter disconnection areas as sheet flow for the water quality storm (1" storm) and cannot be allowed to channelize
		Flow spreading device required at each downspout outlet to distribute flow evenly
Pre-Treatment		Not required for qualifying impervious surfaces indicated above Debris screens for downspouts recommended
Treatment	Required Area	Disconnection length based on slope and hydrologic soil group
	Disconnection Area Width	Minimum 12 feet
	Disconnection Area Length	Minimum 35 feet (HSG A/B) when slopes less than 8% Minimum 50 feet (HSG A/B) when slopes are equal to or greater than 8% Minimum 65 feet (HSG C/D) when slopes less than 8% Minimum 85 feet (HSG C/D) when slopes are equal to or greater than 8%
	Credit Towards Standards	T_V credit is equal to the WQ_V of the disconnected site area. Tv can be applied to Re_V.
Other	Vegetation and Landscaping	Contributing area must be stabilized before runoff is directed to facility. Disconnection area must be densely vegetated.
	Maintenance	General landscaping maintenance and annual inspections



Sources: VA DCR, 2013; NC DENR, 2014

Figure 4-9. Example of Simple Disconnection (Plan View)



Source: Modified from VA DCR, 2013

Figure 4-10. Simple Disconnection (Cross Section and Profiles)

4.2.3.2. Simple Disconnection Feasibility

Required Elements

- A permeable, vegetated treatment flow path equal in length to the minimum flow path length needed for treatment (see Table 4-2, below) must be available down gradient (downslope) of the rooftop to effectively disconnect runoff. An exception is made for impervious surface contributing lengths less than or equal to 10 feet, for which a disconnection length equal to the contributing length shall be specified.
- The treatment area receiving disconnected runoff must be located outside of regulated wetland areas and regulated buffers to a waterbody or wetland.
- The soils underlying the receiving disconnection area must, at minimum, meet the criteria included in the Post-Construction Soil Depth and Quality standard (Section 3.1).
- The contributing surface impervious area to any one discharge location must not exceed 1,000 ft^2. The contributing rooftop area to an individual downspout shall not exceed 1,000 ft^2.
- The maximum contributing impervious flow path length to any one discharge location shall be 75 feet.
- Parking lots shall not be directed to Simple Disconnection areas. Parking lots require pre-treatment and may be disconnected in accordance with the "Disconnection to Filter Strips and Vegetated Buffers" section of this chapter (4.2.3).
- Receiving areas may be adjacent to each other, but there shall be no overlap.
- The vegetated area shall have a maximum slope of 15% with land graded to promote sheet flow. Terraces, berms, or similar grade controls shall be placed every 20 feet along the flow path where maximum slopes exceed 8%.
- For sites with septic systems, the disconnection flow path must be cross-gradient or down-gradient of the leachfield primary and reserve areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the leachfield.

Design Guidance

- Simple disconnection may be used on any soil type, though the required disconnection length along the disconnection flow path varies as a function of infiltration capacity (see Table 4-2, below).
- Simple disconnection is generally not advisable for use on very small residential lots (less than 6,000 square feet in area), although it is often possible to employ an alternate practice.
- Simple disconnection areas should be located at least 25 feet from any property boundaries and consider downslope abutters.

4.2.3.3. Simple Disconnection Conveyance

Required Elements

- Runoff must enter the disconnection area as sheet flow for the applicable design storms and shall not be allowed to channelize.

- Runoff must be conveyed as sheet flow onto and across open areas to maintain proper disconnection. Disconnections shall be located on gradual slopes (≤ 8% maximum without grade controls) and directed away from buildings to both maintain sheet flow and prevent water damage to basements and foundations. If the maximum slope in the disconnection flow path is between 8% and 15%, additional measures (such as terraces or berms) are required every 20 feet along the flow path to maintain sheet flow.
- Where provided, downspouts must be at least 10 feet away from the nearest impervious surface to prevent reconnection to the stormwater drainage system.
- A clean stone diaphragm, level spreader, splash pad, or other accepted flow spreading device shall be installed at each downspout outlet to distribute flows evenly across the flow path.
- Where a gutter/downspout system is not used, runoff must drain as either sheet flow from the contributing surface or drain to a subsurface drain field that is not directly connected to the drainage network.

Design Guidance

- A minimum separation of 5 feet should be provided between the disconnected downspout and building foundations.
- Larger storms that are not applicable should be considered in the design of the sheet flow maintaining devices.

4.2.3.4. Simple Disconnection Pre-Treatment

Required Elements

- Surfaces that qualify for simple disconnection do not require pre-treatment provided that the runoff from those surfaces does not comingle with other runoff.

Design Guidance

- Downspouts for conveying rooftop runoff should be equipped with leaf screens to prevent clogging.

4.2.3.5. Simple Disconnection Treatment

Required Elements

- Flow from each downspout shall be spread over a minimum 12-foot wide disconnection flow path extending down-gradient from the structure.
- A permeable, vegetated treatment area equal to the minimum flow path length needed for treatment (see Table 4-1, below) must be available down gradient (downslope) of the impervious cover to effectively disconnect runoff. Qualifying impervious surfaces with contributing lengths less than 10 feet may provide a disconnection length equal to the contributing length on slopes less than 8% or twice the contributing length on slopes between 8 and 15%.

Table 4-1. Required Simple Disconnection Lengths (in direction of flow) by Soil Infiltration Rate and Slope Class

HSG of soil in disconnection area	Disconnection Area Slope	
	Less than 8%	8-15%
A/B or infiltration rate >=0.5 in./hr	35 feet	50 feet
C/D or infiltration rate < 0.5 in./hr	65 feet	85 feet

- Areas disconnected in accordance with this standard shall receive T_V credit equal to the WQ_V of the disconnected area. T_V for disconnections may be applied to the Recharge Standard where it applies.

4.2.3.6. Simple Disconnection Vegetation and Landscaping

Required Elements

- A dense and vigorous vegetative cover shall be established over the receiving areas.

Design Guidance

- If appropriate vegetation is not already established on site, then seed blend application is recommended. Seed blends should be selected based on local climate. Non-clumping grass species should be selected.
- Runoff may be directed to lawns or as sheet flow to undisturbed natural areas – either forest (with a well-distributed stand of trees) or meadow (with dense grasses and/or shrubs that is mown no more than twice per year).
- Excessively fertilized lawn areas are not considered appropriate receiving areas. In order for lawns to be considered, they must consist of low-maintenance grasses adapted to the New England region.

4.2.3.7. Simple Disconnection Construction Sequencing

Required Elements

- The vegetated receiving area and areas of the site adjacent to the vegetated receiving area shall be stabilized with vegetation, mulch, straw, seed, sod, fiber blankets or other appropriate cover before runoff is routed to the receiving area.

Design Guidance

The following is a typical construction sequence to properly install simple disconnection.

- Design rooftop downspouts and disconnection drainage paths according to maximum contributing drainage area and length standards.
- Ensure that the vegetated receiving areas are uniformly graded with no gullies, low spots, or lateral slopes. Install grade controls as needed. Alternately, measure and delineate natural areas to be used. Avoid compaction of receiving areas.
- Inspect graded area to ensure compliance with the Post-Construction Soil Depth and Quality standard (Section 3.1).

- Install dispersion measures.
- Seed receiving areas as needed to establish vegetation and stabilize soils with straw or matting until vegetation is established.

4.2.3.8. Simple Disconnection Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- After construction, simple disconnection practices shall be inspected following the first two precipitation events of at least 1.0 inch to ensure that the disconnection is functioning properly. Thereafter, inspections shall be conducted on an annual basis.

4.2.3.9. Simple Disconnection Maintenance – Annual

Required Elements

- Inspect practice for consistency with maintenance plan, including any narrative inspection and maintenance requirements.
- Inspection shall verify that sheet flow is being maintained and there is no evidence of areas of concentrated flow or erosion.
- Annual inspections should ensure that:
    - Flows through the disconnection flow path are not channeling or short circuiting;
    - Debris, including leaf matter, and sediment does not build up at the top of the flow path;
    - Level spreaders and energy dissipaters are functioning correctly;
    - Scour and erosion do not occur within the flow path;
    - Sediments and/or decomposed leaves or other debris are cleaned out of conveyance path;
    - Receiving areas maintain healthy and dense vegetation.

Design Guidance

- Maintenance of a simple disconnection flow path typically includes traditional lawn or landscaping maintenance. In some cases, runoff from a simple disconnection may be directed to a more natural, undisturbed setting, thereby reducing or even eliminating the need for maintenance.

4.2.3.10. References

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4.2.4. Disconnection to Filter Strips and Vegetated Buffers

The use of disconnection can provide groundwater recharge and can reduce the volume of runoff exiting the site, reduce pollutant and sediment loads, and reduce or slow peak flows. Filter strips and buffer zones are vegetated areas that receive runoff from adjacent impervious or managed turf surfaces and allow runoff to be slowed and filtered by plants and soil and to infiltrate into the ground. Buffer zones are undisturbed or restored natural open space areas that are protected from development, and may be forested (with a well-distributed stand of trees) or meadow (with dense grasses and/or shrubs that are mown no more than twice per year). Filter strips are managed or engineered vegetated areas, usually adjacent to contributing developed areas.

The effectiveness of disconnection varies considerably based on site conditions such as the contributing drainage area, slope and site grading, and the size and infiltration capacity of the pervious receiving area. Dense vegetative cover, long disconnection lengths, and low surface slopes provide the most effective vegetated filters. Vegetated filter strips and buffer zones are best suited to treating runoff from small segments of impervious cover such as road shoulders and small parking lots that are adjacent to pervious surfaces.

There are two typical configurations for conveying runoff from larger rooftops or ground-level impervious surfaces to filter strips or buffer zones:

- When runoff uniformly enters the practice along a linear edge (such as at the edge of a road or parking lot) and drains down-slope across the filter strip's (or buffer zone's) length, a clean stone diaphragm or similar pre-treatment practice serves as a non-erosive transition between the impervious surface and the filter strip or buffer zone.
- Where the inflow to the practice is concentrated flow from a pipe or channel, an engineered level spreader must be designed to convert the concentrated flow back to sheet flow.

4.2.4.1. Design Summary

Criteria	Element	Requirements
Feasibility	Disconnection Slope	15% or less for filter strips, 8% for buffer zones (maximum slope in disconnection area)
	Soils	Infiltration rate of 0.5 in/hr or greater (HSG A and B) for shortest disconnection flow path lengths; in less permeable soils (HSG C and D) the disconnection length is increased 15-20% Soils in treatment area must meet Post-Construction Soil Depth and Quality standard
	Contributing Drainage Area	Depends on available receiving area, maximum 75 ft. impervious contributing flow path and 150 ft. pervious contributing flow path
Conveyance	Flow Regulation	Non-erosive (3.5 to 5.0 fps) peak velocity for the 1-year storm
		Runoff must enter disconnection areas as sheet flow for the water quality storm (1" storm)
		Terraces, berms, or other grade controls required every 20 feet if slope >8%
	High Flow Bypass	Required if runoff delivered to disconnection area via concentrated flow
	Flow Spreading Devices	Stone diaphragm required for dispersion of sheet flow into disconnection areas Engineered level spreader required for dispersion of concentrated flow into disconnection areas
Pre-Treatment		Stone diaphragm required for runoff delivered to disconnection via sheet flow Forebay and level spreader required if runoff is conveyed via pipe or concentrated flow
Treatment	Required Area	Disconnection length along flow path based on land cover, slope and soil infiltration rate
	Disconnection Area Width	Width of disconnected impervious surface for sheet flow Level spreader length (and thus disconnection area width) for concentrated flow based on peak WQ_v flow rate and land cover in disconnection area (min. 13 feet, max. 130 feet).
	Disconnection Area Length	Minimum 35 feet (HSG A/B when slopes less than 8% Minimum 50 feet (HSG A/B) when slopes are equal to or greater than 8% Minimum 65 feet (HSG C/D) when slopes less than 8% Minimum 85 feet (HSG C/D) when slopes are equal to or greater than 8%
	Credit Towards Standards	T_v credit is equal to the WQ_v of the disconnected site area.
Other	Vegetation and Landscaping	Contributing area must be stabilized before runoff is directed to facility. Disconnection area must be densely vegetated, either in a natural state for buffer zones or managed state for filter strips
	Maintenance	General landscaping maintenance and annual inspections

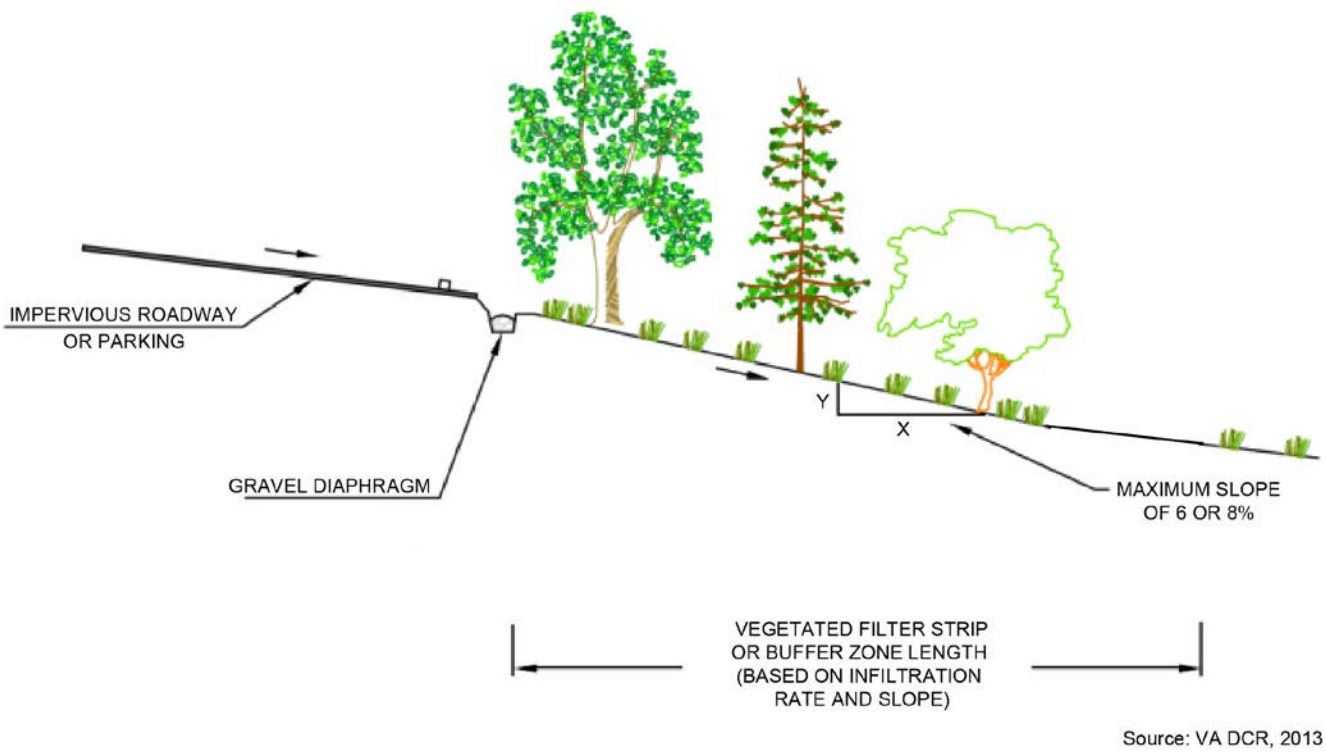

Figure 4-11. Typical Section, Disconnection to Filter Strip or Buffer Zone via Sheet Flow

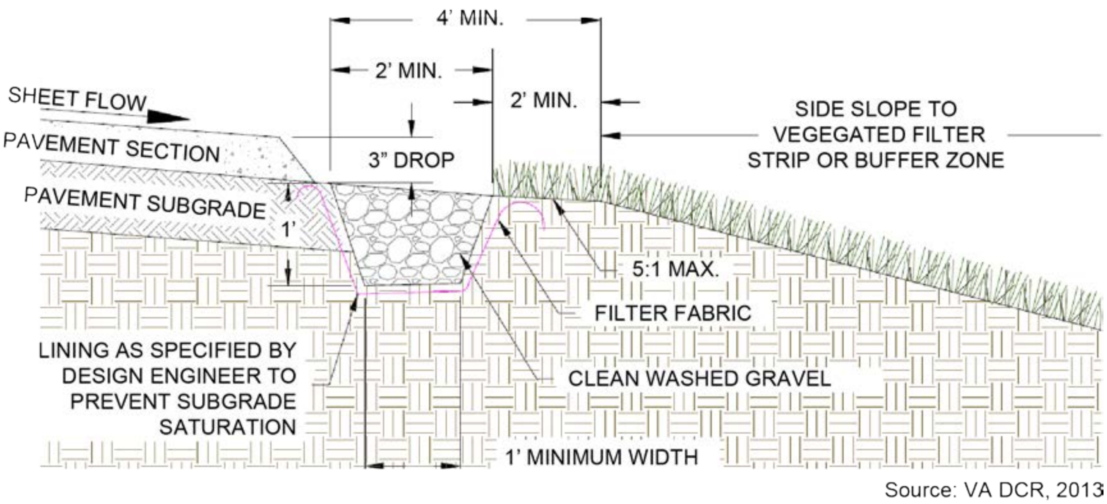

Figure 4-12. Stone Diaphragm – Sheet Flow Pre-treatment

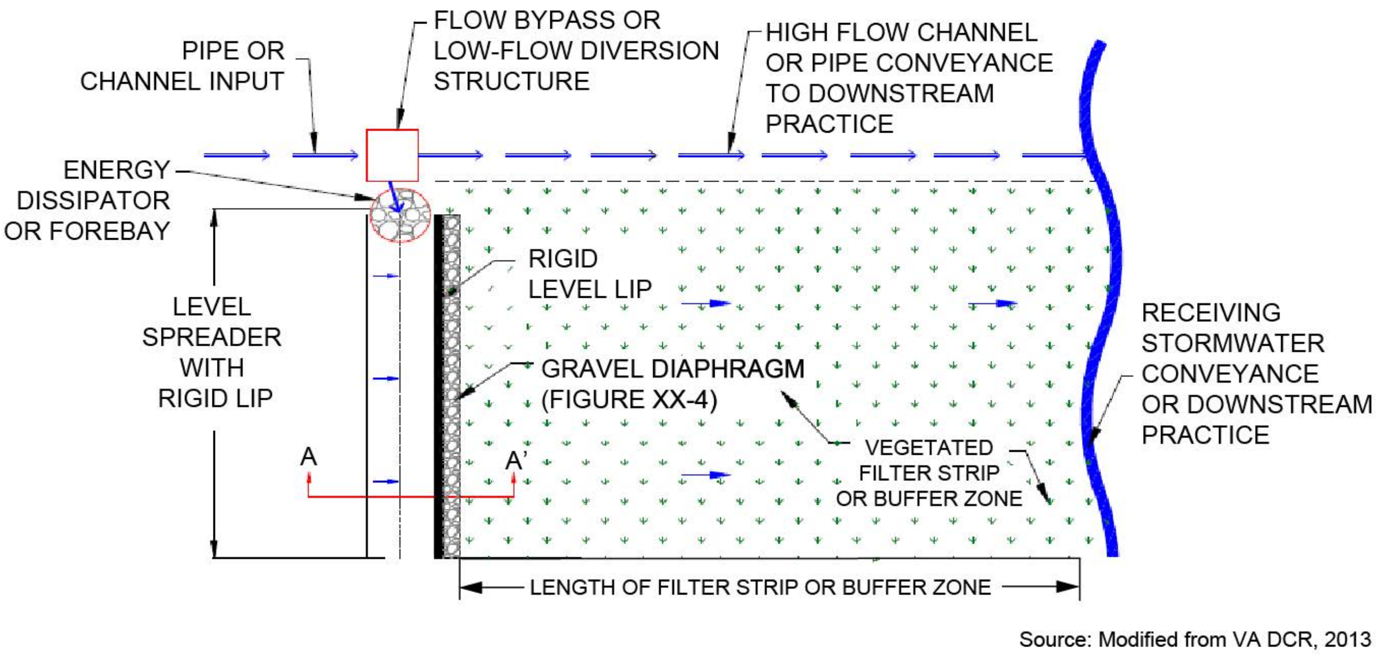

Figure 4-13. Plan View – Disconnection of Concentrated Flow by Rigid Level Lip Spreader

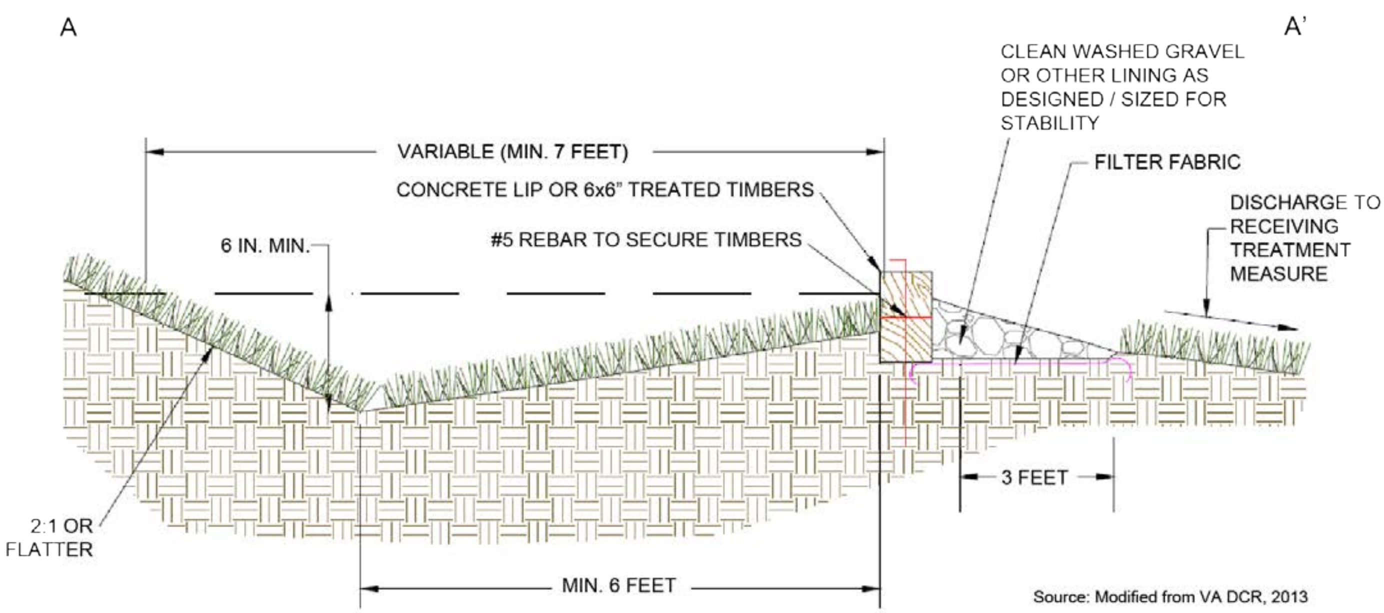

Figure 4-14. Cross Section – Level Spreader with Rigid Lip

4.2.4.2. Disconnection to Filter Strips and Vegetated Buffers Feasibility

Required Elements

- A permeable, vegetated treatment area equal to the minimum disconnection area length needed for treatment (Table 4-3) must be available down gradient (downslope) of the impervious cover to effectively disconnect runoff.
- The entire required disconnection area length must be located outside of regulated wetland areas and regulated buffers to a waterbody or wetland.
- The soils underlying the receiving disconnection area must, at minimum, meet the criteria included in the Post-Construction Soil Depth and Quality standard (Section 3.1).
- Buffer zones shall remain in a natural state and must be protected to ensure that no future development, disturbance, or clearing may occur within the area.
- Vegetated filter strips shall be identified and protected to ensure that no future development, disturbance or clearing may occur within the area, except as stipulated in the vegetation maintenance plan.
- The maximum contributing impervious flow path length to any one discharge location shall be 75 feet, and the maximum contributing pervious flow path shall be 150 feet for runoff delivered to the disconnection area as sheet flow via a stone diaphragm. Longer contributing flow paths may be possible with proper conveyance and engineered level spreaders.
- Buffer zones and filter strips may be adjacent to each other, but there shall be no overlap.
- Buffer zones shall have a maximum slope of 8%, while vegetated filter strips shall have a maximum slope of 15%.
- To qualify for shorter disconnection flow paths, the soils shall have an infiltration rate (f_c) of at least 0.5 inches per hour (e.g., HSG A or B soils), as confirmed by field geotechnical tests (see Appendix C1 of the VSMM, Vol. 2).
- Low-permeability soils with an infiltration rate of less than 0.5 inches per hour (e.g., HSG C or D soils) shall require a longer flow path (see Table 4-3, below).
- For sites with septic systems, the disconnection flow path must be cross-gradient or down-gradient of the leachfield primary and reserve areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the leachfield.

Design Guidance

- The overall contributing drainage area should be relatively flat to ensure sheet flow draining into the filter strip. Where this is not possible, alternative measures, such as an engineered level spreader, can be used.
- Simple disconnection areas should be located at least 25 feet from any property boundaries and consider downslope abutters.

4.2.4.3. Disconnection to Filter Strips and Vegetated Buffers Conveyance

Required Elements

- A clean stone diaphragm or level spreader shall be provided from the disconnected area to the vegetated area to assure that runoff will flow in a safe and non-erosive manner during larger storm events.
- Runoff must be conveyed as sheet flow onto and across open areas to maintain proper disconnection. Disconnections shall be located on gradual slopes (≤ 8% without grade controls) and directed away from buildings to both maintain sheet flow and prevent water damage to basements and foundations. If the maximum slope in the disconnection flow path is between 8% and 15%, additional measures (such as terraces or berms) are required every 20 feet along the flow path to maintain sheet flow.
- The maximum contributing impervious flow path length shall be 75 feet, and the maximum contributing pervious flow path shall be 150 feet to prevent concentration of flow. Longer contributing flow paths may be possible with proper conveyance and engineered level spreaders.
- Stone Diaphragms: A diaphragm of clean stone at the top of the slope is required for both buffer zones and filter strips that receive sheet flow (Figure 4-11 and Figure 4-12).
    - The clean stone diaphragm is created by excavating a 2-foot wide and 1-foot deep trench that runs on the same contour at the top of the filter strip.
    - Flow shall travel over the impervious area and to the practice as sheet flow, and then drop at least 2 inches onto the gravel diaphragm.
    - A layer of filter fabric should be placed between the gravel and the underlying soil trench.
    - If the contributing drainage area is steep (6% slope or greater), then larger stone (clean bank-run gravel) shall be used in the diaphragm, or an engineered level spreader shall be used in place of the gravel diaphragm.
- Engineered Level Spreaders: An engineered level spreader at the top of the slope is required for buffer zones and filter strips that receive concentrated flow from a swale or pipe conveyance, in order to ensure non-erosive sheet flow into the treatment area. Key design elements of the engineered level spreader, as provided in Figure 4-13 and Figure 4-14, include the following:
    - A high flow bypass shall provide safe passage for storms larger than the design storm of the level spreader (Figure 4-13). The bypass channel shall accommodate all peak flows of the bypassed storms.
    - Level spreader length shall be determined by the type of filter area and the design flow. The design flow shall be the peak discharge of the largest storm event routed to the level spreader:
        - 13 feet of level spreader length per every 1 cubic foot per second (cfs) of inflow for discharges to a filter strip or buffer zone consisting of native grasses or thick ground cover;
        - 40 feet of level spreader length per every 1 cfs of inflow when the spreader discharges to a conserved open space consisting of forested or reforested buffer.

    - Where the conserved open space is a mix of grass and forest (or re-forested), the level spreader length shall be established by computing a weighted average of the lengths required for each vegetation type.
    - The minimum level spreader length is 13 feet and the maximum is 130 feet.
    - For determining the level spreader length, the peak discharge shall be determined using the computational procedure outlined in Section 2.6.2.
  - The level spreader lip shall be concrete, wood, pre-fabricated metal, or other durable non-erodible material with a well-anchored and frost-protected footer. Level spreaders must be designed and installed level (uniform 0% slope) and straight or convex in plan view.
  - The ends of the level spreader section shall be tied back into the slope to avoid scouring around the ends of the level spreader.
  - The width of the level spreader channel on the up-stream side of the level lip shall be three times the diameter of the inflow pipe, and the depth shall be 9 inches or one-half the inflow pipe diameter, whichever is greater. The width of the level spreader channel shall be a minimum of 7 feet (Figure 4-14).
  - The level spreader lip shall be placed 3 to 6 inches above the downstream natural grade elevation to avoid blockage due to turf buildup. In order to prevent grade drops that re-concentrate the flows, a 3-foot wide section of open-graded coarse aggregate with a 1" to 2.5" particle size distribution, underlain by filter fabric, shall be installed just below the spreader to transition from the level spreader to natural grade.
  - Vegetated receiving areas down-gradient from the level spreader must be able to withstand the force of the flow coming over the lip of the device.

4.2.4.4. Disconnection to Filter Strips and Vegetated Buffers Pre-Treatment

If rooftop runoff is disconnected to a filter strip or buffer zone, pre-treatment is not required, provided the runoff is routed to the receiving area in a manner such that it is unlikely to accumulate significant additional sediment (e.g., via grass channel), and provided the runoff is not commingled with other runoff.

Required Elements

- A clean stone diaphragm is required as pre-treatment where runoff enters a filter strip or buffer zone via sheet flow (see previous section).
- If stormwater is routed to forebay for required pre-treatment, forebay shall be volumetrically sized for 10% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.

Design Guidance

- If the use of road sand is anticipated in the contributing drainage area and runoff is delivered to the buffer zone or filter strip as concentrated flow, the pre-treatment practice should be sized to account for the increased sediment load resulting from road sand application.

4.2.4.5. Disconnection to Filter Strips and Vegetated Buffers Treatment

Required Elements

- A permeable, vegetated treatment area equal to the minimum disconnection area length needed for treatment (see Table 4-2, below) must be available down gradient (downslope) of the impervious cover to effectively disconnect runoff.
- Buffer zones and filter strips shall be fully vegetated.
- Buffer zones shall remain ungraded and uncompacted to meet the Post-Construction Soil Depth and Quality standard (Section 3.1), and the over-story and under-story vegetation shall be maintained in a natural condition.

Filter strips shall be uniformly graded to less than 15% slope, have a uniform transverse slope, meet the Post-Construction Soil Depth and Quality standard (Section 3.1), and be densely vegetated. Table 4-2. Required Filter Strip and Buffer Zone Lengths (in direction of flow) by Soil Infiltration Rate and Slope Class

HSG of soil in disconnection area	Maximum Disconnection Area Slope	
	Less than 8%	8-15% (filter strips only)
A/B or infiltration rate >=0.5 in./hr	35 feet	50 feet
C/D or infiltration rate < 0.5 in./hr	65 feet	85 feet

- Areas disconnected in accordance with this standard shall receive T_V credit equal to the WQ_V of the disconnected area. T_V for disconnections may be applied to the Recharge Standard where it applies.

4.2.4.6. Disconnection to Filter Strips and Vegetated Buffers Vegetation and Landscaping

Required Elements

- A minimum 90% vegetative cover shall be maintained within buffer zones through natural propagation or targeted planting of native or non-invasive, naturalized species. No grading or clearing of native vegetation is allowed within buffer zones.
- Vegetated filter strips shall be planted at such a density to achieve a 90% grass/herbaceous cover after the second growing season. The filter strip vegetation may consist of turf grasses, meadow grasses, other herbaceous plants, shrubs, and trees, as long as the primary goal of at least 90% coverage with grasses and/or other herbaceous plants is achieved.

Design Guidance

- For vegetated filter strips seeding is recommended over sodding, as seeding develops a better root system and sod may be grown on muck soils that inhibit infiltration. Designers should select vegetation that stabilizes the soil and is salt tolerant.
- At some sites, the proposed buffer zone may be in turf or meadow cover, or overrun with invasive plants and vines. In these situations, a reforestation or restoration plan for the buffer zone may be prepared consistent with the Reforestation practice standard (Section 4.2.1).

- Considerations for invasive species management should be included in landscaping and maintenance plans for buffer zones.

4.2.4.7. Disconnection to Filter Strips and Vegetated Buffers Construction Sequencing

Required Elements

- Do not connect vegetated receiving areas, including associated clean stone diaphragms or level spreaders, until:
    - Impervious areas that will drain to the disconnection practices are completed.
    - Areas of the site adjacent to the buffer zone or filter strip are stabilized with vegetation, mulch, straw, seed, sod, fiber blankets or other appropriate cover.
    - The vegetated receiving area and areas of the site adjacent to the vegetated receiving area shall be stabilized with vegetation, mulch, straw, seed, sod, fiber blankets or other appropriate cover.

Design Guidance – Buffer Zones

The following is a typical construction sequence to properly construct disconnection to a buffer zone.

- Before site work begins, vegetated buffer zone boundaries shall be clearly marked.
- No clearing, grading or heavy equipment access is allowed in natural buffer zones except temporary disturbances associated with incidental utility construction, restoration operations, or management of nuisance vegetation. If light grading is needed at the buffer zone boundary, this shall be completed with tracked vehicles to minimize compaction.
- The perimeter of the conserved buffer zone shall be protected from construction sediment using silt fence or appropriate practices, since the area is down gradient from areas of construction.
- The buffer zone should be inspected for appropriate vegetation and density. If invasive species are present, or vegetative cover in the buffer is less than 90%, invasive plants should be controlled and/or targeted planting of native or non-invasive, naturalized species should be completed.
- Construction of the gravel diaphragm or engineered level spreader shall not commence until the contributing drainage area has been stabilized and perimeter erosion and sedimentation controls have been removed and/or cleaned out.
- Stormwater shall not be diverted into the buffer zone until the clean stone diaphragm and/or level spreader are installed and stabilized.

Design Guidance - Filter Strips

Vegetated filter strips can be within the limits of disturbance during construction. The following is a typical construction sequence to properly install a vegetated filter strip.

- Before site work begins, vegetated filter strip boundaries shall be clearly marked.
- Only vehicular traffic used for filter strip construction shall be allowed within 10 feet of the filter strip.

- If existing topsoil is stripped during grading, it shall be stockpiled for later use.
- Construction runoff shall be directed away from the proposed filter strip site using appropriate erosion control measures and a diversion dike or other measure.
- Construction of the gravel diaphragm or level spreader shall not commence until the contributing drainage area has been stabilized and perimeter erosion and sedimentation controls have been removed and/or cleaned out.
- Vegetated filter strips require light grading to achieve desired elevations and slopes. This shall be completed using tracked vehicles to minimize compaction. Topsoil and/or compost amendments shall be incorporated evenly across the filter strip area, stabilized with seed, and protected by biodegradable erosion control matting or blankets.
- Stormwater should not be diverted into the filter strip until the turf or vegetative cover is dense and well established.

4.2.4.8. Disconnection to Filter Strips and Buffer Zones Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- After construction, disconnection practices shall be inspected following the first two precipitation events of at least 1.0 inch to ensure that the system is functioning properly. Thereafter, inspections shall be conducted on an annual basis.

4.2.4.9. Disconnection to Filter Strips and Vegetated Buffers Maintenance – Annual

Required Elements

- Inspect practice for consistency with annotated design plan provided with permit, including any narrative inspection and maintenance requirements.

Design Guidance

- Annual inspections should be used to trigger maintenance operations such as sediment removal, spot re-vegetation and level spreader repair.
- Annual inspections should check to ensure that:
    - Flows through the filter strip or buffer zone do not short-circuit the overflow control section;
    - Debris and sediment does not build up at the top of the filter strip or buffer zone;
    - Foot or vehicular traffic does not compromise the gravel diaphragm;
    - Scour and erosion do not occur within the filter strip or buffer zone;
    - Sediment is cleaned out of level spreader, forebays and flow splitters;
    - Vegetative density exceeds a 90% cover in the buffer zone or filter strip; and

    - Buffer zones are free of invasive species.

- If the disconnection area is a meadow buffer zone or vegetated filter strip, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If the disconnection area is a wooded buffer zone, then the buffer should be maintained in an undisturbed condition, unless erosion occurs. If erosion of the buffer zone occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.

4.2.4.10. Disconnection to Filter Strips and Vegetated Buffers References

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4.2.5. Watershed Hydrology Protection

This standard is applicable only to high elevation renewable energy projects and may be applied when a group of practices are used to protect water quality. High elevation is defined as mountainous terrain and shall include locations exceeding 1,500 feet in elevation, or as otherwise determined by the Secretary based on an evaluation of site specific conditions including topographic relief relative to surrounding lands, and slope. The Watershed Hydrology Protection Standard is applicable to all portions of a project that are determined to be "high elevation" and adjoining project lands at lower elevation that are otherwise able to meet the standard.

The Water Quality Treatment Standard, Groundwater Recharge Standard, and Channel Protection Standards are completely met for portions of a project where the discharges from which satisfy this standard. The Post-Construction Soil Depth and Quality standard must still be met for applicable site areas (Section 3.1).

Under this standard, all project development must be designed, constructed, and maintained to prevent the undue alteration of the site's natural hydrology. This includes maintaining natural forest cover, and protecting the site's surface and subsurface drainage through the promotion of runoff dispersal, the preservation of natural surface and sub-surface drainage features, and the maintenance of the natural groundwater conditions.

4.2.5.1. Design Summary

Criteria	Element	Requirements
Feasibility	Impervious Cover	Shall not exceed 5% in any watershed within the site If 5% IC exceeded, criteria is met when pre-routed post-developed discharge does not exceed 2 cfs for the 1-year 24 hour storm event (See Channel Protection Standard for waiver requirements)
	Land Cover	Contributing watershed shall be at a minimum, 90% forested land
	Stream Buffers	Required except for construction of necessary stream crossings Buffer widths based on slope per Table 4-3, minimum width 50 feet
	Site Plan	Must include two-foot elevation contours; all surface water features 150' upslope of limits of disturbance and within required distances of all down-slope disconnection areas; all surface channels with potential to concentrate runoff; all areas with potential for significant flow of shallow groundwater flow, including oxyaquic soils
Pre-Treatment		Incorporated into Conveyance and Treatment
Conveyance and Treatment	Collection and Bypass of Runoff and Groundwater	Road ditches in excess of 5% slope shall be stone lined OR have permanent stone check dams installed per calculations in Section 4.2.4.3 Frequent cross-drainage must be provided under roads. Unless otherwise required due to presence of groundwater or other drainage features, distances between drainage structures shall be as specified in Table 4-4
	Groundwater Interception	Interception of the groundwater table shall be avoided Where soils occur with potential for significant flow of shallow sub-surface water, roadways must be elevated to avoid cuts into the seasonal high groundwater table Where cuts into groundwater table are unavoidable, french drains, french mattresses, or rock sandwiches must be used to convey groundwater and redistribute seepage downslope Where sub-surface drainage channels contain flows too great to pass through rock sandwich, culvert must be installed to pass under road and reconnect to downslope subsurface drainage
	Redistribution and Disconnection of Stormwater	Topography must allow runoff to remain well-distributed Vegetation in disconnections must be consistent with Section 4.2.4.3 Disconnection meeting this standard not allowed on wetland soils or on natural slopes over 30%
	Disconnections of Concentrated Flow - Level Spreaders	Concentrated runoff discharges shall be converted to sheet flow using engineeredlevel spreaders: Only allowed for road surfaces, road shoulders, road ditches, and ditch back slopes Peak flow rate from the design storm shall be distribute via sheet flow from the level spreader lip (i.e. flow depth over level lip no greater than 1.2"). Level spreaders shall be constructed per specifications in Section 4.2.4.3 Disconnection flow path shall be a minimum of 150 feet

Criteria	Element	Requirements
	Disconnections of Non-Collected Stormwater – Downhill Side of Road	Non-collected stormwater shall be managed using Disconnection Adjacent to the Downhill Side of Road specifications: Shall only be used where runoff from road surface and shoulder sheets immediately into disconnection. Disconnection flow path length based on vegetative cover type and width of road (Table 4-5); minimum flow path length 55 feet Road bed fill-slopes designed and constructed to allow infiltration per Section 4.2.4.3 may be included in meadow disconnection flow path
Other	Vegetation and Landscaping	Disconnection vegetative cover must be forest, or meadow allowed to regenerate to forest Forest disconnection must have continuous canopy and undisturbed duff over mineral soil Meadow disconnection must have dense cover of grasses, or grasses and (shrubs or trees)
	Maintenance	Annual inspection for consistency with approved design plan

4.2.5.2. Watershed Hydrology Protection Feasibility

Required Elements

- Impervious cover, in aggregate, shall not exceed 5% in any watershed as measured from the project's most downstream discharge point to any given receiving water.
- If the impervious cover exceeds 5% at any given discharge point, the pre-routed post-developed discharge from the site shall not exceed 2 cubic feet per second for the 1-year 24 hour storm event. This requirement is only applicable for discharges relying on this standard for satisfying the requirements of the Channel Protection Standard. Designer shall refer to the Channel Protection Standard for waiver requirements.
- The contributing watershed shall be maintained at a minimum 90% forested land. This requirement is only applicable for discharges relying on the subject standard for satisfying the requirements of the Channel Protection Standard.
- Except for necessary construction of stream crossings, an undisturbed protective strip shall be left along streams and other bodies of water in which only light thinning or selection harvesting can occur so that breaks made in the canopy are minimal and a continuous cover is maintained. The widths of stream buffers or "protective strips" shall be established according to Table 4-3. Distance from stream shall be from top of bank.

Table 4-3. Protective Strip Width Guide

Slope of land Between Roads and Stream Banks or Lake Shores (%)	Width of Strip Between Roads and Stream (Feet Along Surface of Ground)
0-10%	50
11-20%	70
21-30%	90
31-40%*	110

*Add 20 feet for each additional 10 percent side slope except for stream crossing areas

- Projects using this standard shall, at a minimum, provide site plans with the following information:
  - Two-foot elevation contours for the site and all areas relied upon for disconnection.
  - All surface water features, including seeps, wetlands, and vernal pools within 150' upslope of the limits of disturbance, and within the required distances of all down-slope areas relied upon for disconnection (e.g. within 75 feet for disconnection on the downhill side of the road in a forested condition).
  - All surface channels with potential to concentrate runoff within 150' upslope of the limits of disturbance, and within the required distances of all down-slope areas relied upon for disconnection (e.g. within 75 feet for disconnection on the downhill side of the road in a forested condition).
  - All areas with potential for significant flow of shallow groundwater flow, including identification of oxyaquic soils, or wet mineral soils that lack redoximorphic features. The extent of soils characterization may be reduced for portions of a project where the roadway is designed to accommodate the likely maximum surface or shallow groundwater flow.

Design Guidance

- Existing meadow that is managed to allow the meadow to revert to a forested condition may be considered "forested" for purposes of this standard.
- Silvicultural activities, including logging, are allowed provided the lands are under a forest management plan approved by the Agency.

4.2.5.3. Watershed Hydrology Protection Conveyance and Treatment

There are two allowable approaches to managing road runoff: uncollected runoff is managed under "Disconnection Adjacent to Downhill Side of the Road"; collected runoff from ditches is managed under "Disconnection via Level Spreader." General requirements apply to both approaches. Non-road runoff may be disconnected under either approach with the additional provision that the disconnection flow path is a minimum of twice the length of contributing flow path.

Required Elements – Collection and Bypass of Runoff and Groundwater

- All road ditches in excess of 5% slope shall be stone lined per the "Lined Waterway" specifications in the Vermont Standards and Specifications for Erosion Prevention and Sediment Control OR shall have permanent stone check dams installed per the following standards:
  - Check dams shall be spaced as necessary in the channel so that the crest of the downstream dam is at the elevation of the toe of the upstream dam. This spacing is equal to the height of the check dam divided by the channel slope.

    Therefore:

    S = h/s

    Where:
    S = spacing interval (ft.)
    h = height of check dam (ft.)
    s = channel slope (ft./ft.)
  - Check dams shall be comprised of a well graded stone matrix 2 to 9 inches in size.
  - The overflow of the check dams will be stabilized to resist erosion that might be caused by the check dam.
  - Check dams shall be anchored in the channel by a cutoff trench 18 inches wide and 6 inches deep and lined with filter fabric to prevent soil migration.
- Frequent cross-drainage must be provided under roads. Each roadway section aligned across a slope must be constructed to provide for the passage of uphill surface flows under the roadway using culverts, rock sandwiches or other methods to convey flows to the down-slope side of the travel-way. Unless otherwise required due to the presence of groundwater or other drainage features, the distances between drainage structures shall be as follows in Table 4-44.

Table 4-4. Maximum Allowable Distance between Drainage Conveyance Structures

Road Grade (%)	Distance between Structures
1	400
2	250
5	135
10	80
15	60
20	45
25	40
30	35
40	30

- Where the travel-way crosses a permanent or intermittent stream channel or swale, the water must be passed under the travel way and returned to the natural channel on the downhill side of the travel-way.

<u>Required Elements - Groundwater Interception</u>

- Interception of the groundwater table shall be avoided.
- Where medium to coarse textured soils occur with potential for significant flow of shallow sub-surface water, including oxygenated water, the roadway must be elevated to avoid ditch and slope cuts into the seasonal high groundwater table wherever feasible.
- For road sections where ditch cuts or slope cuts into the groundwater table are unavoidable, measures such as use of french drains, french mattresses (i.e. mattress shaped structure made of coarse aggregate), or rock sandwiches, must be used to convey groundwater wherever encountered, and to redistribute the seepage flow to a natural vegetated area on the down-slope side of the travel-way to prevent creating a channel. The length of the flow path in the vegetated area must be at least 50 feet.

  Where sub-surface drainage channels are encountered with flows too great to pass through a rock sandwich, a culvert must be installed to allow the flow to pass under the road and reconnect to the subsurface drainage channel on the down-slope side of the road.

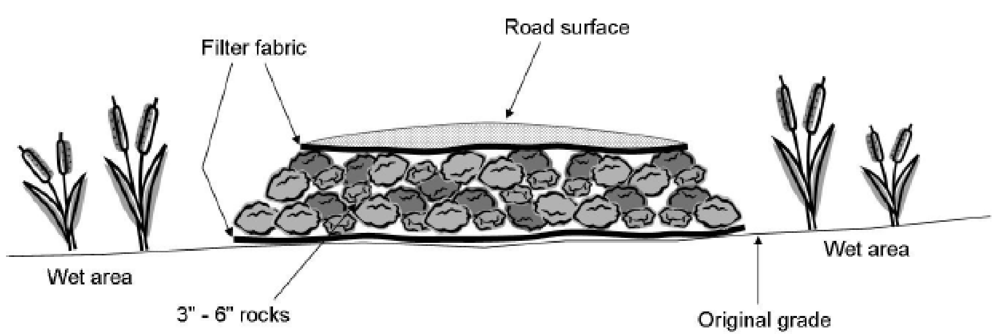

Figure 4-15. Rock Sandwich. Maine DEP, Kennebec County Soil and Water Conservation District, Gravel Road Maintenance Manual (April 2010)

<u>Required Elements - Redistribution and Disconnection of Stormwater</u>

- The topography of a disconnection area must be such that stormwater runoff will remain generally well-distributed. Flow paths across areas that will result in significant collection or channelization are not allowed.
- Vegetation in the disconnection areas must be consistent with the required elements of Section 4.2.4.4 (Watershed Hydrology Protection Vegetation and Landscaping).
- A project discharging concentrated stormwater runoff through a ditch or other conveyance structure shall convert the concentrated flow to sheet flow to prevent erosion of the downstream receiving area per the following Level Spreader specifications:
    - The level spreader disconnection shall be used for collected runoff, including ditch turn outs. Collected runoff shall be diverted to an engineered level spreader that distributes runoff into a disconnection. No areas other than the road surface, road shoulder, road ditch, and ditch back slopes may be directed to the level spreader.
    - The peak flow rate from the design storm shall be distributed via sheet flow from the level spreader lip (i.e. flow depth over level lip no greater than 1.2”).

- The level spreader shall consist of a level lip constructed along the contour and may consist of concrete, wood, stone, or other comparable material. It must be at least one foot high and two feet across the top with 2:1 side slopes. If stone is used for the level lip, stone for the berm must consist of sound durable rock that will not disintegrate by exposure to water or weather. Fieldstone, rough quarried stone, blasted ledge rock or tailings may be used. The rock must be well-graded with a median size of approximately 3 inches and a maximum size of 6 inches.
- The level spreader design shall include sufficient stormwater pre-treatment, and at a minimum shall include a pre-treatment sediment forebay or equivalent pre-treatment storage behind the level spreader lip, that can easily be accessed by maintenance equipment with minimal resulting disturbance following construction.
- Disconnection flow path shall be a minimum of 150 feet.
- A disconnection meeting this standard is not allowed on soils identified as wetland soils or on natural slopes in excess of 30%.

▪ Non-collected stormwater shall be managed in accordance with the following Disconnection Adjacent to the Downhill Side of Road specifications:

- A disconnection adjacent to the downhill side of a road shall only be used when a disconnection is located such that the runoff from the road surface and shoulder sheets immediately into a disconnection. Required disconnection design and sizing for this type of disconnection does not vary with soil type or slope, except that a disconnection meeting this standard is not allowed on soils identified as wetland soils or on natural slopes in excess of 30%.
- Flow path sizing depends on the vegetative cover type of a disconnection and the width of road draining to a disconnection as indicated in Table 4-5.

Table 4-5. Flow Path Sizing

Road Width (feet)	Length of flow path for a forested disconnection (feet)	Length of flow path for a meadow disconnection (feet)
Maximum of 20	55	80
Greater than 20	75	100

- The fill-slope of the road bed may be included as part of a meadow disconnection only if it is designed and constructed to allow infiltration, has a slope not exceeding 30%, provided that vegetation clearing associated with road construction is limited to the extent necessary to accommodate the road’s purpose, and the area is re-vegetated.
- Design and construction to allow infiltration includes, but is not limited to, the in-slope fill material having slopes no steeper than 3:1; constructing a minimum 3” thick top layer of stump grindings; and allowing the surface to re-vegetate naturally. Additionally, fill materials shall consist of well-drained soils or stone.

4.2.5.4. Watershed Hydrology Protection Vegetation and Landscaping

Required Elements

- The vegetative cover type of a disconnection must be either forest or meadow that is allowed to regenerate to forest. In most instances the sizing of a disconnection varies depending on vegetative cover type.
- A forest disconnection must have continuous canopy cover with minimal B-line stocking as determined by USDA Forest Service Silvicultural Guides, and must be maintained as such. A forested disconnection must also have an undisturbed layer of duff covering the mineral soil. Activities that may result in disturbance of the duff layer are prohibited in a disconnection. Silvicultural activities shall be limited to harvesting in dry or winter conditions, with no construction of skidder trails, roads, or landings.
- A meadow disconnection must have a dense cover of grasses, or a combination of grasses and shrubs or trees in the existing condition. A disconnection using a meadow must be allowed to regenerate into forest. If a disconnection is not located on natural soils, but is constructed on fill or reshaped slopes, the constructed disconnection area shall be constructed per the requirements of Table 4-5.

4.2.5.5. Watershed Hydrology Protection Construction Sequencing

Required Elements

- Construction and construction-related equipment shall be prohibited from entering required undisturbed buffers and required "protective strips" and shall be prohibited from entering identified disconnection areas.
- Level spreaders or temporary sediment traps or basins shall not be used to manage/control construction stormwater discharges unless sized for contributing drainage area for 10-year, 24-hour storm event, and designed per the applicable requirements set forth in the Vermont Standards and Specifications for Erosion Prevention and Sediment Control.
- Level spreaders temporarily sized and used to manage/control construction stormwater discharges shall be modified and stabilized to meet post-construction design specifications prior to completion of construction.

4.2.5.6. Watershed Hydrology Protection Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- After construction, disconnection practices shall be inspected following the first two precipitation events of at least 1.0 inch to ensure that the system is functioning properly. Thereafter, inspections shall be conducted on an annual basis.

4.2.5.7. Watershed Hydrology Protection Maintenance – Annual

Required Elements

- Inspect practice for consistency with annotated design plan provided with permit, including any narrative inspection and maintenance requirements

Design Guidance

- Annual inspections should be used to trigger maintenance operations such as sediment removal, spot re-vegetation and level spreader repair.
- Annual inspections should check to ensure that:
  - Concentrated or erosive flows do not occur in the disconnection area;
  - Debris and sediment does not build up in the disconnection area;
  - Sediment is cleaned out of the level spreader, pre-treatment practices, and flow splitters;
  - If the disconnection area is forested, consistent canopy cover is maintained; and
  - Stormwater treatment practices, including but not limited to level spreaders, buffer zones, and required "protective strips," are free of invasive species.
- The buffer should be maintained in an undisturbed condition, unless erosion occurs. If erosion of the buffer zone occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.

4.2.5.8. Watershed Hydrology Protection References

Vermont Department of Environmental Conservation. 2011. Environmental Protection Rules, Chapter 18: Stormwater Management Rule. Effective March 15, 2011. Accessed at http://www.watershedmanagement.vt.gov/stormwater/docs/sw_rule-unimpaired.pdf on February 9, 2015.

Maine Department of Environmental Protection & Kennebec County Soil and Water Conservation District, Gravel Road Maintenance Manual. April 2010. Accessed at http://www.maine.gov/dep/land/watershed/camp/road/gravel_road manual.pdf on February 18, 2016.

4.3. Structural Stormwater Treatment Practices

4.3.1. Bioretention Areas and Rain Gardens

Bioretention practices capture and treat runoff from impervious areas by passing it through a vegetated filter bed, with a filter mixture of sand, soil, and organic matter. Filtered stormwater is either returned to a conveyance system or infiltrated into the native soil. Bioretention is a multi-functional practice that can be easily adapted for new and redevelopment applications, for almost any land use. Stormwater runoff is stored temporarily and filtered in landscaped facilities shaped to take runoff from various sized impervious areas. Bioretention provides water quality treatment and aesthetic value, and can be applied as concave parking lot islands, linear roadway or median filters, terraced slope facilities, residential cul-de-sac islands, and ultra-urban planter boxes.

One of the important design factors to consider in using bioretention is the scale at which it will be applied. Rain gardens are small, distributed practices designed to treat runoff from small areas such as individual rooftops and driveways and are installed in native soils where infiltration can occur and without an underdrain system. Bioretention basins are often used to treat larger drainage areas such as parking lots in commercial or institutional areas and where structural drainage design components are needed (e.g., underdrains, liners, overflow drain inlets). In urban settings, bioretention structures are often incorporated in or retrofitted into tree pits, curb extensions, and foundation planters.

Rain gardens and bioretention facilities are well suited to be used in combination with Simple Disconnection Section 4.2.2) and Disconnection to Filter Strips and Vegetated Buffers (Section 4.2.3). Additional guidance regarding rain gardens can be found in the *Vermont Rain Garden Manual* (http://www.uvm.edu/seagrant/sites/default/files/uploads/publication/VTRainGardenManual_Full.pdf).

4.3.1.1. Design Summary

Criteria	Element	Requirements
Feasibility	Water Table	Bottom of filter media, including gravel sump if any, at or above SHGWT Bioretention designed to infiltrate more the WQ_v, 3 feet separation from bottom of filter media to SHGWT required, unless contributing drainage area (CDA) is less than or equal to 1.0 acre:, then: Minimum of 2 feet separation required when CDA of 1.0 acre or less, is greater than 50% impervious; Minimum of 1 foot separation when CDA of 1.0 acre or less, is less than or equal to 50% impervious. N/A for practices that are lined and underdrained
	Soils	Infiltration rate of 0.2 in/hr or greater if exfiltrating
	Contributing Drainage Area (CDA)	5 acres maximum if CDA is less than or equal to 50% impervious 2.5 acres maximum if CDA is greater than 50% impervious
Conveyance	Flow Regulation	If stormwater is delivered by storm drain, design off-line. For off-line facilities, flow regulator is needed to divert WQ_v to the practice and to bypass larger flows.
	Overflow	Overflow for the 1-year storm to a non-erosive point.
	Underdrains	If not designed to exfiltrate system must be underdrained (minimum 6" perforated pipe underdrain in a 1-foot gravel layer)
Pre-Treatment	Required Pre-treatment	If stormwater is routed to forebay for required pre-treatment, forebay volumetrically sized for 25% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.
Treatment	Required Volume	Total system (including pre-treatment) must be sized to contain 75% of the WQ_v.
	Max. Ponding Depth	12 inches
	Filter Bed Depth	24-48 inches
	Filter Media	Soil media as detailed in Appendix B7, VSMM, Vol. 2
	Storage Layer	Minimum 12 inches below underdrain, if included in design
	Mounding Analysis	Required if practice designed to infiltrate more than the 1-year storm event and vertical separation to seasonal high groundwater table (SHGWT) is less than four feet
	Credit Towards Standards	Volume storage within practice, including pore space and ponding depth, is credited towards WQ_v, for infiltrating practices, this same treatment volume is applied to HC_V. For underdrained practices, HC_V is limited to pore space in the gravel sump.
Other	Vegetation and Landscaping	Contributing area must be stabilized before runoff is directed to facility Detailed landscaping plan required Use of native and salt-tolerant plants recommended

	Maintenance	Inspect annually for consistency with approved design plan Where sediment forebay included, remove sediment ≥6" deep Sediment chamber cleaned if drawdowns exceed 36 hours. Weeding and invasive species control, removal and replacement of dead or diseased vegetation. Routine (annual) trash and debris removal. Silt/sediment removed from filter bed after it reaches 1". If water ponds on filter bed for more than 48 hours, renovate or replace media.

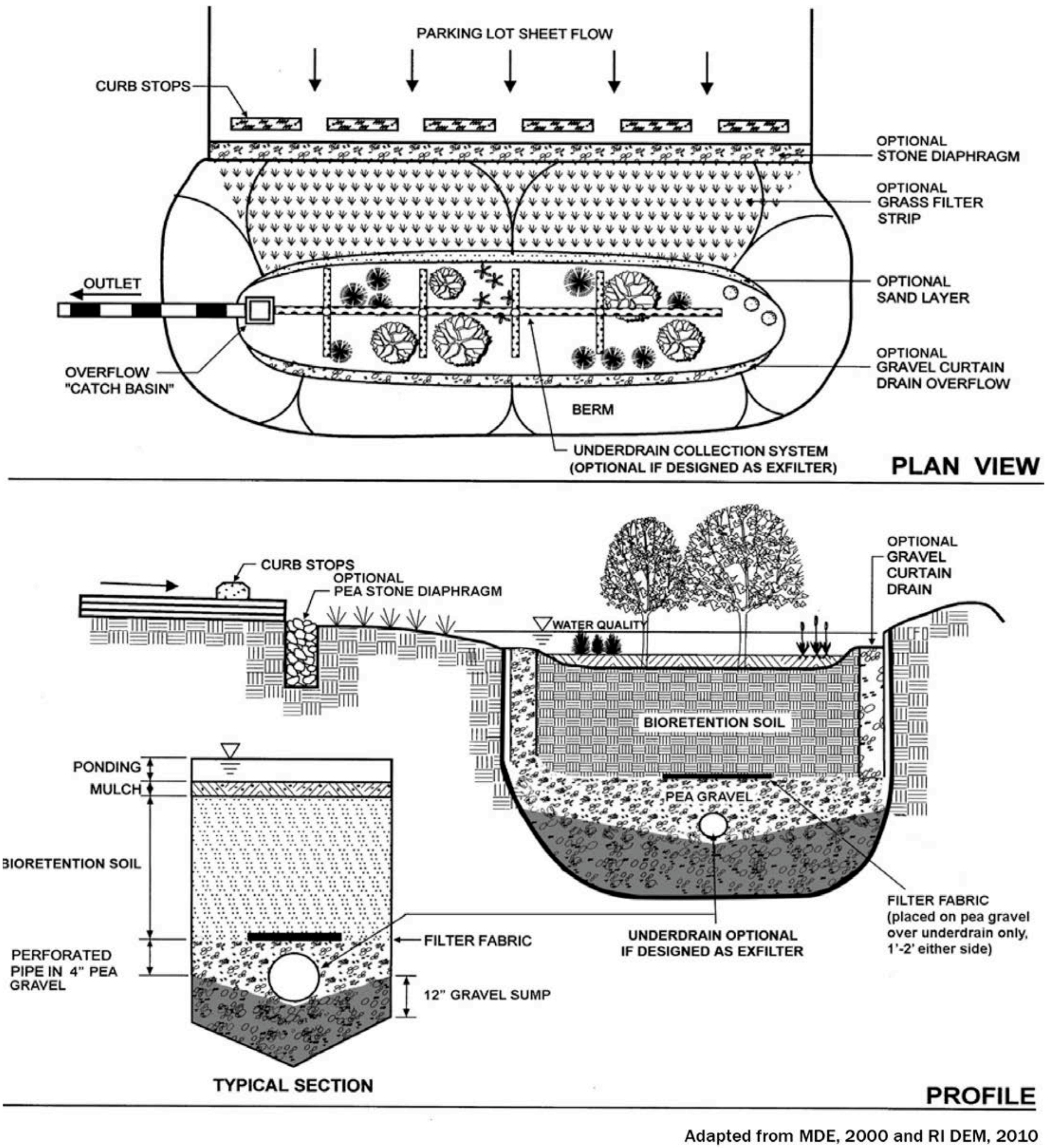

Figure 4-15. Bioretention

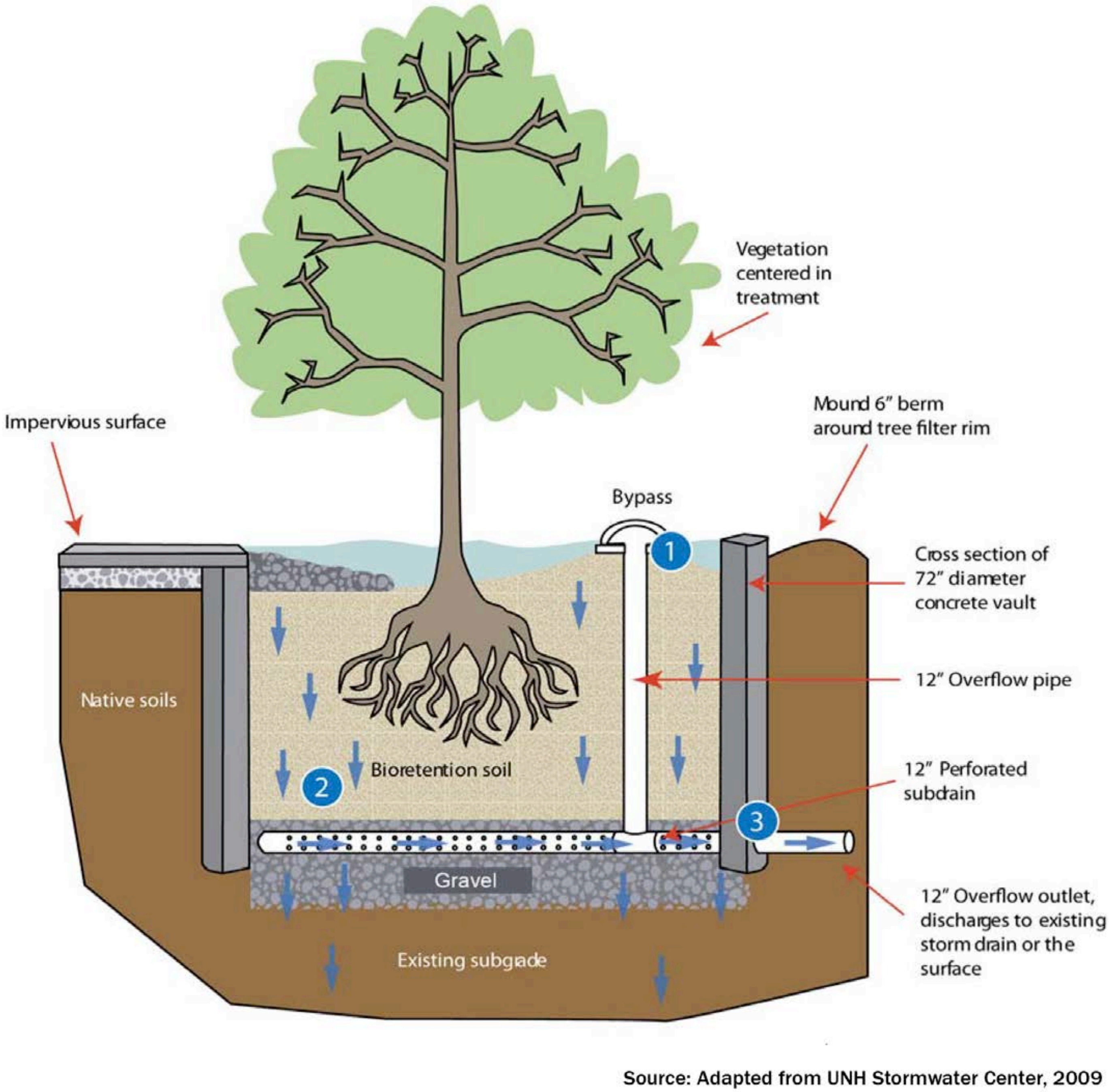

Figure 4-16. Tree Filter

4.3.1.2. Bioretention Feasibility

Required Elements

- The bottom of bioretention systems shall be located at or above the seasonal high groundwater table (SHGWT).
- If the bioretention practice is designed to infiltrate stormwater through the bottom of the practice into underlying soils, the soils shall have an infiltration rate (f_c) of at least 0.2 inches per hour, as confirmed by field geotechnical tests (see Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements).
- For bioretention practices designed to infiltrate stormwater, relevant feasibility required elements for infiltration trench/basin practices must also be met (Section 4.3.6). The separation to SHGWT requirements identified in Section 4.3.6 are not applicable to bioretention practices designed to treat the water quality and groundwater recharge volumes only.
- Systems designed to infiltrate more than the WQ_v shall maintain a minimum 3 foot separation to SHGWT from the bottom of the practice; unless contributing drainage area to the practice is less than or equal to 1.0 acre, than:
  - Minimum of 2 feet separation to SHGWT from bottom of bioretention system when contributing drainage area (CDA) of 1.0 acre or less, is greater than 50% impervious.
  - Minimum of 1 foot separation to SHGWT from bottom of bioretention system when contributing drainage area (CDA) of 1.0 acre or less, is less than or equal to 50% impervious.
- Bioretention practices that are designed to infiltrate more than the 1-year storm event and have a separation from the bottom of the practice to SHGWT of less than four feet shall provide a groundwater mounding analysis based on the Hantush Method or equivalent to demonstrate that the required vertical separation distance between the bottom of the practice and SHGWT can be maintained during and following the design storm (Section 4.3.6 and Appendix C1, VSMM, Vol. 2).
- No soil-related restrictions (minimum separations to seasonal high groundwater or bedrock) are required for bioretention practices that are underdrained and fully enclosed (not designed for infiltration).
- The maximum contributing drainage area to an individual bioretention system shall be 5 acres if impervious cover is less than or equal to 50%. If impervious cover in the contributing drainage area is greater than 50%, the maximum contributing drainage area to an individual bioretention facility shall be 2.5 acres.

Design Guidance

- Slopes of contributing areas should be low to moderate (15% or less). If slopes are too steep (e.g., greater than 8%), then level-spreading devices will be needed to redistribute flow prior to filtering. Filter beds within bioretention practices should be flat or slightly sloping (0.5% maximum). If slopes within bioretention practice are too steep, then a series of check dams, terraces, or berms will be needed to maintain sheet flow internally.
- Tree filters are small bioretention practices that may be contained in a concrete vault with an underdrain connecting to the storm drain system, or may have an open base for infiltration into the underlying soils. All other design criteria and guidance for tree filters are identical to bioretention practices, excepting pre-treatment. Decreased pre-treatment may be warranted in severely constrained site applications and where enhanced maintenance is assured (e.g., a contracted landscaper).

- There are many other forested bioretention practice options, including structural soils and suspended pavement, which can be designed to provide similar or greater stormwater treatment benefits (Stone Environmental 2014a, 2014b). Such options are often most feasible in urban retrofit and redevelopment situations, and designs incorporating these practices are encouraged.

4.3.1.3. Bioretention Conveyance

Required Elements

- Runoff shall enter, flow through, and exit bioretention practices in a safe and non-erosive manner. Flows entering a bioretention facility shall be less than 1.0 foot per second (measured at the end of a stabilized outfall location such as a rip-rap splash pad) to minimize erosion potential. Inflow may be through depressed curbs or curb cuts, or conveyed directly using downspouts, covered drainage pipes, or catch basins.
- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the bioretention practice shall be designed off-line. In these cases, a flow regulator (or flow splitter diversion structure) shall be supplied to divert the WQ_v or HC_v to the filter practice, and allow larger flows to bypass the practice. If bypassing a bioretention practice is impractical, an internal overflow device (e.g., elevated yard inlet) shall be used.
- In cases where bioretention is designed as an on-line practice, an overflow shall be provided within the practice to pass flows in excess of the WQ_v or T_v to a stabilized water course. Designers must indicate how on-line practices will safely pass the 10-year storm without re-suspending or flushing previously trapped material.
- An overflow for the 10-year storm shall be provided to a non-erosive outlet point (i.e., prevent downstream slope erosion).
- Underdrained bioretention practices shall be equipped with a minimum 6" perforated pipe underdrain (8" is preferred) in a 1-foot gravel layer. Synthetic filter fabrics shall not be used to completely separate the filter media from the underdrain bedding material. A 3-inch pea gravel choker course shall be used between underdrain bedding and bioretention media, instead of filter fabric.

Design Guidance

- Bioretention systems should be designed off-line whenever possible. A flow splitter should be used to divert excess high flows away from the filter media to a stable, downstream conveyance system.
- Bioretention practices should be designed to completely drain or dewater within 48 hours (2 days) after a storm event to reduce the potential for nuisance conditions.

4.3.1.4. Bioretention Pre-Treatment

Pre-treatment of roof runoff is not required, provided the runoff is routed to the bioretention practice in a manner such that it is unlikely to accumulate significant additional sediment (e.g., via closed pipe system or grass channel), and provided the runoff is not commingled with other runoff. See Section 4.1 for specific pre-treatment practice requirements and design guidance.

Required Elements

- If stormwater is routed to forebay for required pre-treatment, forebay shall be volumetrically sized for 25% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.

- Pre-treatment for bioretention systems shall incorporate the following (unless a sediment forebay or equivalent pre-treatment is provided for all contributing drainage): grass filter strip below a level spreader or grass channel (using guidelines in Section 4.1) and gravel diaphragm (a small trench running along the edge of the practice).

Design Guidance

- All pre-treatment devices, including sediment forebays, should be designed as level spreaders such that inflows to the filter bed have near zero velocity and spread runoff evenly across the surface.

4.3.1.5. Bioretention Treatment

Required Elements

- A storage volume of at least 75% of the design T_v including the volume over the top of the filter media and the volume in the pretreatment chamber(s), as well within the bioretention soil filter media – is required in order to capture the volume from high-intensity storms prior to filtration and to avoid premature bypass.
- If the cell ponding area uses vegetated soil, then the maximum side slope shall be 2.5:1. If the cell depth exceeds 3 feet, the maximum side slope shall be 3:1. Rockery, concrete walls, or soil wraps shall be used if steeper side slopes are necessary.
- Maximum ponding depth shall be no more than 12 inches above the surface of the filter bed; ponding depths greater than 9 inches will require that the landscaping plan addresses anticipated greater ponding depths to ensure appropriate plant selection.
- Bioretention systems shall consist of the following treatment components: A 24-48 inch deep planting soil bed (depending on requirements of proposed vegetation), a mulch surface layer (or other surface treatment that suppresses weed growth and minimizes exposed soil), and a 6-12 inch deep surface ponding area. Soils shall consist of USDA sand to loamy sand classification and meet the following graduation: sand 85- 88%, silt 8-12%, clay 0-2%, and organic matter (in the form of compost) 3-5%. (see Appendix B7, VSMM, Vol. 2, Construction Specifications for Bioretention)
- A soil phosphorus test using the Mehlich-3 (or equivalent) method is required for facilities with underdrains, to ensure that bioretention soil media will not leach phosphorus. The phosphorus index (P-index) for the soil must be low, between 10 and 30 milligrams per kilogram. A record of the phosphorus test shall be maintained with design and/or permit records and submitted with any applicable stormwater permit design certification requirements.
- The filter area for bioretention shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) should be used as follows:

  Bioretention Soil: 1.0 ft/day for sandy loam soils

  (Note: the above value is conservative to account for clogging associated with accumulated sediment)

  The bioretention filter bed area is computed using the following equation:

$$A_f = \frac{(T_v)(d_f)}{(k)(h_f + d_f)(t_f)}$$

  Where:

A_f = Surface area of filter bed (ft^2)
T_v = Treatment volume (ft^3)
d_f = Filter bed depth (ft)
k = Coefficient of permeability of filter media (ft/day)
h_f = Average height of water above filter bed (ft)
t_f = Design filter bed drain time (days)
(2 days or 48 hours is the recommended maximum t_f for bioretention)

- For infiltrating bioretention systems, credit toward WQ_V, CP_v, Q_p shall be based on the treatment volume provided.
- For bioretention practices used primarily for filtering (e.g., underdrained), credit is given towards CP_v and Q_p only for the void space in the gravel sump beneath the underdrain.

Design Guidance

- The depth of bioretention systems may be reduced to 12" on a case-by-case basis as demonstrated by the designer that the 24" to 48" range is not feasible, such as sites with high groundwater or shallow depth to bedrock or clay soils, or in retrofit situations where pre-existing site constraints exist. In these cases, the designer will need to demonstrate that the facility meets the required 75% T_v storage.
- A soil phosphorus test using the Mehlich-3 (or equivalent) method is required for bioretention soil media in underdrained facilities, but is recommended for all bioretention practices. The phosphorus index (P-index) of 10 - 30 milligrams per kilogram is enough phosphorus to support plant growth, while generally not exporting phosphorus from the cell. When the bioretention soil mix includes lower concentrations of organic matter, a soil test may also be needed to confirm there is adequate phosphorus for plant growth.
- The surface slope bioretention facilities should be level to promote even distribution of flow throughout the practice.
- A mulch layer of shredded hardwood that is well aged (stockpiled or stored for at least 6 months) should be applied to a maximum depth of 3 inches. Hardwood mulch can be very challenging to obtain in New England. Acceptable alternatives include use of softwood mulch, or equivalent alternative, and mulching only around shrubs, and planting a conservation mix elsewhere to create a cover crop that can be mowed or weed-whacked; or planting two species of tall grasses and allowing the whole facility fill in. Regardless of the surface treatment chosen, it should outcompete or suppress weed growth, and minimize exposed soil. Erosion control blankets installed across the bottom of the practice is not successful and should not be proposed.
- Filter beds should be extended below the frost line to prevent the filtering medium from freezing during the winter, or filtering treatment can be combined with another stormwater treatment practice option that can be used as a backup to the filtering system to provide treatment during the winter when the filter bed is frozen.

4.3.1.6. Bioretention Vegetation and Landscaping

Required Elements

- The entire contributing area must be stabilized before runoff can be directed into a filtration practice. A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas, and impervious area construction must be completed.

- Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan must be provided for bioretention areas (see Appendix A, VSMM, Vol. 2).

Design Guidance

Planting recommendations for bioretention facilities are as follows:

- Native plant species should be specified over non-native species, though non-invasive cultivars are also acceptable and can provide the functions needed for a successful bioretention system.
- Vegetation should be selected based on a specified zone of hydric tolerance.
- A selection of trees with an understory of shrubs and herbaceous materials should be provided.
- Woody vegetation should not be specified at inflow locations.
- Trees should be planted primarily along the perimeter of the facility.
- A tree density of approximately one tree per 100 square feet (i.e., 10 feet on-center) is recommended. Shrubs and herbaceous vegetation should generally be planted at higher densities (five feet on-center and 2.5 feet on center, respectively).

4.3.1.7. Bioretention Construction Sequencing

Design Guidance

Construction of the bioretention area should begin after the entire contributing drainage area has been stabilized with vegetation; the bioretention area will fail if sediment is allowed to flow into it. Ideally, bioretention should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment.

The following is a typical construction sequence to properly install a bioretention practice:

- Temporary erosion and sediment controls are needed during construction of the bioretention area to divert stormwater away from the bioretention area until it is completed. Special protection measures such as erosion control fabrics are frequently needed to protect vulnerable side slopes from erosion during the construction phase.
- Any pre-treatment cells should be excavated first and then sealed to trap sediments.
- Excavation work should be completed from the sides to excavate the bioretention area to its appropriate design depth and dimensions. Excavating equipment should never sit inside the footprint of the bioretention area. Contractors should use a cell construction approach in larger bioretention basins, whereby the basin is split into 500 to 1,000 sq. ft. temporary cells with a 10-15 foot earth bridge in between, so that cells can be excavated from the side.
- For silty and clayey soils, where smearing can occur during excavation, it may be necessary to rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.
- Properly install geotextile fabric on the sides of the bioretention facility only, if needed. If a stone storage layer will be used, place the appropriate depth of #57 stone on the bottom, install the perforated underdrain pipe, pack #57 stone to 3 inches above the underdrain pipe, and add approximately 3 inches of choker stone as a filter between the underdrain and the soil media layer. If a stone storage layer is used, the pipe may be placed directly above this layer.

- Install the soil media in 12-inch lifts until the desired top elevation of the bioretention area is achieved. Wait a few days to check for settlement, and add additional media, as needed, to achieve the design elevation.
- Prepare planting holes for any trees and shrubs, install the vegetation.
- Place the surface cover in all cells (mulch, river stone or turf), depending on the design.
- Install the plant materials as shown in the landscaping plan.
- Remove temporary erosion and sediment controls once the bioretention facility and contributing areas have been stabilized.

4.3.1.8. Bioretention Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- During the six months immediately after construction, bioretention practices shall be inspected following the first two precipitation events of at least 1.0 inch to ensure that the system is functioning properly. Thereafter, inspections shall be conducted on an annual basis.
- Successful establishment of bioretention vegetation requires that the following tasks be undertaken in the first year following installation:
    - Spot Reseeding. Bare or eroding areas in the contributing drainage area or around the bioretention area shall be immediately stabilized with grass cover.
    - Watering. Depending on rainfall, watering may be necessary once a week during the first growing season (April-October). Vegetation shall receive ½ inch to 1 inch of water per week, whether through rainfall or watering.
    - Weeding and invasive species control. Inspect for, and remove, any undesired plant growth, whether weeds or invasive plant species.
    - Removal and replacement of dead plants. Construction contracts shall include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction. The typical thresholds below which replacements are required within the first year after planting are 85% survival of plant material, including shrubs, and 100% survival of trees.
- The maintenance plan must indicate the approximate time to drain the maximum design storm runoff volume through the filtering practice. This normal drain or drawdown time shall then be used to evaluate the filter's actual performance.

4.3.1.9. Bioretention Maintenance – Annual

Required Elements

- Inspect practice for consistency with approved plan, including any narrative inspection and maintenance requirements.
- Any bare soil or sediment sources in the contributing drainage area shall be stabilized immediately.
- Sediment shall be cleaned out of forebays or other pre-treatment facilities when it accumulates to a depth of more than 6 inches. Pre-treatment outlet devices shall be cleaned/repaired when drawdown times exceed 36 hours. Trash and debris shall be removed as necessary
- Silt/sediment shall be removed from the bioretention filter bed when the accumulation exceeds one inch. When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), the top 1-3 inches of discolored material shall be removed and shall be replaced with fresh material. The removed sediments shall be disposed in an acceptable manner.

Design Guidance

Annual spring maintenance inspection and cleanup should be conducted for all bioretention practices, and include the following:

- Look for any bare soil or sediment sources in the contributing drainage area, and stabilize them immediately.
- Check for sediment buildup at curb cuts, gravel diaphragms or pavement edges that prevents flow from getting into the bed, and check for other signs of bypassing.
- Check for presence of accumulated sand, sediment and trash at inflow points and in the pre-treatment cell or filter beds, and remove it and properly dispose.
- Inspect bioretention side slopes and grass filter strips for evidence of any rill or gully erosion, and repair as needed. Check the integrity of observation wells and cleanout pipes.
- Check concrete structures and outlets for any evidence of spalling, joint failure, leakage, corrosion, etc.
- Check to see if 75% to 90% cover (mulch plus vegetative cover) has been achieved in the bed, and measure the depth of the remaining mulch. Add mulch as necessary.
- Check for dead or diseased vegetation, and replace this vegetation as needed.
- Check for and remove weeds and invasive plant species.
- Check the bioretention bed for evidence of mulch flotation, excessive ponding, or concentrated flows, and take appropriate remedial action.
- Check for clogged or slow-draining soil media, a crust formed on the top layer, inappropriate soil media, or other causes of insufficient filtering time, and restore proper filtration characteristics.

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4.3.2. Dry Swales and Wet Swales

A bioswale or dry swale is essentially a bioretention cell that is shallower, configured as a linear channel, and covered with turf or surface material other than mulch and ornamental plants. The dry swale is a soil filter system that temporarily stores and then filters a desired runoff volume for treatment. Dry swales rely on a pre-mixed soil media filter below the channel surface. If the native soils are permeable, runoff infiltrates into underlying soils. Otherwise, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff further downstream or safely daylights down-gradient. The underdrain system typically consists of a perforated pipe within a gravel layer on the bottom of the swale, beneath the filter media.

Wet swales can provide runoff filtering and treatment within a conveyance system, and function as a cross between a wetland and a swale. Linear on-line or off-line wetland cells are formed within the channel to intercept shallow groundwater or retain runoff to create saturated soil or shallow standing water conditions (typically less than 6 inches deep) in order to maintain a wetland plant community. The saturated soil and wetland vegetation provide an environment for gravitational settling, biological uptake, and microbial activity. Wet swales, however, do not provide the same level of pollutant removal performance as dry swales, and do not have substantial volume reduction capability, unless designed with extended detention above the permanent pool. Wet swales shall not be used for meeting WQ treatment goals but may be used for meeting CPv and Qp, when extended detention is provided above permanent pool.

4.3.2.1. Design Summary

Criteria	Element	Requirements
Feasibility	Slope	Longitudinal slope of 2% or less without check dams Longitudinal slope of >2% with check dams, up to maximum 6% slope
	Water Table	Bottom of dry swale filter media, including gravel sump if any, at or above SHGWT Dry swales designed to infiltrate more the WQ_v, 3 feet separation from bottom of filter media to SHGWT required, unless contributing drainage area (CDA) is less than or equal to 1.0 acre:, then: Minimum of 2 feet separation required when CDA of ≤ 1.0 acre, impervious >50%; Minimum of 1 foot separation when CDA of ≤ 1.0 acre, impervious ≤50%. Separation to SHGWT N/A for practices that are lined and under drained Wet swale permanent pool typically intersects SHGWT
	Soils	Infiltration rate of 0.2 in/hr or greater if dry swale is designed to infiltrate
	Contributing Drainage Area	2.5 acres maximum contributing drainage area (CDA) to a single wet or dry swale inlet N/A if flow enters via sheet flow along a linear feature (e.g., road)
Conveyance	Flow Regulation	Non-erosive (3.5 to 5.0 fps) peak velocity for the 1-year storm Safe conveyance of the 10-year storm
	Temporary Ponding Time	Maximum of 48 hours
	Side Slope Geometry	3:1 or gentler; 2:1 maximum side slope only where 3:1 slopes are not feasible
	Dry Swale Underdrain	If not designed as exfiltrating system, must be underdrained (minimum 6" perforated pipe underdrain in a 1 foot gravel layer)
Pre-Treatment	Required Pre-treatment	If stormwater is routed to forebay for required pre-treatment, forebay volumetrically sized for 10% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.
Treatment	Required Volume	Total system must be sized to contain WQ_v. ponding plus soil media (dry swale), wet swale does not meet WQ_v requirements.
	Max. Ponding Depth	12 inches during WQ storm, 6” of freeboard required for 10-year storm (or 100-year storm if applicable)
	Dry Swale Filter Bed Depth	24-48 inches
	Dry Swale Filter Media	Soil media as detailed in Appendix B8, VSMM Vol. 2
	Dry Swale Dewatering	Maximum dewatering time of 48 hours
	Credit Towards Standards	Dry swale: Volume storage within practice, including pore space and ponding depth, is credited towards WQ_V; for infiltrating practices, this same treatment volume is applied to HC_V along with any additional infiltrated volume. For underdrained practices that are not lined, HC_V is limited to pore space in the gravel sump. Wet swale: Extended detention volume above permanent pool credited towards CP_V, and Q_P.
Other	Vegetation and Landscaping	Contributing area must be stabilized before runoff is directed to facility Detailed landscaping plan required Use of native and salt-tolerant plants recommended

	Maintenance	Inspect annually for consistency with approved design plan Sediment removal will occur when it reaches 6” or greater depth, or when 25% of open channel treatment volume is filled with silt/sediment. Weeding and invasive species control. Removal and replacement of winter- or salt-killed vegetation. Routine (annual) trash and debris removal. If water ponds on dry swale filter bed for more than 48 hours, renovate or replace media.

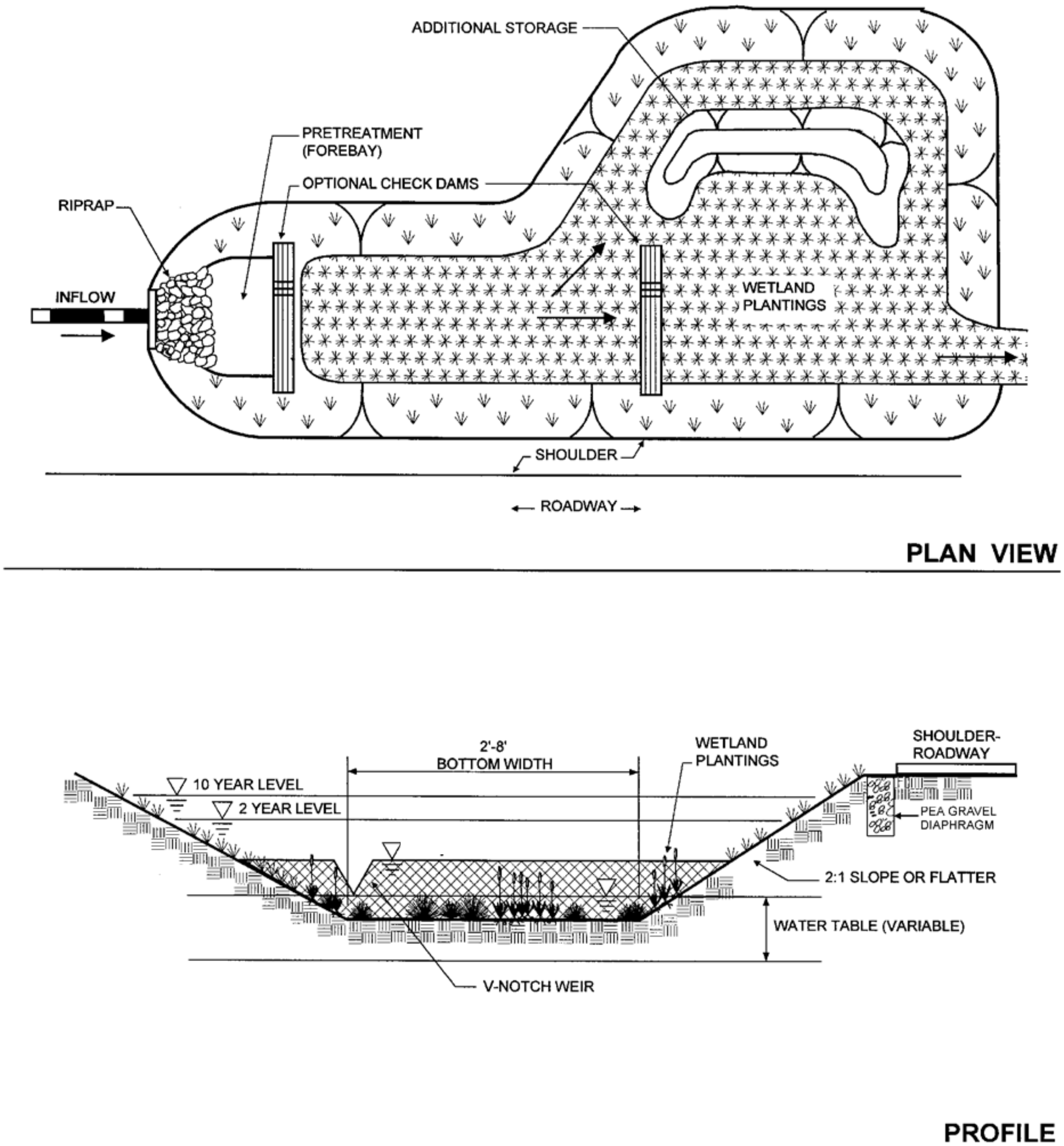

Figure 4-17. Wet Swale

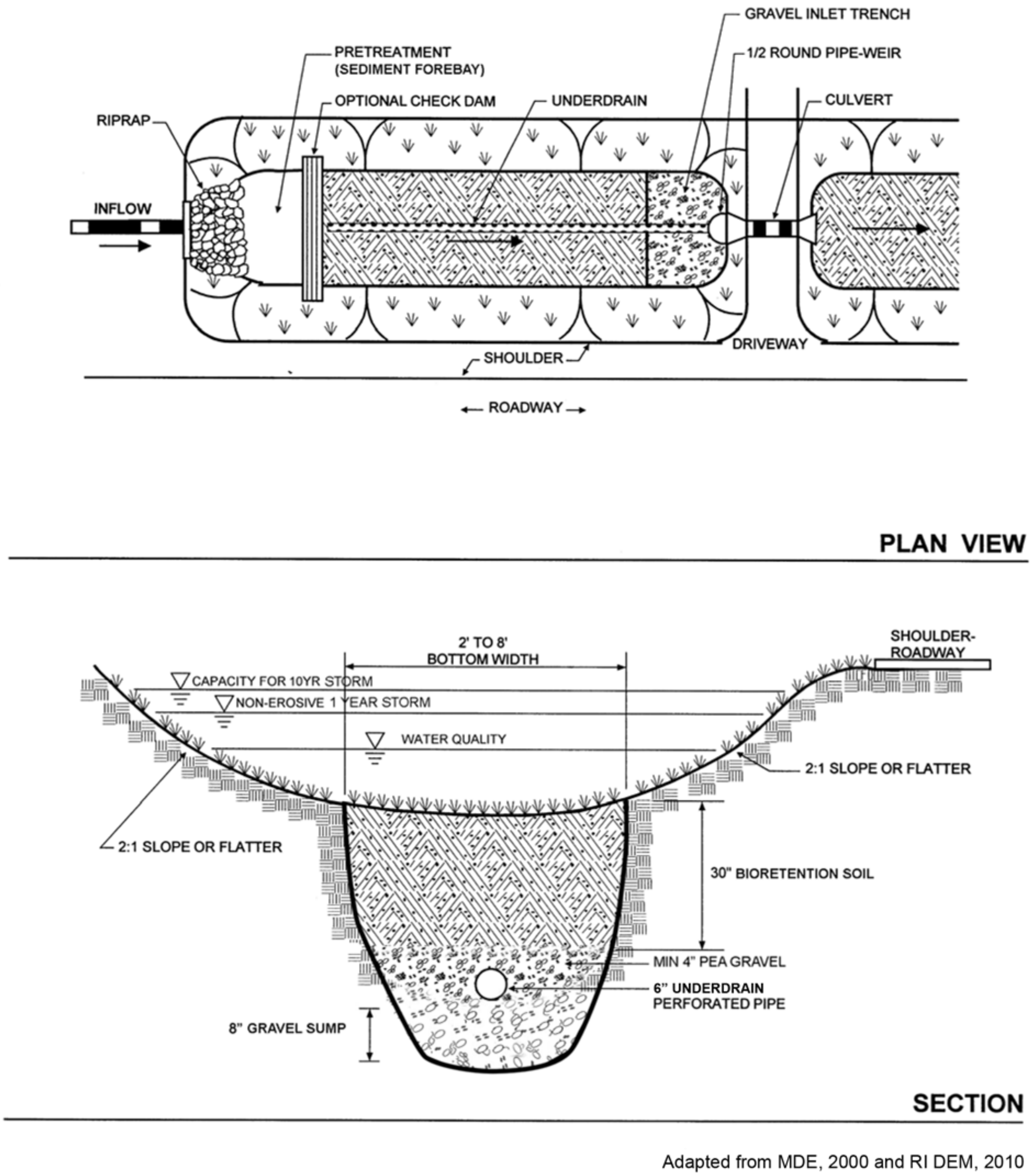

Figure 4-18. Example of a Dry Swale with Underdrain and Gravel Sump

4.3.2.2. Dry Swale and Wet Swale Feasibility

Required Elements

- Open channels constructed without check dams shall have a maximum longitudinal slope of 2%. Open channels constructed on steeper slopes, to a maximum longitudinal slope of 6%, shall include check dams, step pools, or other grade controls.
- The bottom of a dry swale shall be located at or above the seasonal high groundwater table.
- If the dry swale is designed to infiltrate stormwater through the bottom of the practice into underlying soils, the native soils shall have an infiltration rate (fc) of at least 0.2 inches per hour, as confirmed by field geotechnical tests (see Appendix C1, VSMM, Vol. 2, Infiltration-Based Practice Testing Requirements).
- Dry swales designed to infiltrate more than the WQ_v shall maintain a minimum 3 foot separation to SHGWT from the bottom of the practice; unless contributing drainage area to the practice is less than or equal to 1.0 acre, than:
    - Minimum of 2 feet separation to SHGWT from bottom of dry swale system when contributing drainage area (CDA) of 1.0 acre or less, is greater than 50% impervious.
    - Minimum of 1 foot separation to SHGWT from bottom of dry swale system when contributing drainage area (CDA) of 1.0 acre or less, is less than or equal to 50% impervious.
- The maximum contributing drainage area to an individual dry or wet swale inlet shall be 2.5 acres. There is no maximum drainage area limitation if flow enters via sheet flow along a linear feature, such as a road.

Design Guidance

- Steep slopes will increase velocity, erosion, and sediment deposition, thus shortening the design life of the swale. Check dams, step pools, or other grade controls can be used to lengthen the contact time to enhance filtering and/or infiltration. Steeper slopes adjacent to the swale may generate rapid runoff velocities into the swale that may carry a high sediment loading, requiring additional pre-treatment consideration.
- Wet swales may not be appropriate in all residential areas because of the potential for stagnant water and other nuisance ponding.
- In order to maintain the required permanent pool volume, wet swales typically need a longitudinal slope of <1%.
- Dry swale footprints can fit into relatively narrow corridors between utilities, roads, parking areas, or other site constraints. Dry swales should be approximately 3% to 10% of the size of the contributing drainage area, depending on the amount of impervious cover.
- Swale location should be considered carefully. Swales along roadways may be damaged by off-street parking and are susceptible to winter salt applications. The choice of vegetation and landscaping can be limited in adjacent areas.

4.3.2.3. Dry Swale and Wet Swale Conveyance

<u>Required Elements</u>

- The maximum allowable temporary ponding time within a channel shall be less than 48 hours. For dry swales, if the infiltrative capacity of the underlying native soils is less than 0.2 inches per hour, an underdrain system shall be used to ensure this requirement is met.
- Underdrained dry swales shall be equipped with a minimum 6" perforated pipe underdrain (8" is preferred) in a 1-foot gravel layer. Synthetic filter fabrics shall not be used to completely separate the filter media from the underdrain bedding material. A 3-inch gravel choker course shall be used between underdrain bedding and dry swale filter media, instead of filter fabric.
- The peak velocity for the 1-year storm must be non-erosive (Appendix C7, VSMM, Vol. 2).
- Swales shall be designed to safely convey the 10-year, 24-hour storm. The swale shall have a minimum of 6” of freeboard above the design 10-year water surface profile of the channel.
- Channels shall be designed with moderate side slopes (flatter than 3:1) for most conditions. Designers may utilize a 2:1 maximum side slope only where 3:1 slopes are not feasible.
- The longitudinal channel slope shall be less than or equal to 2.0%. If the site slope is greater than 2%, additional measures such as check dams shall be utilized to retain the water quality volume within the swale system.
- **Check Dams:** Check dams or weirs shall be used to increase hydraulic residence time in the swale in steeper applications (see Figure 4-2). Plunge pools or other energy dissipation may also be required where the elevation difference between the tops of weirs to the downstream channel invert is a concern. Design requirements for check dams are as follows:
    - The maximum check dam height shall be 12 inches, and the average ponding depth throughout the channel should be 12 inches.
    - Check dams shall be composed of wood, concrete, stone, or other non-erodible material. The check dam should be designed to facilitate easy mowing (gravel check dams are discouraged).
    - Check dams must be firmly anchored into the side-slopes to prevent outflanking; check dams must also be anchored into the channel bottom a minimum of 6 inches.
    - Check dams must be designed with a center weir sized to pass the channel design storm peak flow (10-year storm event if an on-line practice).
    - Armoring may be needed at the downstream toe of the check dam to prevent erosion.
    - Check dams shall be spaced based on channel slope, as needed, to increase residence time, provide storage volume, or meet volume attenuation requirements. The ponded water at a downhill check dam should not touch the toe of the upstream check dam.
    - Each check dam should have a weep hole or similar drainage feature so it can dewater after storms.
    - Individual channel segments formed by check dams should generally be at least 25 to 40 feet in length.

Design Guidance

- Open channel systems may be designed as off-line systems to reduce erosion during large storm events.
- To prevent culvert freezing, use culvert pipes with a minimum diameter of 18 inches, and design culverts with a minimum 1% slope.

4.3.2.4. Dry Swale and Wet Swale Pre-Treatment

Required Elements

- Pre-treatment of rooftop runoff is not required, provided that the runoff is routed to the swale in such a way that it is prevented from accumulating additional sediment and it does not comingle with other runoff.
- If stormwater is routed to forebay for required pre-treatment, forebay shall be volumetrically sized for 10% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.

Design Guidance

- The storage volume for pre-treatment may be obtained by providing check-dams at pipe inlets and/or driveway crossings.
- Road drainage entering a swale along the length of the road may pre-treat runoff using a vegetative filter strip.
- Open channel systems which directly receive runoff from non-roadway impervious surfaces may have a 6" drop onto a protected shelf (gravel diaphragm) to minimize the clogging potential of the inlet. Runoff from roads should drain over a vegetative slope, check dam, or forebay prior to flowing into a swale.
- A gravel diaphragm and gentle side slopes may be used along the top of channels to provide pre-treatment for lateral sheet flows.
- It is important that there be a 2" to 4" drop from the edge of the pavement to the top of the grass or stone in the pre-treatment structure to prevent accumulation of debris and subsequent clogging.

4.3.2.5. Dry Swale and Wet Swale Treatment

Required Elements

- A dry swale storage volume of at least 75% of the design T_v, including the volume over the top of the filter media and the volume in the pre-treatment practice(s), as well within the bioretention soil filter media – is required in order to capture the volume from high-intensity storms prior to filtration and to avoid premature bypass.
- Volume storage within a dry swale, including pore space and ponding depth, is credited towards WQ_V; for infiltrating practices, this same treatment volume in additional to any additional infiltration volume, is applied to CP_v and Q_P. For underdrained and unlined practices, HCv is limited to pore space in the gravel sump.
- Ponding depth and extended detention within a wet swale is not credited toward WQ_V. Extended detention above permanent pool is credited towards CP_V and Q_P only.
- Dry swales shall consist of the following treatment components: A 24-48" deep bioretention soil bed, a surface vegetation or mulch layer, and no more than a 12" deep average surface ponding depth. Soil media shall meet the specifications outlined for bioretention areas (Section 4.3.4 and Appendix B8, VSMM, Vol. 2).

- A soil phosphorus test using the Mehlich-3 (or equivalent) method is required for dry swale facilities with underdrains, to ensure that bioretention soil media will not leach phosphorus. The phosphorus index (P-index) for the soil must be low, between 10 and 30 milligrams per kilogram.
- The minimum filter area for dry swales shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) shall be used as follows:
  - Dry Swale (same as for bioretention): 1.0 ft/day for sandy loam soils
- The dry swale filter bed area is computed using the following equation:

$$A_f = \frac{(T_v)(d_f)}{(k)(h_f + d_f)(t_f)}$$

Where:

A_f = Surface area of filter bed (ft^2)
T_v = design treatment volume (e.g., WQ_v or HC_v) (ft^3)
d_f = Filter bed depth (ft)
k = Coefficient of permeability of filter media (ft/day)
h_f = Average height of water above filter bed (ft)
t_f = Design filter bed drain time (days)
(2 days or 48 hours is the recommended maximum t_f for bioretention)

- Swales shall have a bottom width between two and eight feet. If a swale will be wider than 8 feet, the designer should incorporate berms, check dams, level spreaders or multi-level cross-sections to prevent braiding and erosion of the swale bottom.

Design Guidance

- Open channels should maintain a maximum ponding depth of 1 foot at the longitudinal mid-point of the channel, and a maximum depth of 18" at the end point of the channel (for head/storage of the WQ_v).
- The permanent pool volume of a wet swale may be included in water quality volume calculations.
- The bioretention soil depth of dry swales may be reduced to 12" on a case-by-case basis as demonstrated by the designer that 24" is not feasible, such as sites with high groundwater or shallow depth to bedrock or clay soils, or in retrofit situations where pre-existing site constraints exist. In these cases, the designer will need to provide a calculation to demonstrate that an equal WQ_v is provided as with a 24" deep soil bed.

4.3.2.6. Dry Swale and Wet Swale Vegetation and Landscaping

Required Elements

- The entire contributing area must be stabilized before runoff can be directed into the practice. A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas, and impervious area construction must be completed.
- A thick vegetative cover shall be provided for proper function.

- A landscaping plan must be provided for both wet and dry swales (Appendix A, VSMM, Vol. 2). For dry swales that are intended to be mowed, a seed specification and seeding rate can take the place of the landscaping plan.

Design Guidance

Planting recommendations for wet and dry swales are as follows:

- Native plant species should be specified over non-native species, though non-invasive cultivars are also acceptable and can provide the functions needed.
- The landscaping plan should specify proper grass species and emergent plants based on specific site, soils, and hydric conditions present along the proposed swale (Appendix A, VSMM, Vol. 2).
- Use salt-tolerant plant species in vegetated swales if the practice is expected to receive runoff from roads or parking lots (Appendix A, VSMM, Vol. 2).

4.3.2.7. Dry Swale and Wet Swale Construction Sequencing

Required Elements (Dry Swale)

- Dry swales that will rely on infiltration must be fully protected by silt fence and/or construction fencing to prevent compaction by heavy equipment during construction.

Design Guidance (Dry Swale)

The following is a typical construction sequence to properly install a dry swale, although the steps may be modified to adapt to different site conditions.

- Dry swales should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Where this is impractical, barriers should be installed at key check dam locations, erosion control fabric should be used to protect the channel, and excavation should be no deeper than 2 feet above the proposed invert of the bottom of the planned underdrain.
- Grading in preparation for installation of the gravel, underdrain, and soil media should begin only after the entire contributing drainage area has been stabilized by vegetation or runoff has been diverted away from the area.
- Pre-treatment cells should be excavated first to trap sediments before they reach the filter beds.
- Excavators or backhoes should work from the sides to excavate the dry swale area to the appropriate design depth and dimensions. Excavating equipment should never sit inside the footprint of the dry swale.
- The bottom of the dry swale should be ripped, roto-tilled or otherwise scarified to promote greater infiltration.
- Place an acceptable filter fabric only on the underground (excavated) sides of the dry swale, if needed. Place the stone needed for storage layer under the filter bed. Install perforated underdrain pipe and check its slope. Add remaining stone jacket, and then add 3 inches of pea gravel as a filter layer/choker course.
- After verifying that the bioretention soil media meets specifications, add the soil media in 12-inch lifts, and compact by saturating with water, until the desired top elevation of the dry swale is achieved. Alternatively, the depth of the bioretention soil media can be increased by 10% to accommodate passive settling.

- Install check dams, driveway culverts, and internal pre-treatment features as specified in the plan.
- Prepare planting holes for specified trees and shrubs (if specified), install erosion control fabric where needed, spread seed or lay sod, and install any temporary irrigation.
- Plant landscaping materials as shown in the landscaping plan, and water weekly during the first 2 months. The construction contract should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.
- Remove temporary erosion and sediment controls once the dry swale and contributing areas have been stabilized.

Design Guidance (Wet Swale)

The following is a typical construction sequence to properly install a wet swale, although steps may be modified to reflect different site conditions.

- Wet swales should be protected during construction to prevent soil compaction by heavy equipment. Temporary erosion and sediment controls such as dikes, silt fences and other erosion control measures should be integrated into the swale design throughout the construction sequence. Barriers should be installed at key check dam locations, and erosion control fabric should be used to protect the channel.
- Wet swale installation may only begin after the entire contributing drainage area has been constructed or stabilized with vegetation. Any accumulation of sediments that does occur within the channel must be removed during the final stages of grading to achieve the design cross-section. Stormwater flows must not be permitted into the swale until the bottom and side slopes are fully stabilized.
- Install check dams, driveway culverts and internal pre-treatment features as shown on the plan. The top of each check dam should be constructed level with the overflow notch at the design elevation.
- Prepare planting holes for specified trees and shrubs (if specified), install erosion control fabric where needed, spread seed or lay sod, and install any temporary irrigation.
- Plant landscaping materials as shown in the landscaping plan, and water weekly during the first 2 months. The construction contract should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.
- Remove temporary erosion and sediment controls once the wet swale has been stabilized.

4.3.2.8. Dry and Wet Swale Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- During the six months immediately after construction, open channel practices shall be inspected following the first two precipitation events of at least 1.0 inch to ensure that the system is functioning properly. Thereafter, inspections shall be conducted on an annual basis.

- Successful establishment of dry and wet swale vegetation requires that the following tasks be undertaken in the first year following installation:
    - Watering. Depending on rainfall, watering of dry swale vegetation may be necessary once a week during the first growing season (April-October). Vegetation shall receive ½ inch to 1 inch of water per week, whether through rainfall or watering.
    - Spot Reseeding. Bare or eroding areas in the contributing drainage area or within a swale shall be immediately stabilized with grass cover.
    - Removal and replacement of dead plants. Construction contracts shall include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction. The typical thresholds below which replacements are required within the first year after planting are 85% survival of plant material, including shrubs, and 100% survival of trees.
    - Weeding and invasive species control. Inspect for, and remove, any undesired plant growth, whether weeds or invasive plant species.
- The maintenance plan must indicate the approximate time to drain the maximum design storm runoff volume through the dry swale practice. This normal drain or drawdown time shall then be used to evaluate the filter's actual performance during annual inspections.

4.3.2.9. Dry and Wet Swale Maintenance – Annual

Required Elements

- Inspect practice for consistency with approved design plan, including any narrative inspection and maintenance requirements.
- Immediately stabilize any bare soil or sediment sources in the contributing drainage area.
- Eroded side slopes and channel bottoms shall be stabilized as necessary.
- Sediment shall be cleaned out of pre-treatment facilities and from behind check-dams when it accumulates to a depth of more than 6 inches. Trash and debris shall be removed as necessary.
- Silt/sediment build-up within the bottom of the channel shall be removed when 25% of the original WQ_v volume has been exceeded.
- Vegetation in dry swales shall be mowed as required to maintain grass heights in the 4-6 inch range, with mandatory mowing once grass heights exceed 10 inches.
- Check for winter- or salt-killed vegetation, and replace.
- Check for and remove weeds and invasive plant species.
- Woody vegetation in wet swales shall be pruned where dead or dying branches are observed, and reinforcement plantings shall be planted if less than 85% of the original vegetation establishes after two years.
- If the surface of the dry swale becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the bottom shall be rototilled or cultivated to break up any hard-packed sediment, and then reseeded.

Design Guidance

- If roadside or parking lot runoff is directed to the practice, mulching and/or soil aeration/manipulation may be required in the spring to restore soil structure and moisture capacity to reduce the impacts of deicing agents.
- In the absence of evidence of contamination, removed debris may be taken to a landfill or other permitted facility. Sediment testing may be required prior to sediment disposal if a hotspot land use is present.
- Every five years, the channel geometry of wet and dry swales should be evaluated for consistency with original design plans. If more than 25% of the original WQ_v storage capacity (dry swale) is filled with silt or sediment buildup, the bottom of the swale should be scraped to remove sediment and to restore original cross section and infiltration rate, and should be seeded to restore ground cover.

4.3.2.10. References

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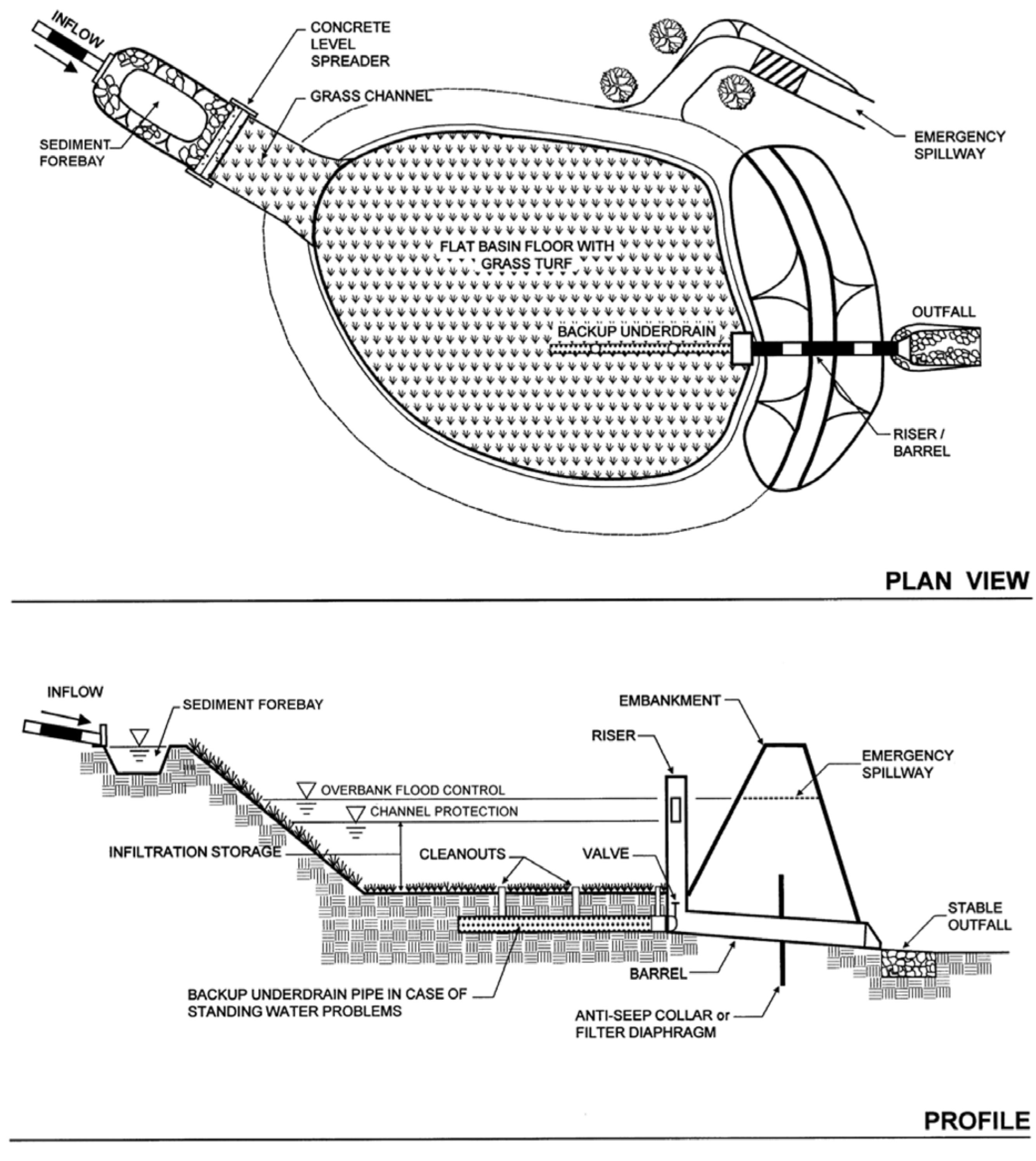
4.3.3. Infiltration Trenches and Basins

Stormwater infiltration practices capture and store runoff, for the express purpose of allowing it to infiltrate into the soil. The use of infiltration practices can provide groundwater recharge as well as reduce the volume of stormwater runoff entering the drainage system and reduce or slow peak flows. Infiltration practices reduce pollutants and total suspended solids via physical filtering of the runoff through a media (most often soil), as well as chemical and biological activity within the media. Infiltration practices (including dry wells) that are properly sited and constructed in accordance with this manual will not be required to obtain a separate permit under the Underground Injection Control Rules (see http://drinkingwater.vt.gov/wastewateruic.htm).

In some cases, infiltration practices can provide extended detention or infiltration for channel protection (CP_v) and overbank or extreme flood (Q_P) storm events on sites with high soil infiltration rates. Extraordinary care should be taken to assure that long-term infiltration rates are achieved through the use of proper pre-treatment, post-construction inspection, and routine, long-term maintenance.

4.3.3.1. Design Summary

Criteria	Element	Requirements
Feasibility	Soils	Infiltration rate of 0.2 in/hr or greater
	Slope	Natural site slope <15%
	Water Table	Vertical separation by at least three feet from the seasonally high groundwater table (SHGWT) or bedrock. Dry wells with less than or equal to 1,000-square feet of contributing residential rooftop runoff, vertical separation to SHGWT shall be a minimum of 1 foot.
	Contributing Drainage Area (CDA)	Basins/Chambers: 10 acres maximum if CDA is less than or equal to 50% impervious Basins/Chambers: 5 acres maximum if CDA is greater than 50% impervious Trenches: 5 acres maximum if CDA is less than or equal to 50% impervious Trenches: 2.5 acres maximum if CDA is greater than 50% impervious Dry wells: 1 acre maximum
Conveyance	Flow Regulation	Non-erosive (3.5 to 5.0 fps) peak velocity for the 1-year storm Safe conveyance of the 10-year storm
	Overflow	Stabilized channel required if overflow above practice capacity will exceed erosive velocities.
Pre-Treatment	Required Pre-Treatment	If stormwater is routed to forebay for required pre-treatment, forebay volumetrically sized for percentage of WQ_v as noted below. Otherwise, required pre-treatment designed in accordance Section 4.1. Minimum pre-treatment volume dependent on infiltration rate of the treatment practice. If infiltration rate is ≤2 inches per hour, minimum pre-treatment volume is 25% of WQv If infiltration rate is >2 inches per hour, minimum pre-treatment volume is 50% of WQv If infiltration rate is >5 inches per hour, minimum pre-treatment volume is 100% of WQv Pre-treatment not required for properly conveyed rooftop runoff
Treatment	Required Volume	Total system must be sized to contain WQ_v and exfiltrate through bottom of practice
	Dewatering Time	Maximum dewatering time for T_v of 48 hours
	Mounding Analysis	Required if practice designed to infiltrate more than the 1-year storm event and vertical separation to SHGWT is less than four feet
	Credit Towards Standards	Treatment volume (T_V) infiltrated is credited towards WQ_V CPv, and Qp..
Other	Vegetation	Contributing area must be stabilized before runoff is directed to facility
	Maintenance	Inspect annually for consistency with approved design plan Remove accumulated sediment from pre-treatment practices when less than 50% of original storage volume remains Remove accumulated sediment from infiltration trench or basin when sediment is visible on surface Inspect for vegetation health, density, and diversity twice annually during growing and non-growing seasons Take corrective action if water fails to infiltrate 72 hours after rainfall



Adapted from MDE, 2000

Figure 4-19. Example of Infiltration Basin

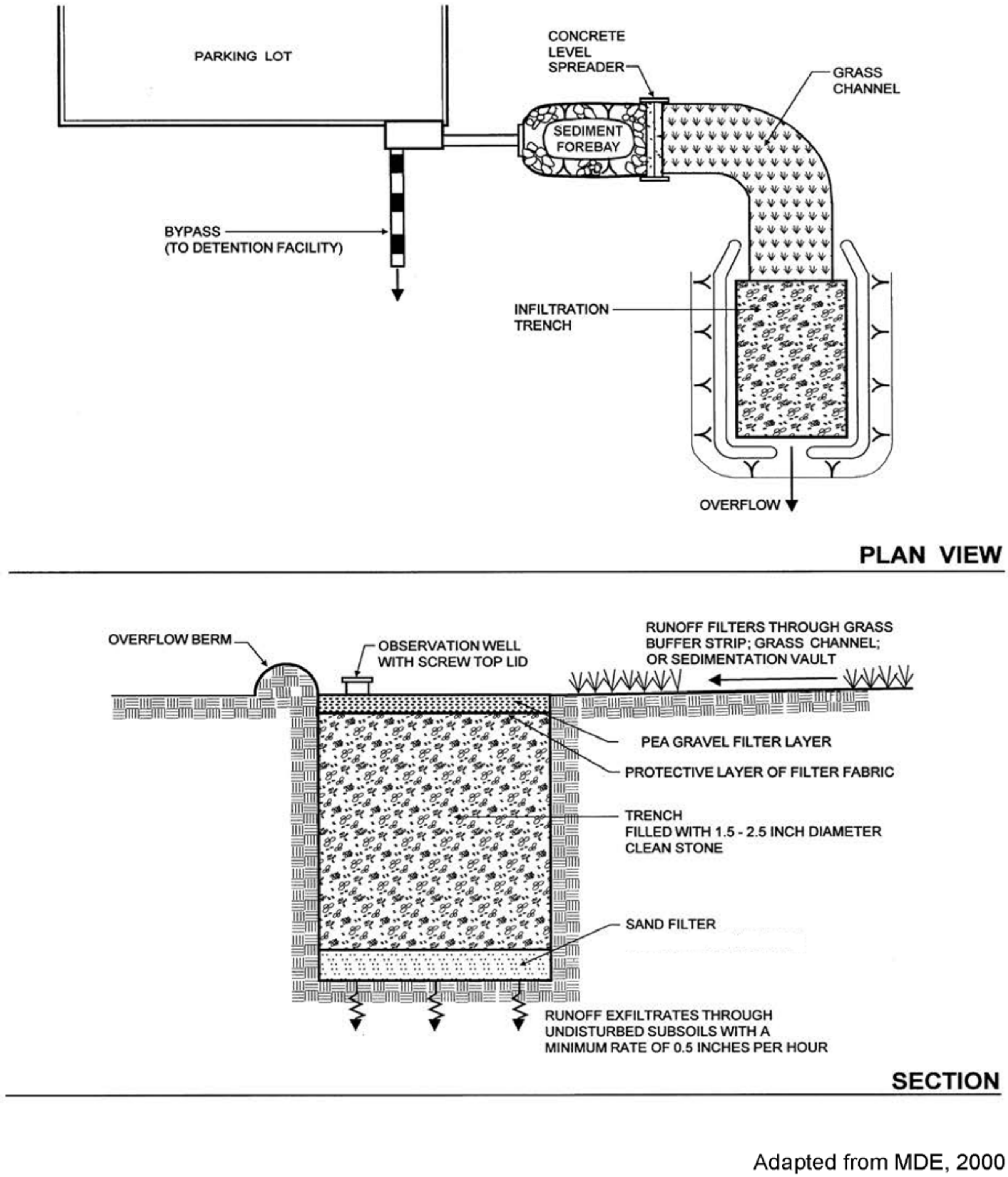


Figure 4-20. Example of Infiltration Trench

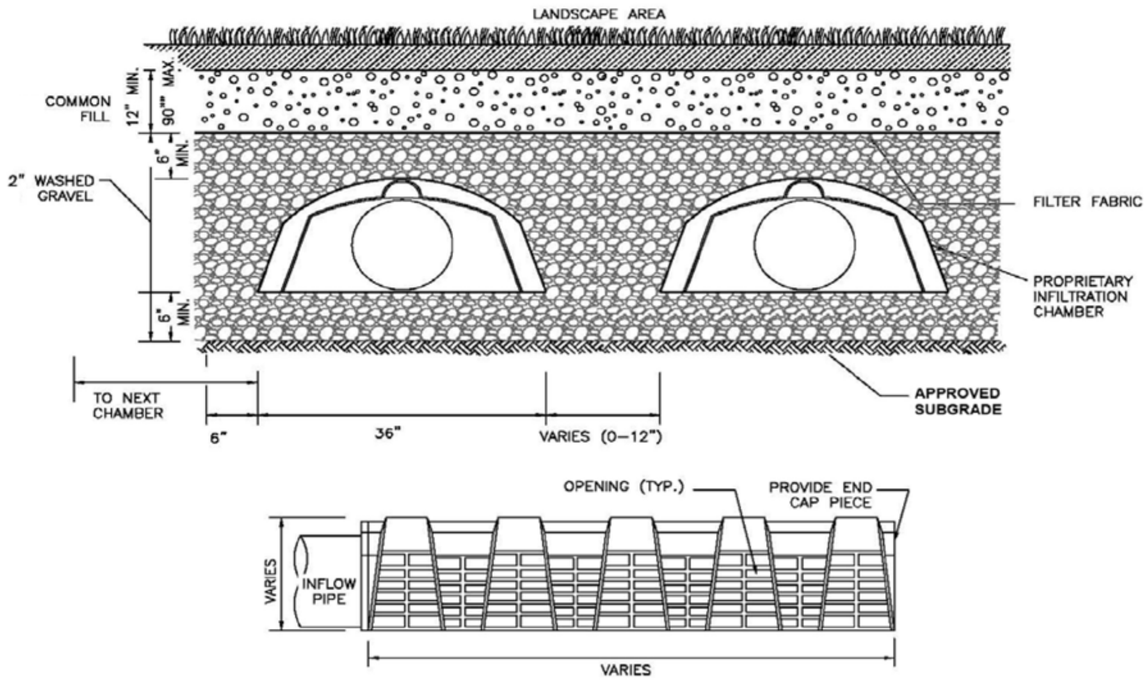


Figure 4-21. Example of Underground Infiltration Chambers (Source: RI DEM, 2010)

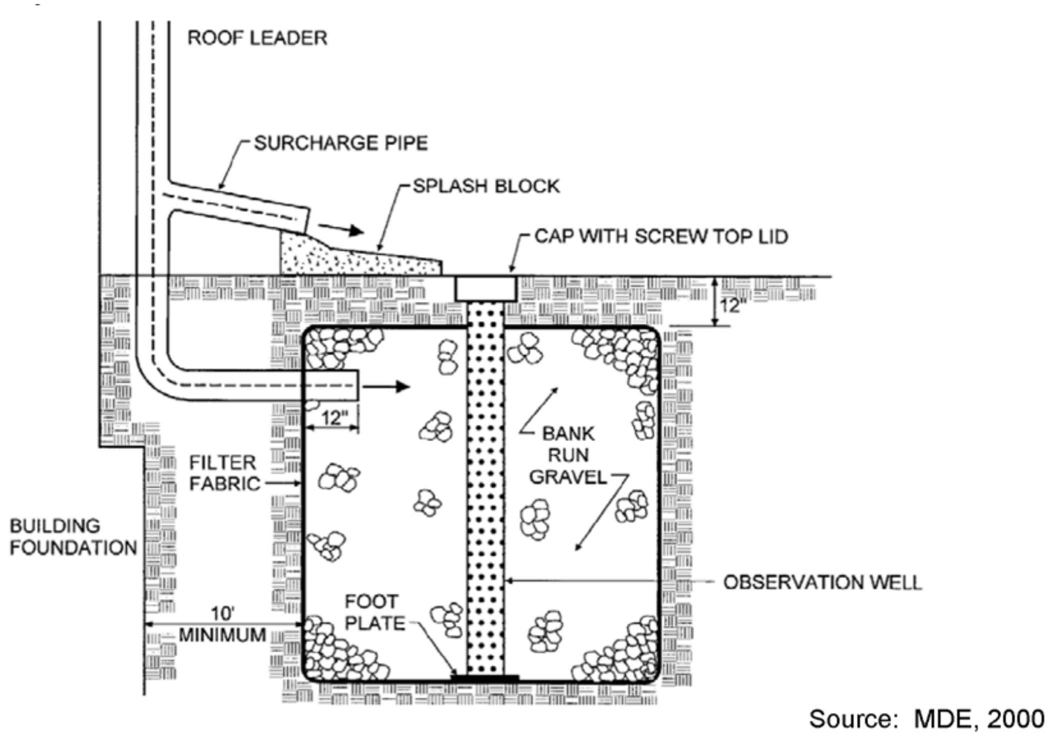


Figure 4-22. Dry Well

4.3.3.2. Infiltration Feasibility

Required Elements

- Underlying soils shall have an infiltration rate (f_c) of at least 0..2 inches per hour, as confirmed by field geotechnical tests (see Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements).Infiltration practices cannot be located on areas with natural slopes greater than 15%.
- Infiltration practices cannot be located in fill soils, except for strictly residential land uses, for which the bottom of practices may be located in up to two feet of fill consisting of material suitable for long-term infiltration after placement, as confirmed by field geotechnical tests (Appendix C1, VSMM, Vol. 2). In limited residential circumstances where design is allowable on up to two feet of suitable fill, designer shall consider the use of conservative infiltration rates and designer shall confirm that actual soil infiltration rates meet design specifications during project construction. Practices for non-residential sites that cannot be placed in natural soil may be designed as filtering systems, and must meet the media requirements for filtering systems.
- The bottom of the infiltration facility shall be separated by at least three feet vertically from the seasonally high groundwater table (SHGWT) or bedrock layer, as documented by on-site soil testing. Dry wells with less than or equal to 1,000-square feet of contributing residential rooftop runoff, vertical separation to SHGWT shall be a minimum of 1 foot.
- Infiltration basins shall have vegetated side slopes of 2:1 or flatter.
- Locating an infiltration practice within 100 feet of a drinking water source located in bedrock or a confined unconsolidated aquifer is prohibited, or as otherwise specified in the Vermont Wastewater and Potable Water Supply Rules (or their replacement).
- Locating an infiltration practice within 150 feet of a drinking water source located in an unconfined aquifer is prohibited, or as otherwise specified in the Vermont Wastewater and Potable Water Supply Rules (or their replacement).
- Infiltration practices shall not be placed in locations that cause water intrusion problems for down-gradient structures. Infiltration practices shall be set back 75 feet down-gradient wastewater disposal areas systems and set back at least 35 feet from structures, 35 feet up-gradient of wastewater disposal systems, and 75 feet down-gradient of wastewater disposal systems, or as otherwise required by the Vermont Wastewater and Potable Water Supply Rules (or their replacement). Dry wells shall be separated by a minimum of 10 feet from structures.
- Infiltration practices should not be used where subsurface contamination is present from prior land use due to the increased threat of pollutant migration associated with increased hydraulic loading from infiltration systems, unless contaminated soil is removed and the site remediated, or if approved by the Agency on a case-by-case basis. On redevelopment sites, applicants are responsible for identifying potential contamination prior to submitting an application. Infiltration practices shall not be used for snow storage, as road sand used in winter maintenance can cause clogging and failure of the practices.

Design Guidance

- The maximum contributing area to dry wells should generally be less than one acre, and include rooftop runoff only. The maximum contributing area for trenches should be less than 5 acres. Infiltration basins or chamber systems can receive runoff from larger contributing areas (up to 10 acres), provided that the soil is highly permeable.

- Infiltration practices should not be hydraulically connected to structure foundations or pavement to avoid seepage and frost heave concerns, respectively.

4.3.3.3. Infiltration Conveyance

Required Elements

- Flow velocities of surface runoff exceeding the capacity of the infiltration system shall be evaluated against erosive velocities during the overbank events. If computed flow velocities exceed erosive velocities (3.0 to 5.0 fps) (Appendix D7, VSMM, Vol. 2) for the 1-year storm event, an overflow channel to a stabilized watercourse and/or level spreader shall be provided. If a level spreader is provided, it shall be designed consistent with the requirements in the Disconnection to Filter Strips and Vegetated Buffers practice standard (Section 4.2.3).
- For infiltration basins and trenches, adequate stormwater outfalls shall be provided for the overflow associated with the 10-year design storm event (the design shall provide for non-erosive velocities on the down-slope).
- All infiltration systems shall be designed to fully de-water the treatment volume (T_v) within 48 hours after the storm event.
- If runoff is delivered by a storm drain pipe or along the main conveyance system, the infiltration practice must be designed as an off-line practice, except when used to also meet Cp_v and Q_p.

Design Guidance

- For dry wells, all flows that exceed the capacity of the dry well should be passed through the surcharge pipe.

4.3.3.4. Infiltration Pre-treatment

Required Elements

- Pre-treatment provided prior to entry to an infiltration facility is dependent on the infiltration rate of the treatment practice. Volumetrically sized pre-treatment practices such as a forebay shall be sized for a percentage of the WQ_v as follows:
    - If the infiltration rate is ≤2 inches per hour, then the minimum pre-treatment volume is 25% of the WQ_v
    - If the infiltration rate is >2 inches per hour, then the minimum pre-treatment volume is 50% of the WQ_v
    - If the infiltration rate is >5 inches per hour, then the minimum pre-treatment volume is 100% of the WQ_v
- Pre-treatment of rooftop runoff is not required, provided that the runoff is routed to the infiltration practice in such a way that it is prevented from accumulating additional sediment and it does not comingle with other runoff.
- Exit velocities from pretreatment chambers flowing over vegetated channels shall be non-erosive (3.5 to 5.0 fps) during the 1-year design storm (Appendix C7, VSMM, Vol. 2, Critical Erosive Velocities for Grass and Soil).

- Infiltration basins or trenches shall have robust pre-treatment methods to ensure the long-term integrity of the infiltration rate. This must be achieved by using one or more of the following options (see Section 4.1 for pretreatment design requirements):
    - Pre-treatment swale (grass channel)
    - Vegetated filter strip
    - Sediment forebay with impermeable liner
    - Deep sump catch basin AND <u>one</u> of the following:
        - Upper sand layer (6" min with filter fabric at the sand/gravel interface); or
        - Washed gravel (1/8" to 3/8")
    - Proprietary device
- Provide a fixed vertical sediment marker to measure depth of accumulated sediment.

4.3.3.5. Infiltration Treatment

<u>Required Elements</u>

- Infiltration practices shall be designed to exfiltrate the entire T_v through the floor of each practice (sides are not considered in sizing) in soil horizons (not through bedrock).
- Infiltration practices that are designed to infiltrate more than the 1-year storm event or greater and have a separation from the bottom of the practice to seasonal high groundwater table (SHGWT) of less than four feet shall provide a groundwater mounding analysis based on the Hantush Method or equivalent to demonstrate that the required vertical separation distance between the bottom of the practice and SHGWT can be maintained during and following the design storm (Appendix C1, VSMM, Vol. 2).
- An observation well shall be installed in every infiltration trench and dry well, consisting of an anchored 4- to 6-inch diameter perforated PVC pipe with a screw-top cap or equivalent installed flush with the ground surface. Multiple observation wells (e.g., 1 well per 50 linear feet of chamber) may be required for large underground chamber systems.
- Direct access shall be provided to infiltration practices for maintenance and rehabilitation. If a stone reservoir or perforated pipe is used to temporarily store runoff prior to infiltration, the practice shall not be covered by an impermeable surface.

<u>Design Guidance</u>

- Calculate the surface area of infiltration trenches using following equation:

$$\mathrm{Ap} = \mathrm{Tvndt} + \mathrm{fcT}/12$$

Where:

A_p = practice surface area (ft^2)
T_v = design treatment volume (e.g., WQ_v, CP_v, or Q_p) (ft^3)
n = porosity (assume 0.33)
d_t = trench depth, maximum of four feet and separated from seasonal high groundwater as required (ft)

f_c = design infiltration rate (in/hr) (i.e. soils below floor of practice)
T = time to fill trench (hours), assumed to be 2 hours for design purposes

- Calculate the approximate bottom area of trapezoidal infiltration basins using the following equation:

$$Ab = 2Tv - Atdbdb - P/6 + fcT/6$$

Where:

A_b = surface area at the bottom of the basin (ft^2)
T_v = design treatment volume (e.g., WQ_V, CPv, Qp)(ft^3)
A_t = surface area at the top of the basin (ft^2)
d_b = depth of the basin, separated from seasonal high groundwater as required (ft)
P = design rainfall depth (in)
f_c = design infiltration rate (in/hr) (i.e. soils below floor of practice)
T = time to fill basin (hours), assumed to be 2 hours for design purposes

- Calculate the design treatment volume of manufactured infiltration chambers using the following equation:

$$T_v = L\left[(wdn) - (XA_c n) + (XA_c) + \left(\frac{wf_c T}{12}\right)\right]$$

Where:

T_v = design treatment volume (e.g., WQ_V, CPv, or Qp) (ft^3)
L = length of infiltration facility (ft)
w = width of infiltration facility (ft)
d = depth of infiltration facility, separated from seasonal high groundwater as required (ft)
X = number of rows of chambers
A_c = cross-sectional area of chamber, see manufacturer's specifications (ft^2)
n = porosity (assume 0.33)
f_c = design infiltration rate (in/hr)
T = time to fill chambers (hours), assumed to be 2 hours for design purposes

Design Guidance

- Infiltration practices are best used in conjunction with other practices, and downstream detention is often needed to meet the Cp_v and Q_p sizing criteria, where required.
- The bottom of all infiltration practices should be flat, in order to enable even distribution and infiltration of stormwater. The longitudinal slope should range only from the ideal 0% up to 1%, and the lateral slope should be held at 0%.
- The sides of infiltration trenches and dry wells should be lined with an acceptable filter fabric that prevents soil piping.
- In infiltration trench designs, incorporate a fine gravel or sand layer above the coarse gravel treatment reservoir to serve as a filter layer.

- The bottom of the stone reservoir should be completely flat so that runoff will be able to infiltrate through the entire surface.
- Infiltration basins requiring embankments should follow the general design guidelines for ponds when considering side slopes, riser location, and other important features.

4.3.3.6. Infiltration Vegetation and Landscaping

Required Elements

- A dense and vigorous vegetative cover (e.g., at least 80% cover) shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility.
- Landscape design shall specify proper grass or plant species based on the specific site and soil conditions present in the practice.

Design Guidance

- The selection of upland landscaping materials should include salt-tolerant grasses where appropriate.

4.3.3.7. Infiltration Construction Sequencing

Required Elements

- Infiltration practices shall never serve as a sediment control device during site construction phase. In addition, the plan for the site shall clearly indicate how sediment will be prevented from entering an infiltration facility during construction.
- The construction sequence and specifications for each infiltration practice shall be precisely followed. Experience has shown that the longevity of infiltration practices is strongly influenced by the care taken during construction.
- The location of the infiltration practice must be marked off before the start of construction in order to prevent compaction of the infiltration area.
- Infiltration trenches, basins, and chamber systems shall not be constructed until all of the contributing drainage area has been completely stabilized.

Design Guidance

- OSHA trench safety standards should be consulted if the infiltration trench will be excavated more than five feet.
- A common method used to protect the infiltration facility during the construction phase involves using diversion berms around the perimeter of the practice, along with immediate vegetative stabilization and/or mulching.

4.3.3.8. Infiltration Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- The maintenance plan must indicate the approximate time to drain the maximum design storm runoff volume below the bottom of the trench or basin. This normal drain or drawdown time shall then be used to evaluate the basin's actual performance.
- Biweekly inspections of vegetation health shall be performed during the first growing season or until the vegetation is established.
- The facility shall be inspected after at least two initial storm events to ensure proper drainage and that there are no erosion/scour problems.

Design Guidance

- Infiltration designs should include dewatering methods in the event of failure. Dewatering can be accomplished with underdrain pipe systems that accommodate drawdown.

4.3.3.9. Infiltration Maintenance - Annual

Required Elements

- Inspect practice for consistency with approved design plan, including any narrative inspection and maintenance requirements.
- Inspect all structural components for cracking, subsidence, spalling, erosion, and deterioration.
- Inspect all infiltration trench or basin components expected to receive or trap debris and sediment (such as bottoms, riprap or gabion aprons, and inflow points) for clogging and excessive accumulation annually as well as after every storm exceeding 1 inch of rainfall.
- Accumulated sediment shall be removed from sediment traps, forebays, or pretreatment swales when less than 50% of the original storage volume remains, as measured against the fixed vertical sediment marker.
- Accumulated sediment shall be removed from the infiltration trench or basin when there is evidence of sedimentation on the surface. Remove sediment from trench or basin surfaces only when the facilities are thoroughly dry.
- Inspections of vegetation health, density, and diversity shall be performed at least twice annually during both the growing and non-growing season.
- If water fails to infiltrate 72 hours after the end of the storm as observed in a practice's observation wells, corrective measures must be taken. Additionally, if significant increases or decreases in the normal drain time are observed, the basin's bottom surface, subsoil, and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the basin.

- If sediment or organic debris build-up has limited the infiltration capability of an infiltration trench or basin to below the design rate, the top 6 inches shall be removed and the surface tilled to a depth of 12 inches. The basin bottom should be restored according to original design specifications.

Design Guidance

- Inspect infiltration practices and vegetated areas for erosion/scour and stabilize or repair as necessary. Mow/trim vegetation as needed based on site conditions and at least twice per year.
- All vegetation deficiencies should be addressed without the use of pesticides, herbicides, or fertilizers whenever possible.
- In the absence of evidence of contamination, removed debris may be taken to a landfill or other permitted facility. Any oil or grease found at the time of the inspection should be cleaned with oil absorption pads and disposed of in an approved location.

4.3.3.10. References

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4.3.4. Filtering Systems

Stormwater filtering systems capture and temporarily store the T_v and pass it through a filter bed of sand or augmented media. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Design variants include:

- Surface Sand Filter
- Underground Sand Filter
- Perimeter Sand Filter
- Alternative, Augmented, or Proprietary Media Filter (See Alternative Stormwater Treatment Practices for approval requirements, Section 4.4)

Filtering systems should not be designed to provide channel protection (CP_V) or stormwater detention (Q_P) except under extremely unusual conditions. Filtering practices should generally be combined with a separate facility to provide quantity controls.

4.3.4.1. Design Summary

Criteria	Element	Requirements
Feasibility	Water Table	Bottom of filter at or above SHGWT N/A for practices that are lined and underdrained
	Soils	0.2 in/hr or greater if exfiltrating
	Contributing Drainage Area	Surface filters: 5 acres maximum Underground and perimeter filters: 2 acres maximum
Conveyance	Flow Regulation	If stormwater is delivered by storm drain, design off-line. For off-line facilities, flow regulator is needed to divert WQ_v to the practice and to bypass larger flows.
	Overflow	Overflow for the 1-year storm to a non-erosive point.
	Underdrains	If not designed as exfiltrating system, must be underdrained
Pre-Treatment	Required Pre-treatment	If stormwater is routed to forebay for required pre-treatment, forebay volumetrically sized for 25% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.
Treatment	Required Volume	Total system (including pre-treatment) must be sized to contain 75% of the WQ_v.
	Filter Media	Filter media shall be ASTM C-33 sand for sand filters
	Credit Towards Standards	Treatment volume is credited towards WQ_V; for filtering practices designed to infiltrate, Re_V and HC_V are credited
Other	Vegetation	Contributing area must be stabilized before runoff is directed to facility
	Maintenance	Inspect annually for consistency with approved design plan Sediment cleaned out of sediment forebay when it reaches more than 6" in depth. Vegetation height limited to 18". Sediment chamber cleaned if drawdowns exceed 36 hours. Routine (annual) trash and debris removal. Silt/sediment removed from filter bed after it reaches 1". If water ponds on the filter bed for more than 48 hours, renovate or replace filter media to restore filtering capacity.

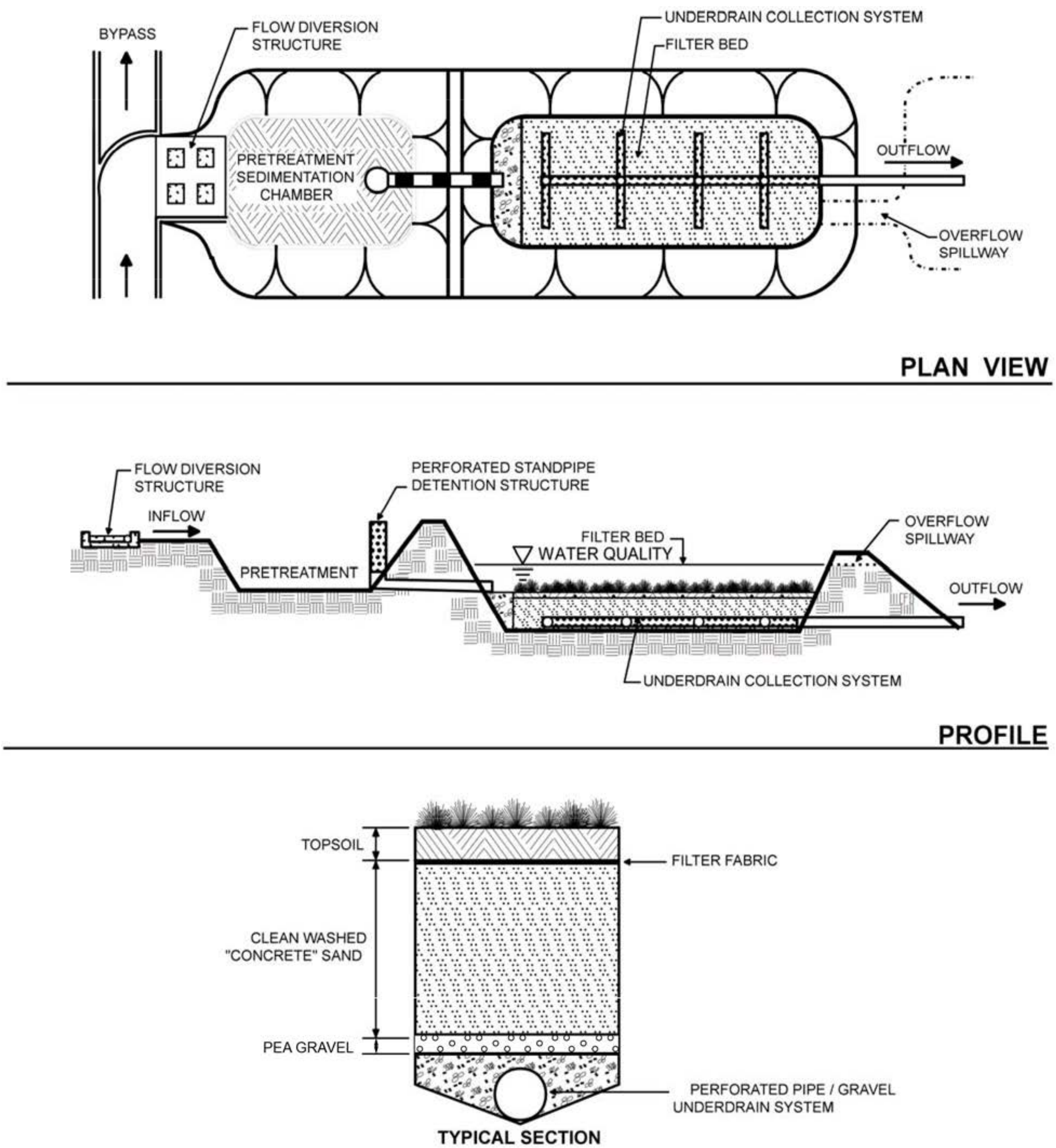

Figure 4-23. Surface Sand Filter

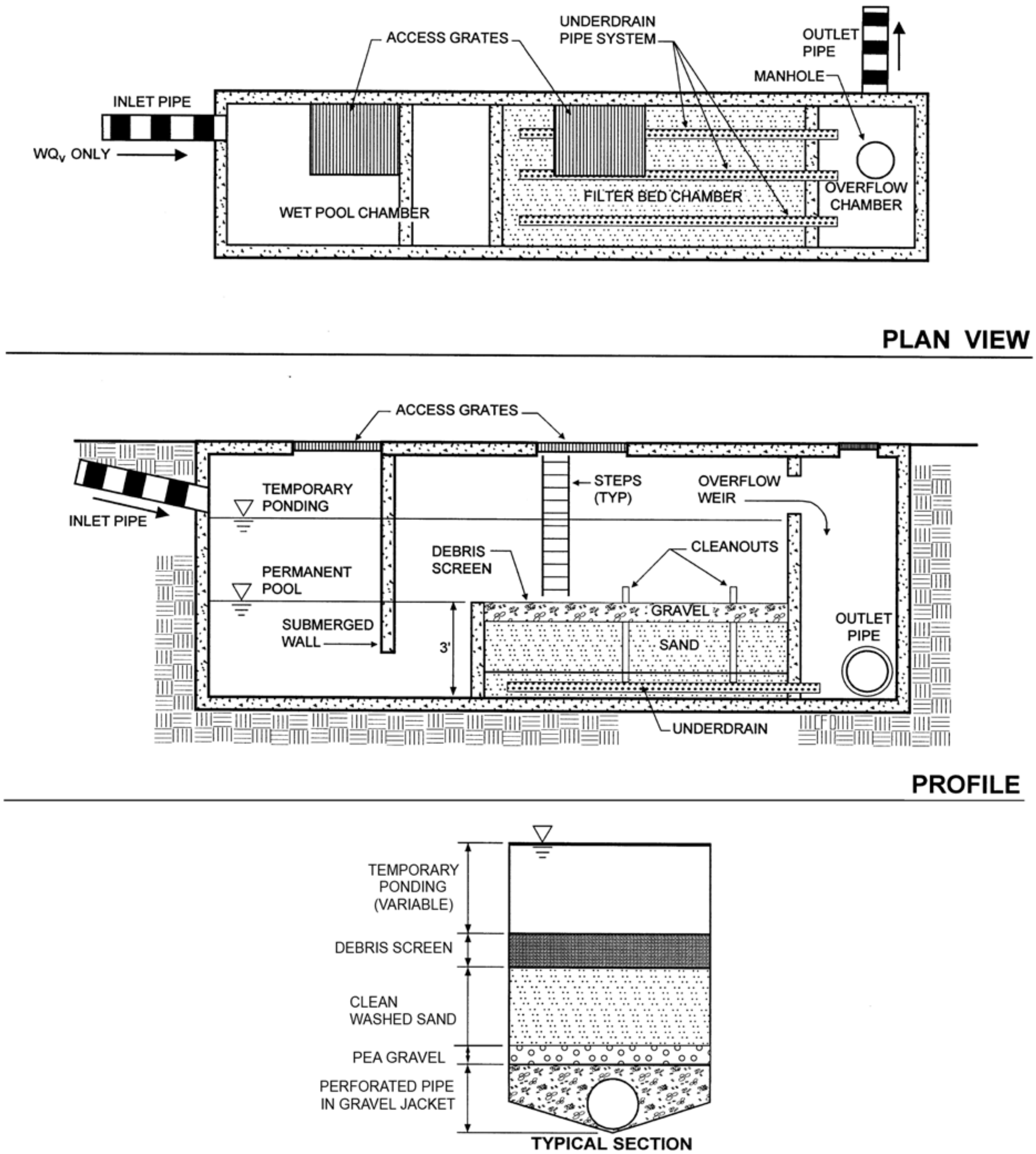

Figure 4-24. Underground Sand Filter

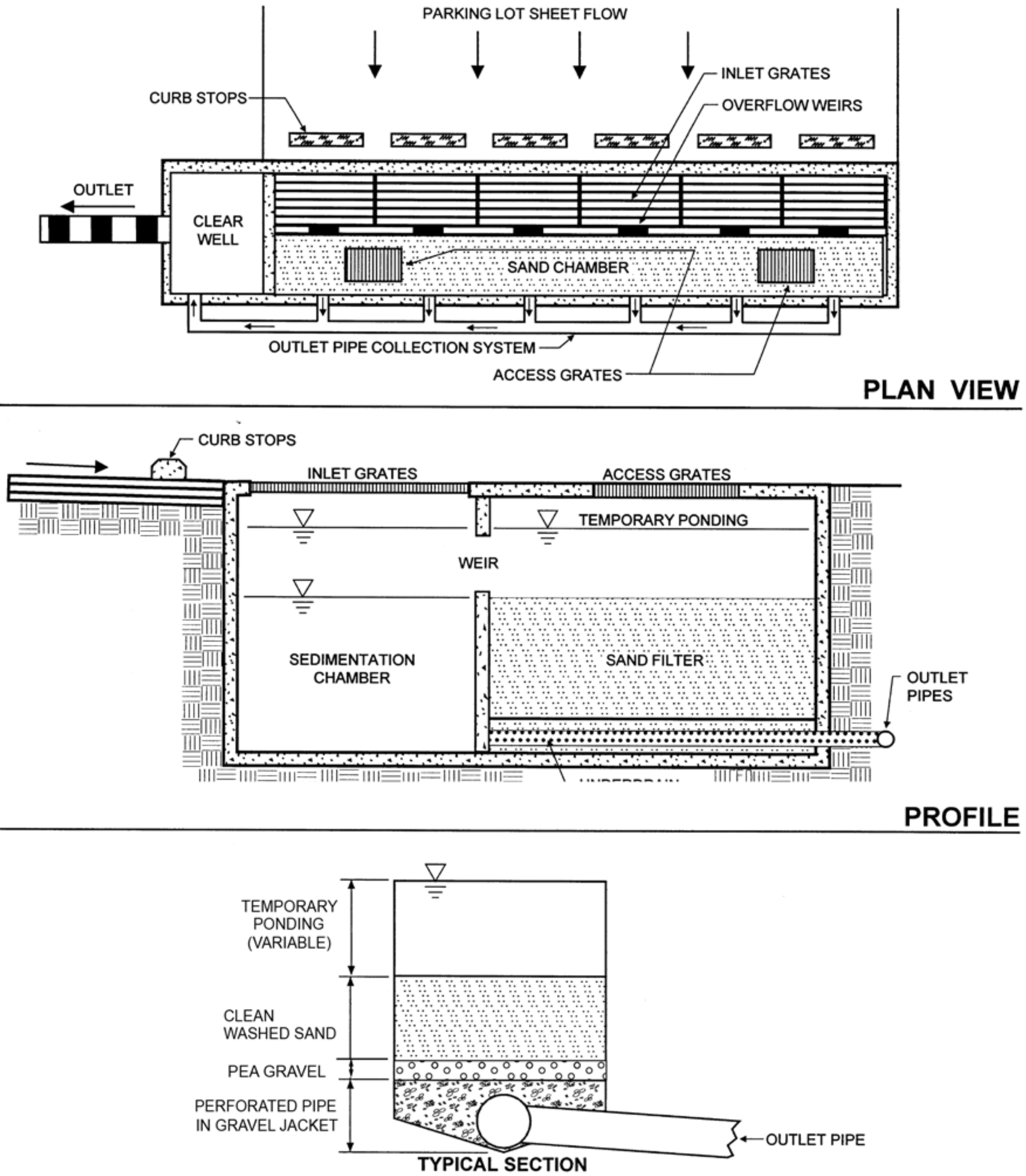

Figure 4-25. Perimeter Sand Filter

4.3.4.2. Filtering Feasibility

Required Elements

- The bottom of filtering systems shall be located at or above the seasonal high groundwater table (SHGWT).
- If the filtering practice is designed to infiltrate stormwater through the bottom of the practice into underlying soils, the soils shall have an infiltration rate (fc) of at least 0.0.2 inches per hour, as confirmed by field geotechnical tests (see Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements).
- For filtering practices designed to infiltrate stormwater, relevant feasibility required elements for infiltration trench/basin practices must also be met (Section 4.3.6). The separation to SHGWT requirements identified in Section 4.3.6 are not applicable to filtering practices designed to treat the water quality and groundwater recharge volumes only.
- Systems designed to infiltrate more than the WQ_v shall maintain a minimum 3 foot separation to SHGWT from the bottom of the practice; unless contributing drainage area to the practice is less than or equal to 1.0 acre, than:
    - Minimum of 2 feet separation to SHGWT from bottom of filtering system when contributing drainage area (CDA) of 1.0 acre or less, is greater than 50% impervious.
    - Minimum of 1 foot separation to SHGWT from bottom of filtering system when contributing drainage area (CDA) of 1.0 acre or less, is less than or equal to 50% impervious.
- No soil-related restrictions (minimum separations to seasonal high groundwater or bedrock) are required for media filters that are underdrained and fully enclosed (not designed for infiltration).
- The maximum contributing drainage area to an individual surface sand filtering system shall be 5 acres. The maximum contributing drainage area for perimeter or underground filters shall be 2 acres.

Design Guidance

- Most stormwater filters require four to six feet of head, depending on site configuration and land area available. The perimeter sand filter, however, can be designed to function with as little as 18" to 24" of head.
- Sand filtering systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with contributing area imperviousness greater than 75%, and sites with high sediment loading (such as aggressive use of road sand for de-icing), will require more aggressive sedimentation pretreatment techniques.

4.3.4.3. Filtering Conveyance

Required Elements

- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filter practice shall be designed off-line. In these cases, a flow regulator (or flow splitter diversion structure) shall be supplied to divert the WQ_v to the filter practice, and allow larger flows to bypass the practice.
- In cases where filtering practices are designed as on-line practices, an overflow shall be provided within the practice to pass flows in excess of the WQ_v or T_v to a stabilized water course. Designers must indicate how on-

line filtering practices will safely pass the 10-year storm without resuspending or flushing previously trapped material.

- An overflow for the 10-year storm shall be provided to a non-erosive outlet point (i.e., prevent downstream slope erosion).
- Stormwater filters shall be equipped with a minimum 6" perforated pipe underdrain (8" is preferred) in a 1-foot gravel layer. Synthetic filter fabrics shall not be used to completely separate the filter media from the underdrain bedding material. A 3-inch gravel choker course shall be used between underdrain bedding and sand media, instead of filter fabric.

Design Guidance

- When designing the flow splitter, the designer should exercise caution to ensure that 75% of the WQ_v can enter the treatment system prior to flow bypass occurring at the flow splitter. The overflow weir between the sedimentation and filtration chambers may be adjusted to be lower in elevation than the flow splitter weir to minimize bypass of the filter system prior to inflow filling the 75% WQ_v storage.
- Filtering practices should be designed to completely drain or dewater within 48 hours (2 days) after a storm event to reduce the potential for nuisance conditions.

4.3.4.4. Filtering Pre-Treatment

Pre-treatment of roof runoff is not required, provided the runoff is routed to the filtering practice in a manner such that it is unlikely to accumulate significant additional sediment (e.g., via closed pipe system or grass channel), and provided the runoff is not commingled with other runoff.

Required Elements

- If stormwater is routed to forebay for required pre-treatment, forebay shall be volumetrically sized for 25% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.
- The typical pre-treatment method is a sedimentation basin that has a minimum length to width ratio of 1.5:1.

Design Guidance

- All pre-treatment devices, including sediment forebays should be designed as level spreaders such that inflows to the filter bed have near zero velocity and spread runoff evenly across the surface.

4.3.4.5. Filtering Treatment

Required Elements

- A storage volume of at least 75% of the design T_v – including the volume over the top of the filter media and the volume in the sediment forebay, as well within the filter media – is required in order to capture the volume from high-intensity storms prior to filtration and avoid premature bypass.
- Filter media shall consist of a medium sand (meeting ASTM C- 33 concrete sand).
- The filter bed shall have a minimum depth of 18". The perimeter filter shall have a minimum filter bed depth of 12".

- The filter area for sand filters shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) should be used as follows:

  Sand: 3.5 ft/day (City of Austin, 1988; VA DCR 2013)
  (Note: the above value is conservative to account for clogging associated with accumulated sediment)

The filter bed area is computed using the following equation:

$$A_f = \frac{(T_v)(d_f)}{(k)(h_f + d_f)(t_f)}$$

Where:

A_f = Surface area of filter bed (ft^2)
T_v = Treatment volume (ft^3)
d_f = Filter bed depth (ft)
k = Coefficient of permeability of filter media (ft/day)
h_f = Average height of water above filter bed (ft)
t_f = Design filter bed drain time (days)
(2 days or 48 hours is the recommended maximum t_f for sand filters)

Design Guidance

- The depth of the filter media plays a role in how quickly stormwater moves through the filter bed and how well it removes pollutants. A minimum filter bed depth of 12 to 18 inches is recommended for most applications. Greater filter media depths can be used in order to facilitate the removal of 1 to 3 inches of sand during maintenance without having to replace sand every time the top few inches of sand is removed.
- The surface slope of media filters should be level to promote even distribution of flow throughout the practice.
- Filter beds should be extended below the frost line to prevent the filtering medium from freezing during the winter.
- Combine filtering treatments with another stormwater treatment practice option that can be used as a backup to the filtering system to provide treatment during the winter when the filter bed is frozen.

4.3.4.6. Filtering Vegetation and Landscaping

Required Elements

- The entire contributing area must be stabilized before runoff can be directed into a filtration practice. A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas, and impervious area construction must be completed.

Design Guidance

- Surface filters can have a grass cover to aid in pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought.

4.3.4.7. Filtering Construction Sequencing

Required Elements

The following is a typical construction sequence to properly install a structural stormwater filter.

- During site construction activities, sediment from the contributing drainage area must be prevented from flowing into or clogging the filter. Filtering practices shall not be constructed or opened to runoff until after the contributing drainage area to the facility is completely stabilized.
- Construction materials shall be staged on site and inspected to make sure they meet design specifications.
- Excavate/grade until appropriate design elevations are achieved for the bottom and side slopes of the filtering practice.
- Install the filter structure and check all design elevations (e.g. concrete vault pipe cut-out holes, bottom of excavation for surface filters, etc.).
- For enclosed and underdrained practices, ensure watertight storage and filter structure. Upon completion of the filter structure shell, the inlets and outlets should be temporarily plugged and the structure filled with water to the brim to demonstrate watertightness.
- Install underdrain, and gravel and choker stone layers.
- Spread filter media across the filter bed in 1-foot lifts up to the design elevation. Backhoes or other equipment should deliver the media from outside the filter structure. Sand should be manually raked.
- Consolidate filter media by filling the sedimentation and filter media chambers with clean water and allowing them to drain, hydraulically compacting the sand layers. Verify the depth of filter media meets the design minimum.
- For surface filters, install filter fabric (if specified) over the sand, add a topsoil layer with pea gravel inlet diaphragms (if specified), and immediately seed with the permanent grass species. The grass should be watered, and the facility should not be brought on-line until a vigorous grass cover has become established. For underground or perimeter filters, install permeable fabric and thin layer of pea gravel ballast (if specified) over the filter media.
- Stabilize exposed soils on the perimeter of the structure with temporary seed mixtures appropriate for a buffer.
- Conduct the final construction inspection. Remove excess straw and any unwanted vegetation.

4.3.4.8. Filtering Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- During the six months immediately after construction, filter practices shall be inspected following at least the first two precipitation events of at least 1.0 inch to ensure that the system is functioning properly. Thereafter, inspections shall be conducted on an annual basis and after storm events of greater than or equal the 1-year, 24-hour storm event.

- The maintenance plan must indicate the approximate time to drain the maximum design storm runoff volume through the filtering practice. This normal drain or drawdown time shall then be used to evaluate the filter's actual performance.

4.3.4.9. Filtering Maintenance – Annual

Required Elements

- Inspect practice for consistency with approved design plan, including any narrative inspection and maintenance requirements.
- Filters must be inspected for sand build-up in the filter chamber following the spring melt event.
- Sediment shall be cleaned out of forebays or other pre-treatment facilities when it accumulates to a depth of more than 6 inches. Pre-treatment outlet devices shall be cleaned/repaired when drawdown times exceed 36 hours. Trash and debris shall be removed as necessary.
- Silt/sediment shall be removed from the filter bed when the accumulation exceeds one inch. When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), the top 1-3 inches of discolored material shall be removed and shall be replaced with fresh material. The removed sediments shall be disposed in an acceptable manner (i.e., landfilled).

Design Guidance

Maintenance inspections should include checking for the following:

- Inspect whether the contributing drainage area to the filter is stable and not a source of sediment.
- Check to see if inlets and flow splitters are clear of debris and are operating properly.
- Check to see if sediment accumulation in the sedimentation chamber has exceeded 6 inches. If so, schedule a cleanout. Sediment testing may be required prior to sediment disposal when filtering practices are used for treatment at a hotspot land use.
- Check the dry sediment chamber and sand filter bed for any evidence of standing water or ponding more than 48 hours after a storm, and take necessary corrective action to restore permeability.
- Dig a small test pit in the sand filter bed to determine whether the first 3 inches of sand are visibly discolored and need replacement.
- Check whether turf on the filter bed and buffer is more than 12 inches high, and schedule necessary mowing operations.
- Check the integrity of observation wells and cleanout pipes.
- Check concrete structures and outlets for any evidence of spalling, joint failure, leakage, corrosion, etc.
- Ensure that the filter bed is level and remove trash and debris from the filter bed. Sand or gravel covers should be raked to a depth of 3 inches. Filters with a turf cover should have 95% vegetative cover.

4.3.4.10. References

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4.3.4.11. Treatment Wetlands

Constructed treatment wetlands are stormwater wetland systems that maximize pollutant removal and the uptake of nutrients through wetland vegetation, retention and settling. The two primary categories of constructed wetlands that are recommended for stormwater treatment include shallow surface wetlands and gravel wetlands. Shallow surface wetlands use organic wetland soils at the surface, and have a permanent pool of water with varying pool depths that supports the growth of wetland plants. The pools in shallow surface systems are designed with zones that have varying depth ranges:

- Deep water – greater than 18 inch depth, up to the maximum design depth of typically 4 to 6 feet;
- Low marsh – 6 inch to 18 inch depth below normal pool;
- High marsh – Up to 6 inches depth below normal pool; and
- Semi-wet – Areas above normal pool that are periodically inundated and expected to support wetland vegetation.

In contrast to the shallow surface wetlands, gravel wetlands store water within the interstitial void spaces of the gravel. Gravel systems typically have a 24 inch to 36 inch deep gravel bed that is saturated to the surface or just below the surface.

4.3.4.12. Design Summary

Criteria	Element	Requirements
Feasibility	Location	Shall not be located within existing jurisdictional waters, wetlands, or streams
	Soils	Liner required if infiltration rate greater than 0.05 inches/hour
	Minimum drainage area	10 acres for shallow surface wetland and no minimum drainage area for gravel wetland
Pretreatment	Required Pre-treatment	If stormwater is routed to forebay for required pre-treatment, forebay volumetrically sized for 10% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.
Shallow Wetland Treatment	Permanent pool	Minimum of 50% of WQv is stored in permanent pool. 50% of the WQv can be designed as extended detention above the permanent pool.
	Permanent pool depth zones	35% of the total surface area in depths 6 inches or less, and 65% of the total surface area shallower than 18 inches. Remaining 35% allocated to deep water zone (i.e. generally 4-6 feet). 35% of the WQv in deepwater zones (inclusive of forebay volume). The remaining 65% of the WQv shall be provided in some combination of shallow permanent pool and ED. ED storage volume shall not exceed 50% of the WQv and shall drain over 24 hours.
	Geometry (length to width ratio)	Minimum flowpath of 2:1 (length to width).
Gravel Wetland Treatment	Permanent pool	100% of the WQv (inclusive of forebay volume) may be provided in some combination of one or more basins filled with gravel and ED storage above the gravel. ED storage volume shall not exceed 50% of the WQv and shall drain over 24 hours. Gravel substrate shall be maintained in saturated condition.
	Geometry (length to width ratio)	Minimum flowpath of 1:1
Landscaping	Planting plan	A detailed planting plan is required specifying plants, locations, and installation and maintenance.
Other Considerations	Construction sequencing	If area is used for temporary sediment basin during construction, remove all accumulated sediments prior to conversion to permanent control practice in accordance with approved design plans.
	Maintenance	Inspect annually for consistency with approved design plans Operation and Maintenance Plan to specify reinforcement plantings after second season if 50% coverage not achieved Where sediment forebay included, sediment removal will occur when it reaches 6" or greater depth. Maintenance access must extend to the facility from a public or private road.

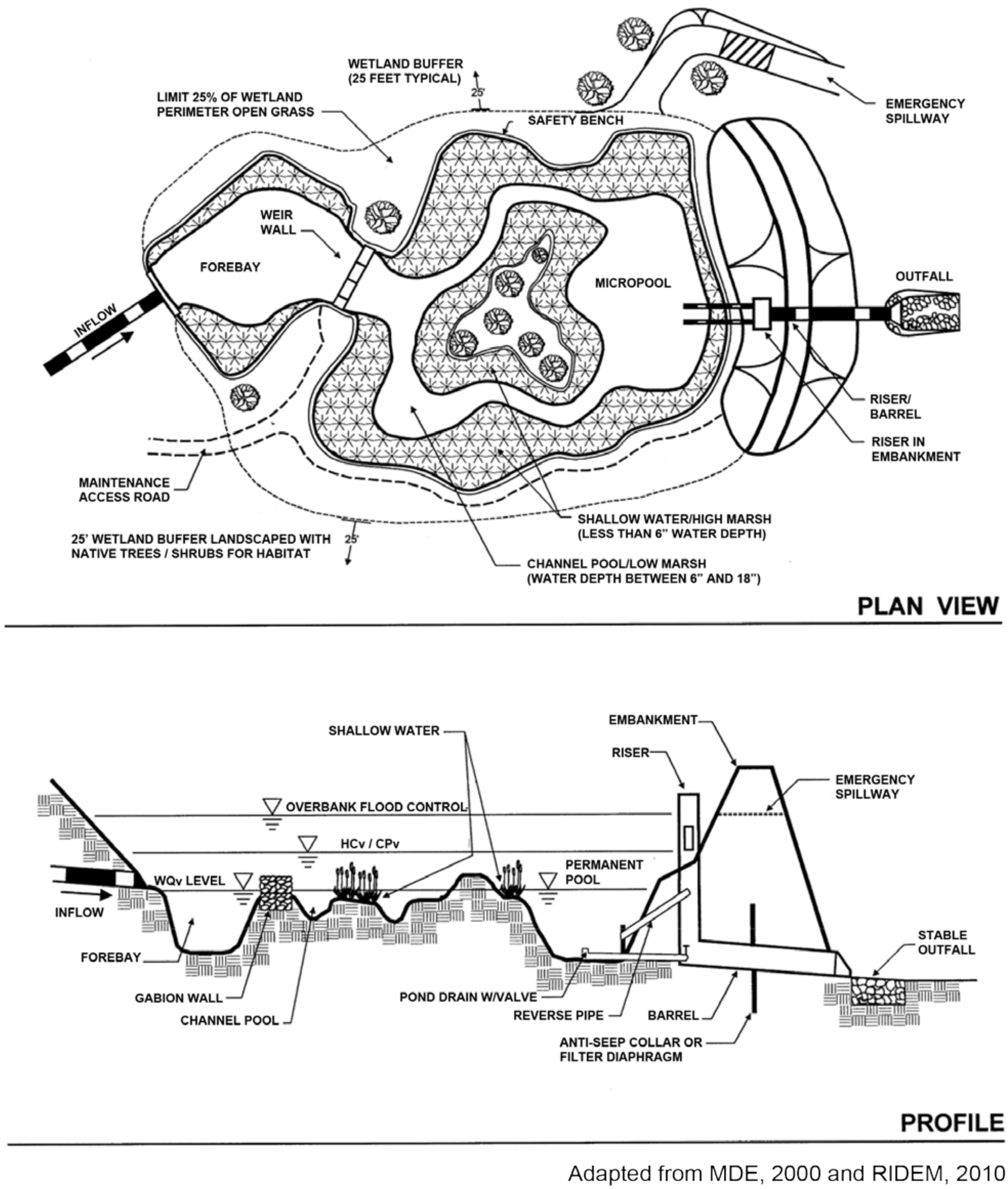

Figure 4-26. Shallow Surface Treatment Wetland

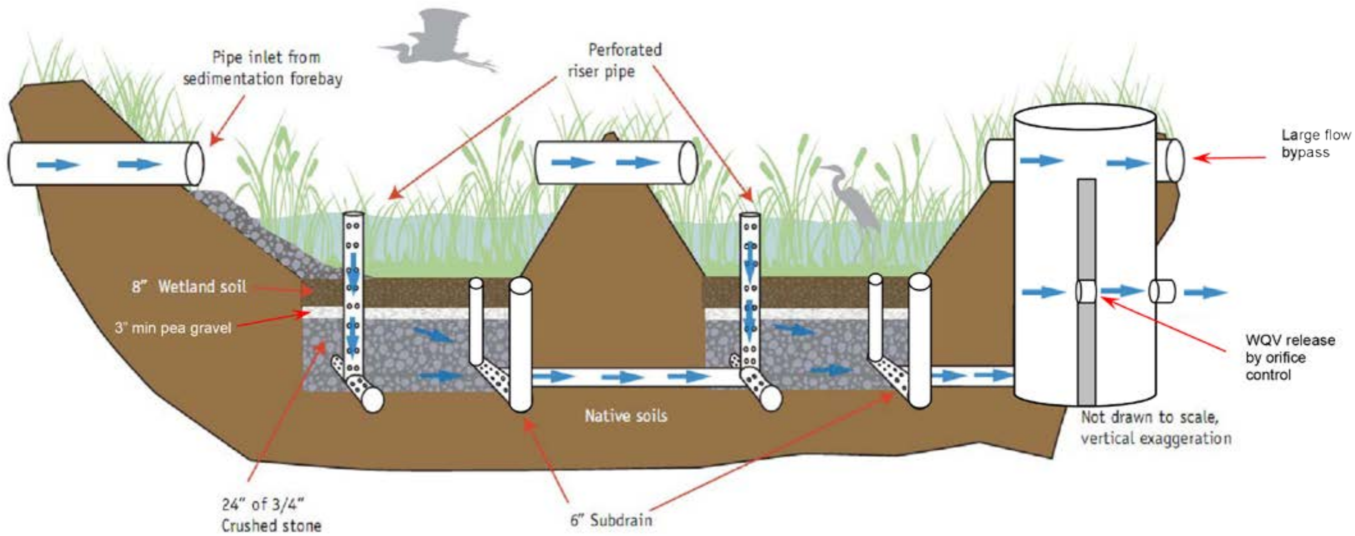

Figure 4-27. Gravel Treatment Wetland (University of New Hampshire Stormwater Center, 2009)

4.3.5. Wetland Feasibility

Required Elements

- Treatment wetlands shall not be located within jurisdictional waters, including wetlands. Treatment wetlands designs may be allowed in jurisdictional upland buffers in areas already altered under existing conditions, subject to approval by the Agency
- Shallow surface wetland discharges discharging directly to cold-water fishery streams shall be designed to discharge up to and including the CP_v through an underdrained gravel trench outlet (gravel wetlands have no restriction). Additional storage for Q_p may be discharged through traditional outlet structures.

Design Guidance

- Generally, shallow treatment wetlands require a minimum contributing drainage area of 10 acres to maintain a permanent pool, unless the practice intercepts groundwater. Likewise, a gravel wetland design generally requires a minimum drainage area of 5 acres unless the practice intercepts groundwater. Some flexibility in these target areas may be granted by the Agency on a case-by-case basis.
- A site evaluation by the designer is necessary to establish the Hazard Classification. It shall be the designer's responsibility to determine the design elements required to ensure dam safety and to incorporate those elements into the pond design (see Appendix B1, VSMM, Vol. 2, Technical Guidance, or other comparable guidance). Designers may choose to consider alternative placement and/or design refinements to reduce or eliminate the potential for designation as a significant or high hazard dam.

4.3.5.1. Wetland Conveyance

Required Elements

- Flow paths from the inflow points to the outflow points of shallow treatment wetlands shall be maximized through the use of internal design geometry and the inclusion of features such as berms, baffles, and islands in design plans. The minimum length to width ratio for a shallow treatment wetland is 2:1 (i.e., length relative to width
- Inlet areas must be stabilized to ensure that non-erosive conditions exist for at least the 1 year frequency storm event.
- For shallow surface wetlands, inlet pipes shall be set at the permanent pool or slightly above to limit erosive conditions. For gravel wetlands, inlet pipes shall be set either at the permanent pool or at the base of the gravel bed.
- Gravel treatment wetlands designed with an organic soil layer at the surface shall have vertical perforated riser pipes (or other conveyance means) that deliver stormwater from the surface down to the subsurface perforated distribution lines. The vertical risers shall not be capped, but rather covered with an inlet grate to allow for overflow when the water level exceeds the WQv.
- The channel immediately below a treatment wetland outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, typically by use of appropriately sized riprap placed over filter cloth. A stilling basin or outlet protection shall be used to reduce flow velocities from the principal spillway to non-erosive velocities (3.5 to 5.0 fps).
- A subsurface water level must be maintained in the gravel treatment wetland through the design of the outlet elevation (invert just below the surface).
- When a treatment wetland is located in medium to coarse sands and above the average groundwater table, a liner shall be used to sustain a permanent pool of water. If geotechnical tests confirm the need for a liner (soils with an infiltration rate of 0.05 in/hr or greater), acceptable options include: (a) 6 to 12 inches of clay soil (minimum 15% passing the #200 sieve and a maximum permeability of 1 x 10-5 cm/sec), (b) a 30 mil poly-liner, or (c) bentonite.
- For discharges from shallow surface wetlands into waters designated as cold-water fisheries, an underdrained gravel trench (Figure 4-34) shall be designed to meet the following requirements:
    - Shall be at least four feet wide, located at least 2 feet from the permanent pool, and located at the furthest location opposite from the principal inflow location to the facility;
    - The trench shall have a length of 3 feet per 1,000 ft^3 of extended detention storage volume, have a depth of at least 3 feet, and maintain 2 feet of gravel cover over a 6-inch diameter perforated pipe outlet (Rigid Sch. 40 PVC or SDR35);
    - Shall utilize geotextile fabric placed between the gravel trench and adjacent soil; and
    - Shall utilize clean poorly-graded gravel (i.e., uniform stone size).

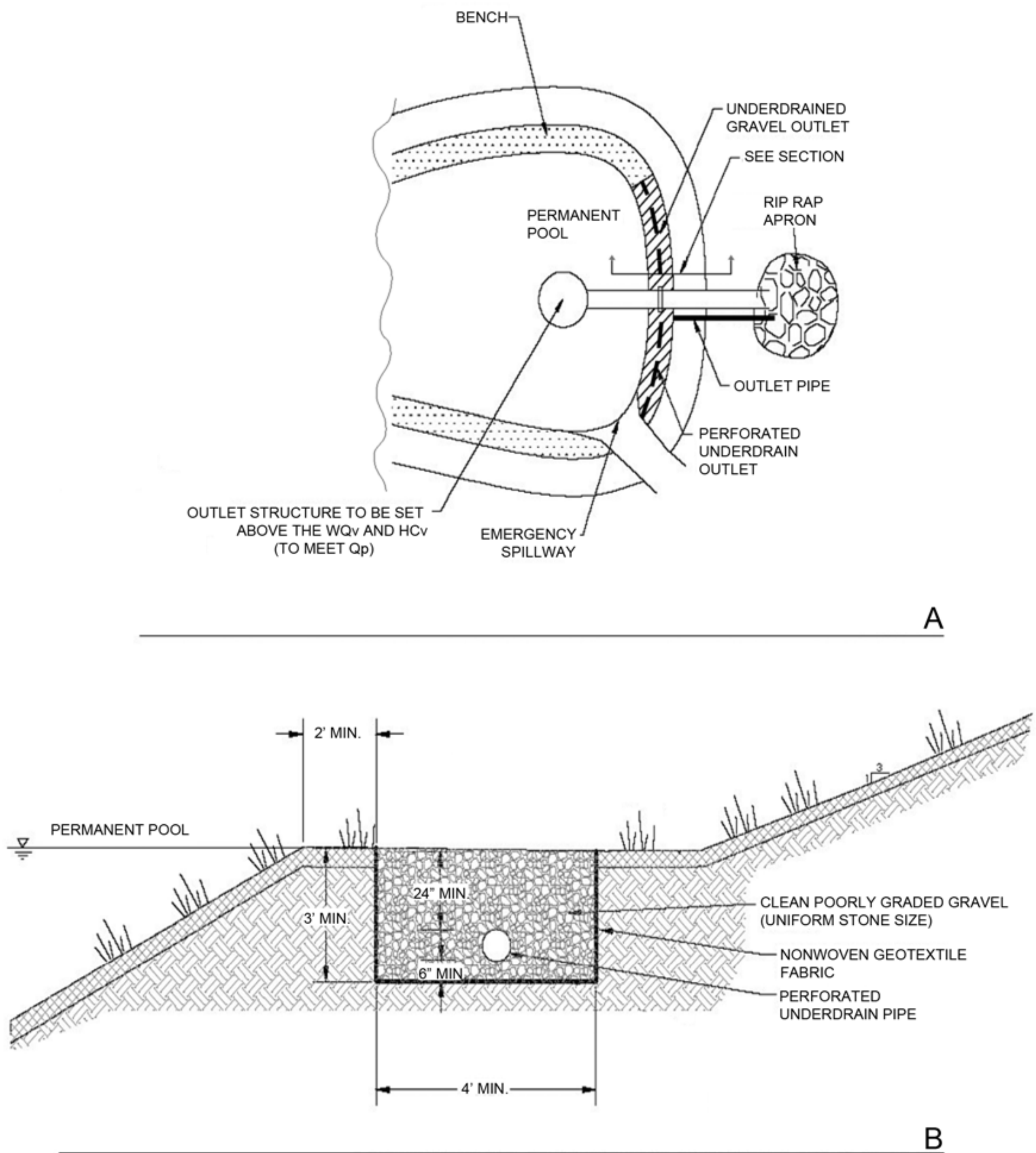

Figure 4-28. (A) Generalized plan view of underdrained gravel trench outlet for a shallow treatment wetland or basin and (B) Profile of underdrained gravel trench (adapted from Maine DEP 2006 and RI DEM 2010)

<u>**Design Guidance**</u>

- Outfalls should be constructed such that they do not increase erosion or have undue influence on the downstream geomorphology of any natural watercourse by discharging at or near the stream water surface elevation or into an energy dissipating step-pool arrangement.
- The gravel treatment wetland outlet structure should be based on a calculated release rate by orifice control to drain the WQv over 24 hrs. The practice may also have an additional orifice for draining the CPv as required by the Channel Protection Standard.

4.3.5.2. Treatment Wetland Pre-Treatment

Required Elements

- If a forebay is utilized for pre-treatment, the forebay shall be volumetrically sized to contain a minimum of 10% of the computed WQv. Otherwise, required pre-treatment designed in accordance with Section 4.1. Forebay storage volume counts toward the total WQv requirement.
- Otherwise, required pre-treatment designed in accordance with Section 4.1.
- Exit velocities from pretreatment chambers flowing over vegetated channels shall be non-erosive (3.5 to 5.0 fps) during the 1-year design storm (Appendix C7, VSMM, Vol. 2).

Design Guidance

- The bottom of the forebay may be hardened (i.e., concrete, asphalt, grouted riprap) to make sediment removal easier.

4.3.5.3. Treatment Wetland Treatment

Required Elements

- For shallow surface treatment wetlands: A minimum of 35% of the total surface area in the permanent pool shall have a depth of 6 inches or less, and at least 65% of the total permanent pool surface area shall be shallower than 18 inches. At least 10% of the WQv shall be provided in a sediment forebay if used for pre-treatment. At least 25% of the WQv shall be provided in "deep water zones" with a depth equal to or greater than 4 feet. The remaining WQv shall be provided in some combination of shallow permanent pool (depth less than 4 feet) and the extended detention (ED) storage volume above the permanent pool, as applicable. ED storage volume shall not exceed 50% of the WQv and shall drain over 24 hours.
- For shallow surface treatment wetlands: length to width ratio of 2:1 (L:W)
- For gravel treatment wetlands: At least 10% of the WQv shall be provided in a sediment forebay if used for pre-treatment. The remaining WQv shall be provided in some combination of one or more basins or chambers filled with a minimum 24-inch gravel layer and the open, ED storage volume above the gravel, as applicable. ED storage volume shall not exceed 50% of the WQv and shall drain over 24 hours.
- For a gravel treatment wetland: length to width ratio of 1:1 (L:W) or greater is needed for each treatment cell, with a minimum flow path (L) within the gravel substrate of 15 feet.

Design Guidance

- Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flow paths, high surface area to volume ratios, complex microtopography (complex contours along the bottom of the shallow treatment wetland, providing greater depth variation), and/or redundant treatment methods (combinations of pool, ED, and emergent vegetation). Basins shall follow natural landforms to the greatest extent possible or be shaped to mimic a naturally formed depression.
- For gravel treatment wetlands, a layer of organic soil may be used as substrate for emergent vegetation, but is not necessary depending on chosen species. If an organic soil layer is used as a top layer, it should have a minimum thickness of 8 inches, should be leveled (constructed with a surface slope of zero), and should be

underlain by 3” minimum thickness of an intermediate layer of a graded aggregate filter to prevent the organic soil from moving down into the gravel sublayer. If organic soil is utilized, it shall meet the material specifications in Appendix B2, VSMM, Vol. 2.

4.3.5.4. Treatment Wetland Landscaping and Vegetation

Required Elements

- The perimeter of all deep pool areas (four feet or greater in depth) shall be surrounded by two benches as follows (Figure 4-35):
  - o Except when side slopes are 4:1 (h:v) or flatter, provide a safety bench that generally extends 15 ft. outward (a 10 ft. minimum bench is allowable on sites with extreme space limitations at the discretion of the approving agency) from the normal water edge to the toe of the treatment wetland side slope. The maximum slope of the safety bench shall be 6%; and
  - o Incorporate an aquatic bench that generally extends up to 15 feet inward from the normal edge of water, has an irregular configuration, and a maximum depth of 18 inches below the normal pool water surface elevation.

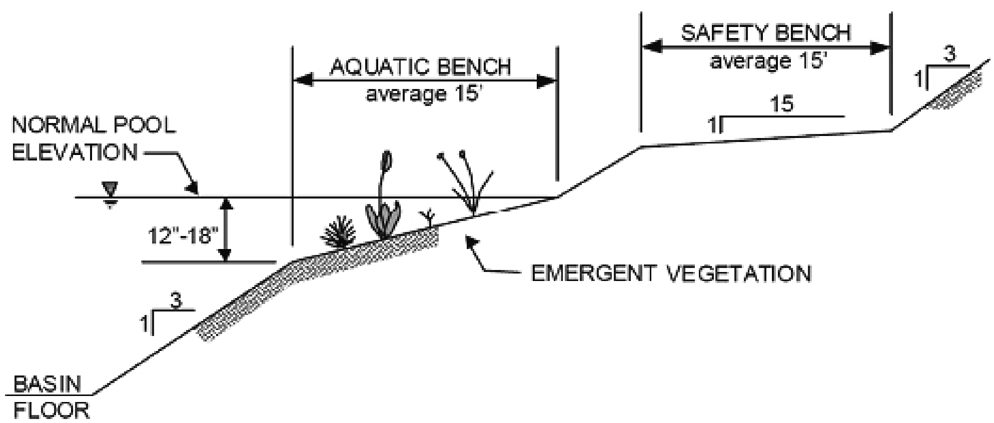

Figure 4-29. Typical Shallow Treatment Wetland Bench Geometry (ARC, 2001 and RIDEM, 2010)

- A planting plan for a treatment wetland and surrounding areas shall be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation. Minimum elements of a plan include: delineation of pondscaping zones, selection of corresponding plant species, plant locations, sequence for preparing treatment wetland bed (including soil amendments, if needed), and sources of plant material.
- Donor organic soils for treatment wetlands shall not be removed from natural wetlands.
- A setback from the treatment wetland shall be provided that extends 25 feet outward from the maximum design water surface elevation of the facility.
- Woody vegetation shall not be planted or allowed to grow on a dam, or within 15 feet of a dam or toe of the embankment, or within 25 feet of a principal spillway outlet.

Design Guidance

- The best elevations for establishing emergent plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.
- The soils surrounding a treatment wetland are often severely compacted during the construction process to ensure stability. The density of these compacted soils is often so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil.
- A gravel treatment wetland should be planted to achieve a rigorous root mat with grasses, forbs, and shrubs, using obligate and facultative-wetland plant species.
- Planting holes should be the same depth as the root ball and two to three times wider than the diameter of the root ball. In addition, the root ball of container-grown stock should be gently loosened or scored along the outside layer of roots to stimulate new root development. This practice should enable the stock to develop unconfined root systems. Avoid species that require full shade or are prone to wind damage. Proper mulching around the base of trees and shrubs (2-4 inches of mulch, kept 1-2 inches away from trunks or stems) is strongly recommended as a means of conserving moisture and suppressing weed growth.
- Structures such as fascines, coconut rolls, or carefully designed stone weirs can be used to create shallow cells in high-energy flow areas of the shallow treatment wetland.
- Existing trees should be preserved around the treatment wetland area during construction. It is also desirable to locate forest conservation or reforestation areas adjacent to treatment wetlands. To help encourage reforestation and discourage resident geese populations, the area immediately surrounding the permanent pool can be planted with trees, shrubs and native ground covers.
- Annual mowing of the area immediately surrounding the permanent pool is only required along maintenance rights-of-way and the embankment. The remaining upland area can be managed as a meadow (mowing every other year) or forest.

4.3.5.5. Treatment Wetland Construction Sequencing

Design Guidance

Construction of the treatment wetlands can be accomplished in stages and these practices may serve as temporary erosion and sediment control sedimentation basins, but will need to be converted prior to going on-line as a permanent stormwater treatment practice.

The following is a typical construction sequence to properly install treatment wetlands:

- Prior to commencing construction, a preconstruction meeting shall be held among the owner, contractor and engineer.
- Stake out limit of disturbance, basin bottom, and inlet/outlet flow control devices.
- Install perimeter erosion and sediment control practices.
- Clear/grub proposed disturbed area.
- Strip and stockpile topsoil in location approved by the engineer. Surround stockpile with sediment control barrier.

- Rough grade treatment wetland basin and sediment forebay areas during general site grading. Install diversion swales as necessary to keep surface runoff from flowing into the forebay and treatment wetland prior to being permanently stabilized.
- Install inflow drainage system as applicable.
- Install overflow outlet structure per details.
- Install approved subgrade material and construct all berms and spillways as shown in the details.
- Install planting soil as shown in the details.
- Stabilize all remaining disturbed areas around facility by seeding, hydroseeding and/or other erosion control methods as outlined in the plans and details.
- Install plantings as shown on planting plans and details. No planting should occur before remaining disturbed areas around the facility have been stabilized. The contractor will be required to remove any sediment which washes into the treatment wetland area during the construction and planting phases.
- Install remaining planting soil around plants as shown in details.
- Fill in temporary diversion swales and remove remaining erosion and sediment controls only after surrounding exposed soil areas have been properly stabilized.

4.3.5.6. Treatment Wetland Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated design plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- Within the first year of operation, inspect facility after events greater than or equal to 1.0 inches of rainfall to verify the following.
    - Verify that landscaping and vegetation has been established over more than 85% of the planting zones within the treatment wetland;
    - Remove dead plants and replace them with new stock. Up to 10% of the plant stock may die off in the first year. Construction contracts shall include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction. The typical thresholds below which replacement is required are 85% survival of plant material and 100% survival of trees.
    - Inspect for, and remove, any invasive plant species.
    - For facilities with the gravel trench outlet, inspections shall verify that the treatment wetland is draining to the permanent pool elevation within design requirement and that potentially clogging material, such as decaying leaves or debris, does not prevent discharge through the gravel.

4.3.5.7. Treatment Wetland Maintenance – Annual

Required Elements

- Inspect practice for consistency with approved design plan, including any narrative inspection and maintenance requirements.
- A maintenance access road or pathway shall be identified on the plans and extend to the treatment wetland from a public or private road.
- The principal spillway shall be equipped with a removable trash rack, and generally accessible from dry land.
- A maintenance and operation plan must specify that sediment removal in the shallow wetland or gravel wetland pre-treatment forebay (or other pre-treatment practice) shall occur every 5 years or after 50% of total pre-treatment facility storage capacity has been lost, whichever occurs first.
- The annotated design plan's maintenance requirements shall specify that if a minimum vegetative coverage of 50% is not achieved in the planted areas after the second growing season, a reinforcement planting is required.
- Organic material build-up (e.g., dead growth from grasses and perennial plants) shall be removed from a gravel treatment wetland as needed; this typically will be needed every two years at the end of the growing season.
- In the gravel treatment wetland, vertical cleanouts must be constructed that are connected to the distribution and collection subdrains at each end.
- Remove any invasive or woody vegetation that is growing within or encroaching on the wetland.

Design Guidance

- Sediments excavated from treatment wetlands that do not receive runoff from designated hotspot land use are generally not considered toxic or hazardous material, and can be safely disposed by either land application or land filling. Sediment testing may be required prior to sediment disposal when a hotspot is present. Sediment removed from a treatment wetland should be disposed of according to an approved comprehensive operation and maintenance plan.
- The slopes of the treatment wetland should be inspected for erosion and gullying. Reinforce existing riprap if riprap is found to be deficient, erosion is present at the outfalls of any control structures, or the existing riprap has been compromised. Re-vegetate slopes as necessary for stabilization.
- All structural components, which include, but are not limited to, trash racks, access gates, valves, pipes, weir walls, orifice structures, and spillway structures should be inspected and any deficiencies should be corrected. This includes a visual inspection of all stormwater control structures for damage and/or accumulation of sediment.
- All dead or dying vegetation within the extents of the treatment wetland should be removed, as well as all herbaceous vegetation rootstock when overcrowding is observed and any vegetation that has a negative impact on stormwater flowage through the facility. Any invasive vegetation encroaching upon the perimeter of the facility should be pruned or removed if it is prohibiting access, compromising sight visibility and/or compromising original design vegetation.

- The maintenance access road/pathway should be at least 10 feet wide, have a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles. The maintenance access should extend to the forebay(s), safety bench, emergency spillway, outlet control structure, and outlet and be designed to allow vehicles to turn around.

4.3.5.8. References

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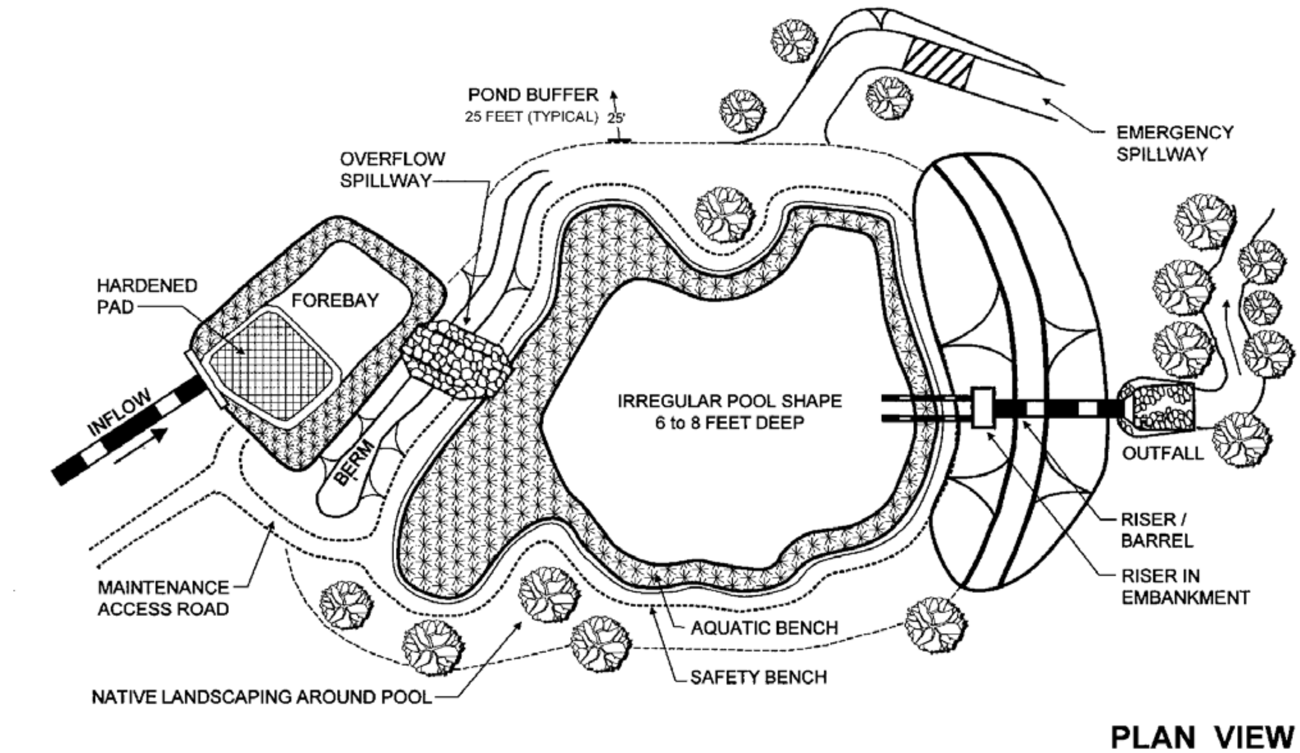
4.3.6. Wet Ponds

Wet ponds consist of a permanent pool of standing water that promotes a stable environment for gravitational settling, biological uptake, and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a residence time that ranges from many days to several weeks, which allows numerous pollutant removal mechanisms to operate. Wet ponds can also provide extended detention (ED) above the permanent pool to help meet CP_V and Q_P requirements.

4.3.6.1. Design Summary

Criteria	Element	Requirements
Feasibility	Location	Shall not be located within existing jurisdictional waters, wetlands, or streams
	Contributing Drainage Area	10 acres or more
Conveyance	Outlets and spillway	Wet ponds draining to cold water fisheries shall discharge the CPv through an underdrained gravel trench outlet Outfall shall be stable for the Q design storm event Stilling basin or outlet protection shall be used to reduce flow velocities from the principal spillway to non-erosive velocities (2.5 to 5.0 fps).
	Forebay or similar functional device	If stormwater is routed to forebay for required pre-treatment, forebay volumetrically sized for 10% of the computed WQ_v. Otherwise, required pre-treatment designed in accordance with Section 4.1.
Pre-Treatment	Permanent pool	Minimum of 50% of WQ_v is stored in permanent pool. 50% of the WQ_v can be as extended detention above the permanent pool.
Treatment	Extended Detention Volumes	Extended Detention (ED) storage volume shall not exceed 50% of the WQ_v
	Permanent pool depth zones	25% of the WQ_v in deepwater zones. The remaining WQ_v shall be provided in some combination of shallow permanent pool and ED. ED storage volume shall not exceed 50% of the WQ_v and shall drain over 24 hours.
	Minimum surface area	Surface area must be minimum of 1.5% of drainage area.
	Geometry (length to width ratio)	3:1 or more
	Length of Shortest Flow Path/Overall Length	0.8 or more; in the case of multiple inflows, the flow path is measured from the dominant inflows (that comprise 80% or more of total pond inflow)
	Benches	Safety bench and aquatic bench required
Landscaping	Planting plan	A detailed planting plan is required specifying plants, locations, and installation and maintenance.
	Construction sequencing	If used for temporary E&SC, remove all accumulated sediments prior to conversion to permanent control practice.
Other Considerations	Maintenance	Operation and Maintenance Plan to specify reinforcement plantings after second season if 50% coverage not achieved Sediment shall be removed from forebay every 5 years, or after 50% of total forebay capacity has been lost Maintenance access must extend to the facility from a public or private road.



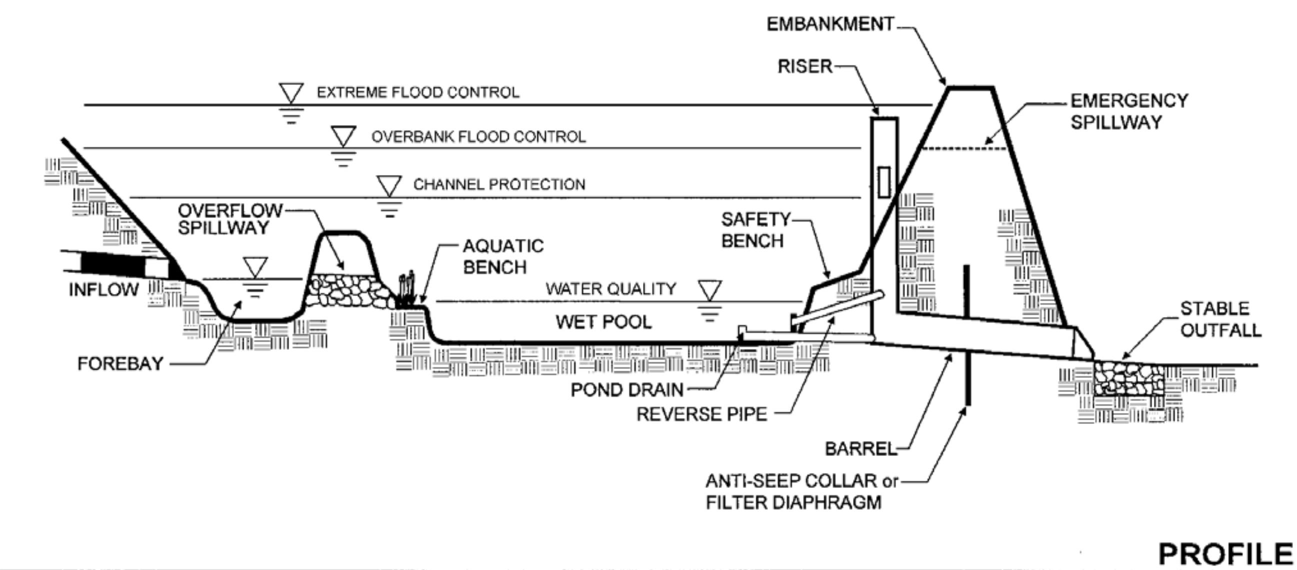
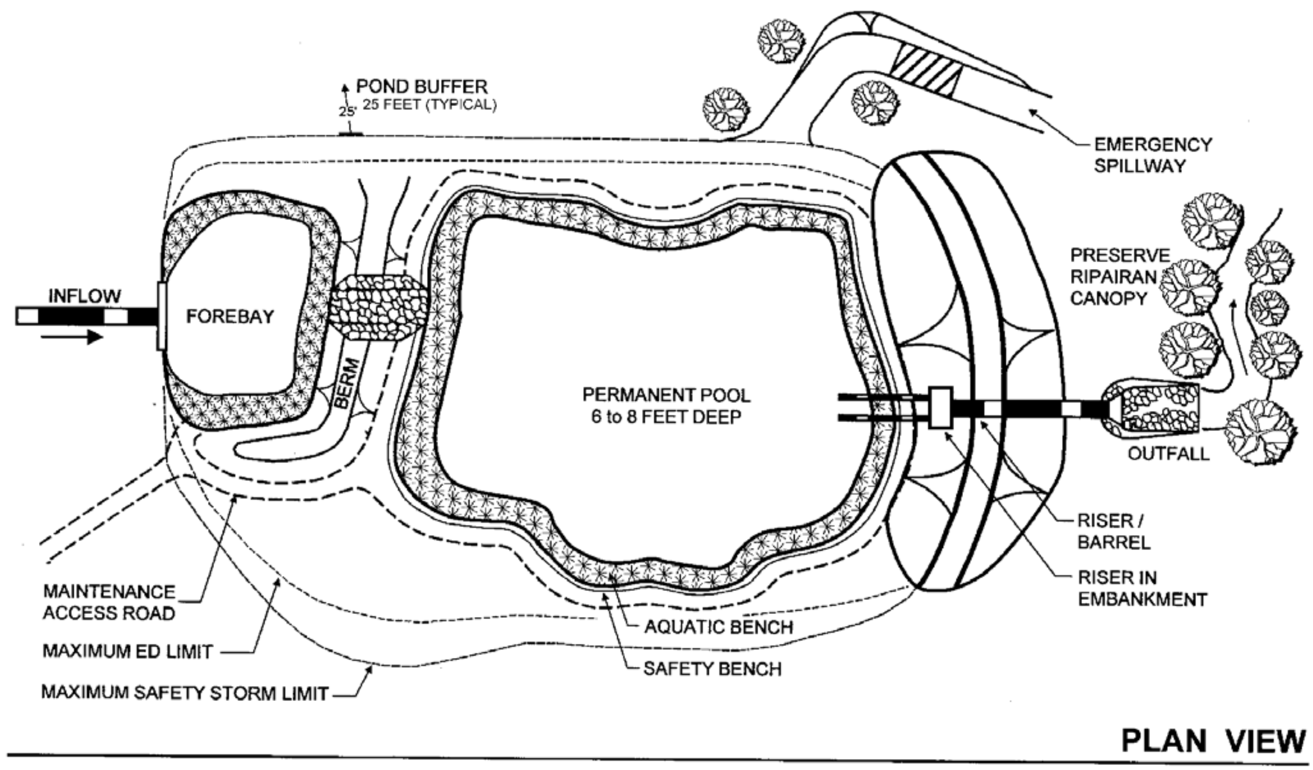


Figure 4-30. Wet Pond



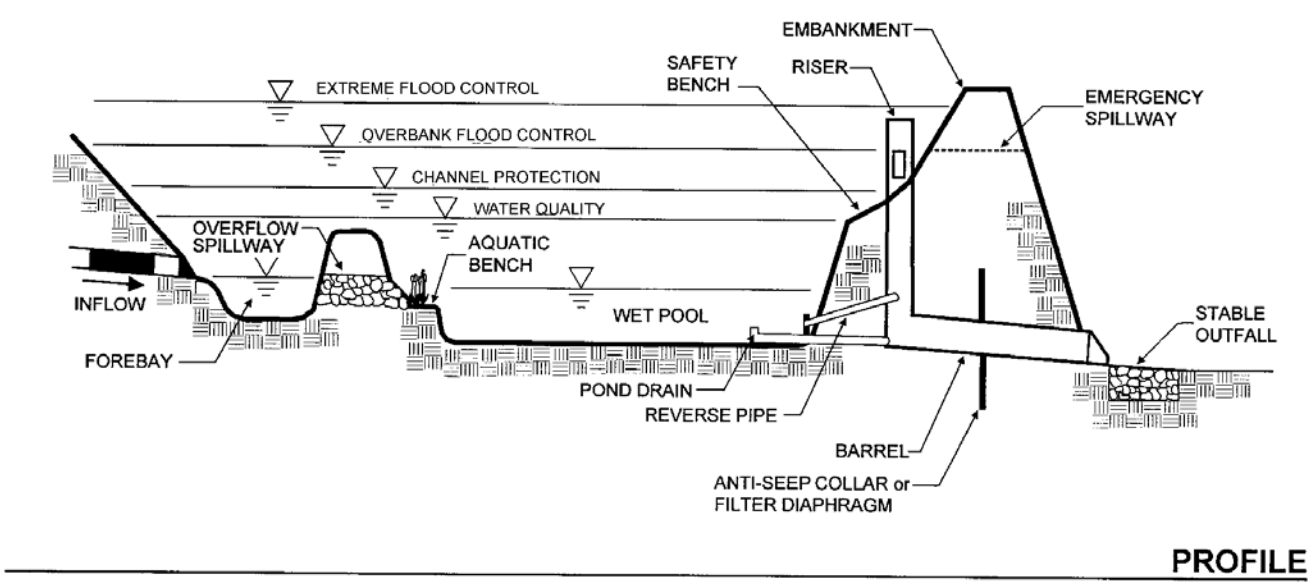


Figure 4-31. Wet Extended Detention Pond

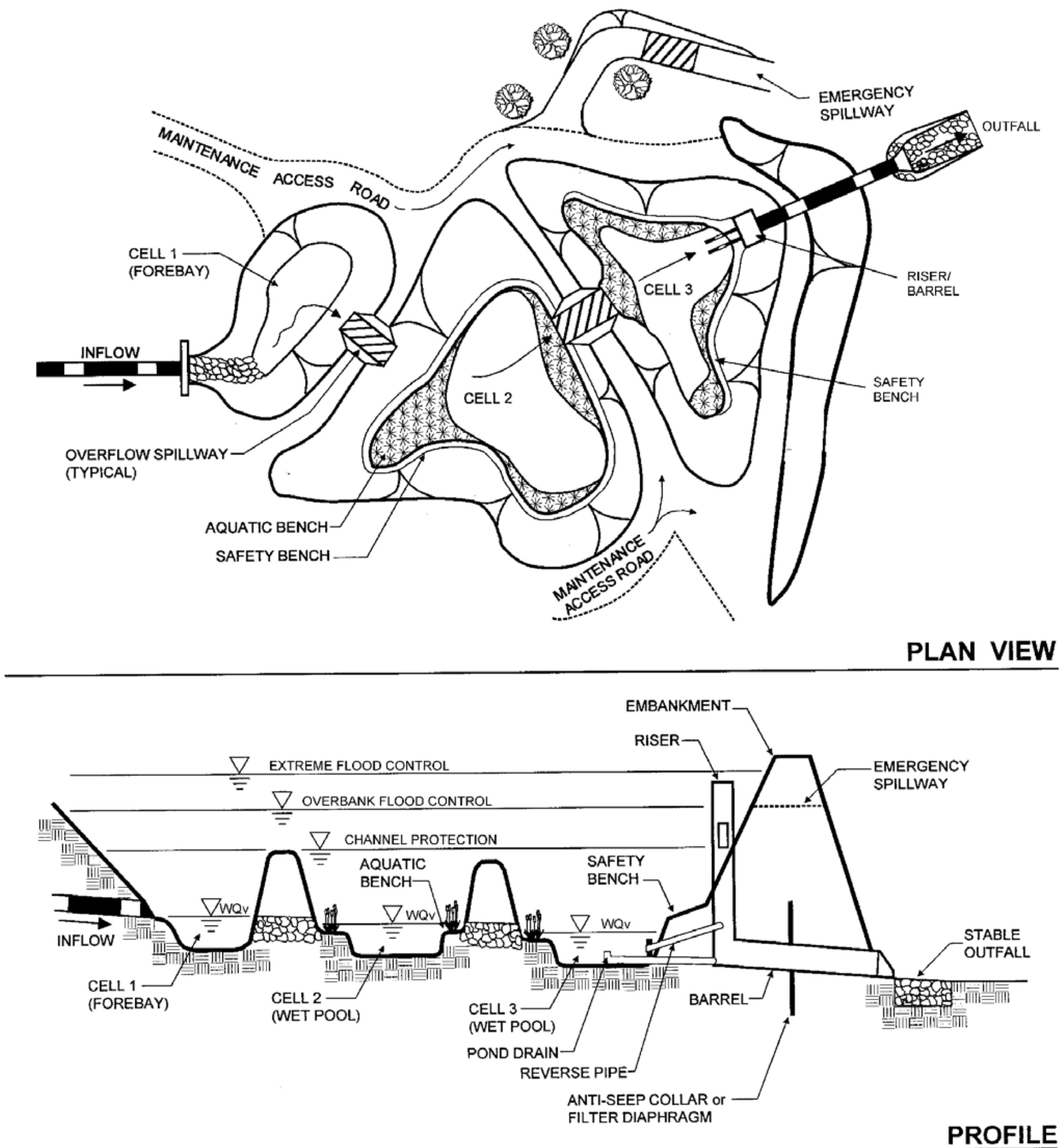


Figure 4-32. Multiple Pond System

4.3.6.2. Wet Pond Feasibility

Required Elements

- Wet ponds shall have a minimum contributing drainage area of 10 acres.
- Stormwater ponds shall not be located within jurisdictional waters, including wetlands, except that on already developed sites, pond designs may be allowed in jurisdictional upland buffers in areas already altered under existing conditions, if acceptable to the approving agency.
- A basin setback from structures, roads, and parking lots shall be provided that extends 25 feet outward from the maximum water surface elevation of the basin.
- Ponds receiving runoff from stormwater hotspots must be lined and shall not intercept ground water.
- Ponds shall not include the volume of the permanent pool in storage calculations for storms greater than the water quality event.

Design Guidance

- A site evaluation by the designer is necessary to establish the Hazard Classification. It shall be the designer's responsibility to determine the design elements required to ensure dam safety and to incorporate those elements into the pond design (see Appendix B1, VSMM, Vol. 2, Technical Guidance, or other comparable guidance). Designers may choose to consider alternative placement and/or design refinements to reduce or eliminate the potential for designation as a significant or high hazard dam.
- Slopes immediately adjacent to ponds should be less than 25% but greater than 1% to promote flow toward the pond.
- The use of wet ponds is highly constrained at development sites with steep terrain. Some adjustments can be made by terracing pond cells in a linear manner, using 1 to 2 foot armored elevation drop between individual cells. Terracing may work well on longitudinal slopes with gradients up to approximately 10%.
- The permanent pool should hold a minimum of 0.5"/impervious acre draining to the basin for aesthetics and ease of maintenance. A water balance should be calculated to assess whether the wet pond will draw down by more than 2 feet after a 30-day summer drought.
- The depth of a wet pond should be determined by the hydraulic head available on the site. The bottom elevation is normally the invert of the existing downstream conveyance system to which the wet pond discharges. Typically, a minimum of 6 to 8 feet of head are needed for a wet pond to function.
- Highly permeable soils make it difficult to maintain a constant level for the permanent pool. Underlying soils of Hydrologic Soil Group (HSG) C or D should be adequate to maintain a permanent pool. Most HSG A soils and some HSG B soils will require a liner. Geotechnical tests should be conducted to determine the infiltration rates and other subsurface properties of the soils beneath the proposed pond to determine if a liner is needed. If geotechnical tests confirm the need for a liner, acceptable options include: (a) 6 to 12 inches of clay soil (minimum 15% passing the #200 sieve and a maximum permeability of 1 x 10-5 cm/sec), (b) a 30 mil poly-liner (c) bentonite.
- For situations with shallow bedrock and groundwater, pond use is limited due to the available depth, which will affect the surface area required as well as the aesthetics of the pond. Consider stormwater treatment wetlands as an alternative.

4.3.6.3. Wet Pond Conveyance

Required Elements

- Inlet areas shall be stabilized to ensure that non-erosive conditions exist during events up to the Q_{10} event.
- A low-flow orifice shall be provided when the wet pond is sized for the CP_v, and designed to ensure that no clogging shall occur.
- Wet ponds in watersheds draining to cold water fisheries shall be designed to discharge volumes up to the CP_v through an underdrained gravel trench outlet (Figure 4-31) that meets the following requirements:
    - The trench shall be excavated in a pond bench having a minimum width of 8 feet. The trench must be four feet wide, located at least two feet laterally from the permanent pool (e.g., pond-side edge of the bench), and located at the furthest location opposite from the principal inflow location to the facility;
    - The bench must be set at the permanent pool elevation such that the CP_v will be stored between the bench surface elevation and the elevation of any flood control or emergency spillway outlets;
    - The trench shall have a length of 3 feet per 1,000 ft^3 of extended detention storage volume, have a depth of at least 3 feet, and maintain 2 feet of gravel cover over and 6 inches below a 6-inch diameter perforated pipe outlet (Rigid Sch. 40 PVC or SDR35);
    - Shall utilize geotextile fabric placed between the sides of the gravel trench and adjacent soil; and,
    - Shall utilize clean, uniformly-sized stone;
    - The pond outlet or orifice shall be designed to prevent clogging and to allow access to the underdrain outlet for inspection and maintenance.

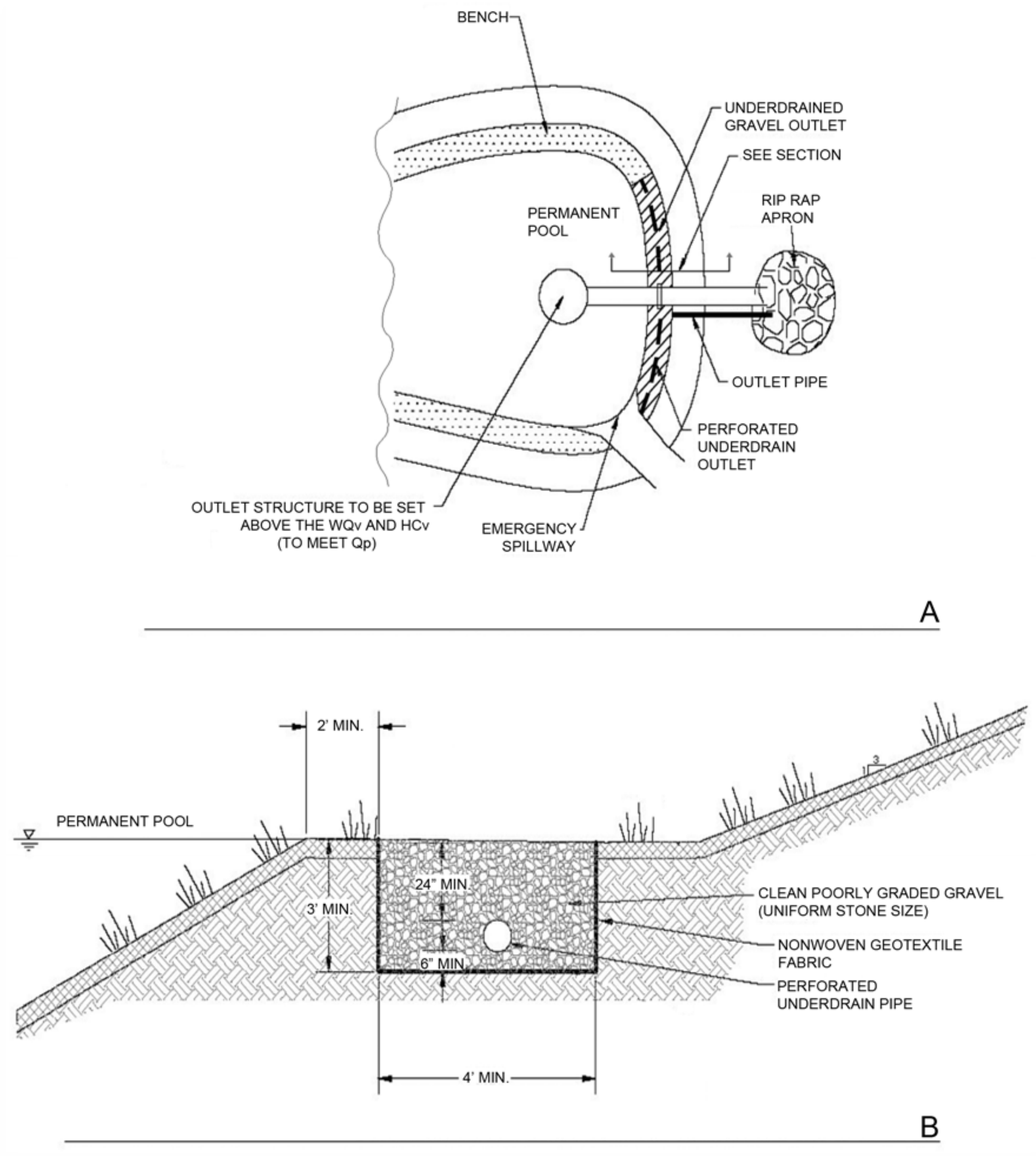


Figure 4-33. (A) Generalized plan view of underdrained gravel trench outlet for a shallow treatment wetland or basin and (B) Profile of underdrained gravel trench (adapted from Maine DEP 2006 and RI DEM 2010)

- Additional storage for Q_P may be discharged through traditional basin outlet structures.
- The design must specify an outfall that will be stable for the Q_{10} design storm event.
- A stilling basin or outlet protection shall be used to reduce flow velocities from the principal spillway to non-erosive velocities, 2.5 to 5.0 fps (see Appendix C6, VSMM, Vol. 2).
- The outlet control structure shall be located within the embankment for maintenance access and safety.

- All basins shall have an emergency outlet, maintaining at least one foot of freeboard between the peak storage elevation and the top of the embankment crest, and to safely convey the 100-year storm without overtopping the embankment.
- Emergency spillways (those placed above the water elevation of the largest managed storm) are required if not already provided as part of the conveyance of the 100-year storm event and must be a minimum of 8-feet wide and 1-foot deep, with 2:1 channel side slopes.
- The principal spillway opening shall not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter shall be fenced with pipe or rebar at 8-inch intervals to prevent a hazard.

Design Guidance

- Inlet pipe inverts should generally be located at or slightly below the permanent pool surface. If the inlet is partially submerged it can limit erosive conditions. In no case should it be submerged more than one half of the pipe diameter.
- Inlet pipes should have a slope of no less than 1% to prevent standing water in the pipe and reduce the potential for ice formation.
- The longitudinal slope through the pond should be at least 0.5% to 1% to promote positive flow through the pond practice.
- The low-flow orifice should be adequately protected from clogging by either an acceptable external trash rack (recommended minimum orifice of 3") or by internal orifice protection that may allow for smaller diameters (recommended minimum orifice of 1").
    - The preferred method is a submerged reverse-slope pipe that extends downward from the outlet control structure to an inflow point one foot below the normal pool elevation
    - Alternative methods are to employ a broad-crested rectangular, V-notch, or proportional weir, protected by a half-round pipe or "hood" that extends at least 12 inches below the normal pool.
    - Vertical pipes may be used as an alternative where a permanent pool of sufficient depth is present.
- Outfalls should be constructed such that they do not increase erosion or have an undue influence on the downstream geomorphology of any natural watercourse by discharging at or near the stream water surface elevation or into an energy dissipating step-pool arrangement.
- Access to the outlet control structure should be provided by a lockable manhole cover and manhole steps within easy reach of valves and other controls.

4.3.6.4. Wet Pond Pre-Treatment

Required Elements

- Each wet pond shall have a sediment forebay volumentrically sized for at least 10% of the WQ_V. Otherwise, pre-treatment sized in accordance with Section 4.1.
- If winter road sanding is prevalent in the contributing drainage area, increase the forebay size to 25% of the WQv to accommodate additional sediment loading.

Design Guidance

- The bottom of the forebay may be hardened (i.e., concrete, asphalt, grouted riprap) to make sediment removal easier.

4.3.6.5. Wet Pond Treatment

Required Elements

- At least 25% of the WQ_v shall be provided in "deep water zones" with a depth equal to or greater than four feet, but not more than eight feet. As required above, at least 10% of the WQ_v shall be provided in a sediment forebay or other pretreatment practice. The remaining 65% of the WQ_v shall be provided in some combination of shallow permanent pool (depth less than four feet) and the extended detention (ED) storage volume above the permanent pool, as applicable. ED storage volume shall not exceed 50% of the WQ_v.
- Flow paths at the normal water level from the inflow points to the outflow points shall be maximized through the use of geometry and features such as internal berms, baffles, vegetated peninsulas or islands. The minimum flow path length to practice width ratio is 3:1.
- The ratio of the shortest flow path (distance from the closest inlet to the outlet) to the overall length (distance from the farthest inlet to the outlet) must be at least 0.8. In some cases – due to site geometry, storm sewer infrastructure or other factors – some inlets may not be able to meet these ratios; the drainage area served by these "closer" inlets must not constitute more than 20% of the total contributing drainage area. The Agency may require additional pre-treatment for closer inlets.

Design Guidance

- Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided using multiple cells, long flow paths, high surface area to volume ratios, complex microtopography (e.g., complex contours along the bottom of the pond, providing greater depth variation) and/or redundant treatment methods (e.g., combinations of pool, extended detention, and emergent vegetation). A berm or simple weir should be used instead of pipes to separate multiple pond cells.
- The bed of the wet pond should be graded to create maximum internal flow path and microtopography. Microtopography is encouraged to enhance habitat diversity.

4.3.6.6. Wet Pond Vegetation and Landscaping

Required Elements

- The perimeter of all deep pool areas (four feet or greater in depth) shall be surrounded by two benches as follows:
    - Except when side slopes are 4:1 (h:v) or flatter, provide a safety bench that generally extends 15 ft outward (a 10ft minimum bench is allowable on sites with extreme space limitations) from the normal water edge to the toe of the side slope. The maximum slope of the safety bench shall be 6%; and
    - Incorporate an aquatic bench that generally extends up to 15 feet inward (a 10ft minimum bench is allowable on sites with extreme space limitations)from the normal edge of water, has an irregular configuration, and a maximum depth of 18 inches below the normal pool water surface elevation.

- A setback shall be provided that extends 25 feet outward from the maximum design water surface elevation of the wet pond. Permanent structures (e.g., buildings) shall not be constructed within the buffer.
- A planting plan for the wet pond and its setback shall be prepared to indicate how aquatic and terrestrial areas will be stabilized, as well as how vegetated cover will be established and maintained. Minimum elements of a plan include: delineation of pondscaping zones, selection of corresponding plant specifies, plant locations, sequence for preparing planting areas (including soil amendments, if needed), and sources of plant material.
- Salt tolerant vegetation shall be specified for pond benches.
- Woody vegetation that is more than two inches in diameter shall not be planted or allowed to grow on a dam, or within 15 feet of a dam or the toe of the embankment, or within 25 feet of the principal spillway structure.

Design Guidance

- Existing trees should be preserved in the setback area during construction. It is desirable to locate reforestation areas adjacent to wet ponds, which can help discourage populations of resident geese.
- The best elevations for establishing emergent plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.
- The soils of the setback are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil. Additional information on best practice for tree planting, including planting specifications, are provided in Reforestation (Section 4.2.1).
- Planting holes should be the same depth as the root ball and two to three times wider than the diameter of the root ball. In addition, the root ball of container-grown stock should be gently loosened or scored along the outside layer or roots to stimulate new root development. This practice should enable the stock to develop unconfined root systems. Avoid species that require full shade or are prone to wind damage. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.
- Species that require full shade, are susceptible to winterkill, or are prone to wind damage should be avoided.
- Both the safety bench and the aquatic bench should be landscaped to discourage resident geese populations on the permanent pool.
- Pond fencing is generally not encouraged, but may be required in some situations or by some municipalities. A preferred method is to manage the contours of the pond to eliminate drop-offs or other safety features.
- Warning signs prohibiting swimming and skating may be posted.

4.3.6.7. Wet Pond Construction Sequencing

Design Guidance

- A wet pond may serve as a sediment basin during project construction. If this is done, the volume should be based on the more stringent sizing rule (erosion and sediment control requirement vs. water quality treatment requirement). Installation of the permanent riser should be initiated during the construction phase, and design elevations should be set with final cleanout of the sediment basin and conversion to the post-construction wet pond in mind. The bottom elevation of the wet pond should be lower than the bottom elevation of the temporary sediment basin.

- Construction notes should clearly indicate that the facility will be dewatered, dredged, and regarded to design dimensions after construction is complete. Appropriate procedures should be implemented to prevent discharge of turbid waters when the basin is being converted into a wet pond.
- The following is a typical construction sequence to properly install a wet pond. The steps may be modified to reflect different wet pond designs, site conditions, and the size, complexity and configuration of the proposed facility.
    - Stabilize the Drainage Area. Wet ponds should only be constructed after the contributing drainage area to the pond is completely stabilized. If the proposed pond site will be used as a sediment trap or basin during the construction phase, the construction notes should clearly indicate that the facility will be de-watered, dredged, and re-graded to design dimensions after the original site construction is complete.
    - Assemble construction materials on-site, make sure they meet design specifications, and prepare any staging areas.
    - Install E&S controls prior to construction, including temporary de-watering devices and stormwater diversion practices. All areas surrounding the pond that are graded or denuded during construction must be planted with turf grass, native plantings, or other approved methods of soil stabilization.
    - Clear and strip the project area to the desired sub-grade.
    - Excavate the core trench and install the spillway pipe.
    - Install the riser or outflow structure, and ensure the top invert of the overflow weir is constructed level at the design elevation.
    - Construct the embankment and any internal berms in 8- to 12-inch lifts, compact the lifts with appropriate equipment.
    - Excavate/grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the pond.
    - Construct the emergency spillway in cut or structurally stabilized soils.
    - Install outlet pipes, including downstream rip-rap apron protection.
    - Stabilize exposed soils with temporary seed mixtures appropriate for the pond buffer. All areas above the normal pool elevation should be permanently stabilized by hydroseeding or seeding over straw.
    - Plant the pond buffer area, following the pondscaping plan.

4.3.6.8. Wet Pond Maintenance -Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- For the first six months following construction, the site shall be inspected by the permittee or their designee after storm events that exceed one inch of rainfall within 24 hours, as indicated in the site-specific maintenance plan.
- For discharges in cold-water fisheries, the gravel trench outlet shall be inspected after every storm greater than one inch of rainfall in 24 hours in the first three months of operation to ensure proper function.
- The principal spillway shall be equipped with a removable trash rack and be generally accessible from dry land. Trash racks shall be placed at a shallow angle to prevent ice formation.
- A maintenance right-of-way or easement shall extend to a pond from a public or private road.

Design Guidance

- Maintenance access should be at least 10 feet wide, having a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles. Steeper grades may be allowable with stabilization techniques such as a gravel road.
- The maintenance access should extend to the forebay, safety bench, emergency spillway, outlet control structure, and outlet and be designed to allow vehicles to turn around.
- Except where local slopes prohibit this design, each pond should have a drain pipe that can completely or partially drain the pond. The drain pipe should have an elbow or protected intake within the pond to prevent sediment deposition, and a diameter capable of draining the pond within 24 hours.
- Both the WQ_v release pipe and the pond drain should be sized one pipe size greater than the calculated design diameter.
- Both the WQ_v release pipe and the pond drain should be equipped with an adjustable gate valve (typically a handwheel activated knife gate valve). To prevent vandalism and/or accidental draining of the pond, access should be secured by a lockable structure.
- Valves should be located inside of the riser at a point where they will not normally be inundated and can be operated in a safe manner.

4.3.6.9. Wet Pond Maintenance – Annual

Required Elements

- General inspections shall be conducted on an annual basis.
- Sediment removal in the forebay shall occur every 5 years or after 50% of total forebay capacity has been lost, whichever occurs first.

- Ponds shall not be drained in the spring, without prior approval from the Agency, as temperature stratification and high chloride concentrations can occur at the pond bottom and result in negative downstream effects.
- For discharges in cold-water fisheries, the gravel trench outlet shall be inspected at least once annually. Inspection shall consist of verifying that the pond is draining to the permanent pool elevation within the 24-hour design requirement and that potentially clogging material, such as accumulation of decaying leaves or debris, does not prevent discharge through the gravel. When clogging occurs, at least the top 8 inches of gravel shall be replaced with new material. Sediments shall be disposed of in an acceptable manner.
- The inlet and outlet of the pond shall be inspected periodically to ensure that flow structures are not blocked by debris. All ditches or pipes connecting ponds in series shall be checked for debris that may obstruct flow. It is important to design flow structures that can be easily inspected for debris blockage.
- Areas with a permanent pool shall be inspected on an annual basis. The maintenance objectives for these practices include preserving the hydraulic and removal efficiency of the pond and maintaining the structural integrity.
- The slopes of the basin shall be inspected for erosion and gullying. Reinforce existing riprap if riprap is found to be deficient, erosion is present at the outfalls of any control structures, or the existing riprap has been compromised. Revegetate slopes as necessary for stabilization.
- All structural components including, but not limited to trash racks, access gates, valves, pipes, weir walls, orifice structures, and spillway structures shall be inspected and any deficiencies should be reported. This includes a visual inspection of all stormwater control structures for damage and/or accumulation of sediment.
- All dead or dying vegetation within the extents of the wet pond and its setback shall be removed, as well as excess herbaceous vegetation rootstock when overcrowding is observed and any vegetation that has a negative impact on stormwater flows through the facility.
- Any invasive vegetation encroaching upon the perimeter of the facility shall be pruned or removed if it is prohibiting access, compromising sight visibility and/or compromising original design vegetation.
- The grass around the perimeter of the wet pond shall be mowed at least four times annually.

<u>Design Guidance</u>

- Annual mowing of the setback area is only required along maintenance rights-of-way and the embankment. The remaining setback can be managed as a meadow (mowing every other year) or forest.

4.3.6.10. References

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4.3.7. Green Roofs

There are two common approaches for using alternative stormwater management treatments for the rainfall that falls on building rooftops. “Green roofs” are rooftop areas that are partially or completely landscaped with vegetation. The other approach involves strictly rooftop detention and is commonly referred to as a “blue roof.” Blue roofs have been applied in combined sewer overflow (CSOs) areas to help attenuate rooftop flows to reduce CSOs, and would be potentially applicable in places such as the City of Burlington. But since they provide only modest runoff reduction capabilities, and do not offer widespread application in Vermont, they are not examined further in this manual as an applicable green stormwater infrastructure practice.

A typical green roof includes vegetation planted in a substrate over a drainage layer and a root barrier membrane. There are two main types: intensive (planted with woody vegetation with a deeper planting soil and walkways, designed for performance and public access) and extensive (vegetated with short, drought-tolerant species, such as sedums, and a shallow growing media designed for performance). Some green roofs are constructed with stormwater detention tanks and a pump back system to recirculate water during dry periods and allow for additional uptake of first flush pollutants. Green roofs provide several benefits, including reduction of stormwater runoff through absorption, storage, and evapotranspiration. Ancillary benefits include reduction of urban heat island effects and increased building energy efficiency; and increased roof durability and lifespan.

4.3.7.1. Design Summary

Criteria	Element	Requirements
Feasibility	Slope	Maximum slope of 20%
	Max. Contributing Drainage Area	Run on from adjacent roofs cannot exceed 25% of the green roof area
Conveyance	Overflow	Overflow system to building roof drains sized per local/state plumbing code
	Number of Drains	Minimum 2 outlets, or outlet and overflow
	Overflow Conveyance	Flows exceeding green roof capacity conveyed to drainage system or downstream practice. Overland flow paths shall include stabilized channel or be designed to convey at non-erosive velocities (3.5 fps or less) for the 1-year storm event.
Pre-treatment	Pre-treatment sizing	N/A; practice treats only rainfall that falls on it
Treatment	Depth of Practice	Varies based on growing media = 2 to 8 inches, and target for runoff capture in the voids of the planting medium.
	Min/Max Depth of filter layer	Geotextile fabric between planting medium and drainage layer
	Drainage layer structure	Designed to carry flows greater than the WQ_v to an overflow system
	Credit Towards Standards	T_V is credited based on the void space of the planting medium. No credit is given towards Re_V or WQ_V.
Other	Landscaping	A landscape plan shall specify plant species Target of vegetative coverage of at least 75% within one year
	Maintenance	Ensure overflow drainage systems are not overgrown Clear drains of materials with potential to clog inlets Inspect for leaks on a quarterly basis Plant materials shall be maintained to provide 90% plant cover Growing medium shall be inspected for evidence of erosion from wind or water; stabilize with additional growing medium as necessary

Figure 4-34. Example of extensive green roof, Philadelphia, PA (Source: UNHSC)

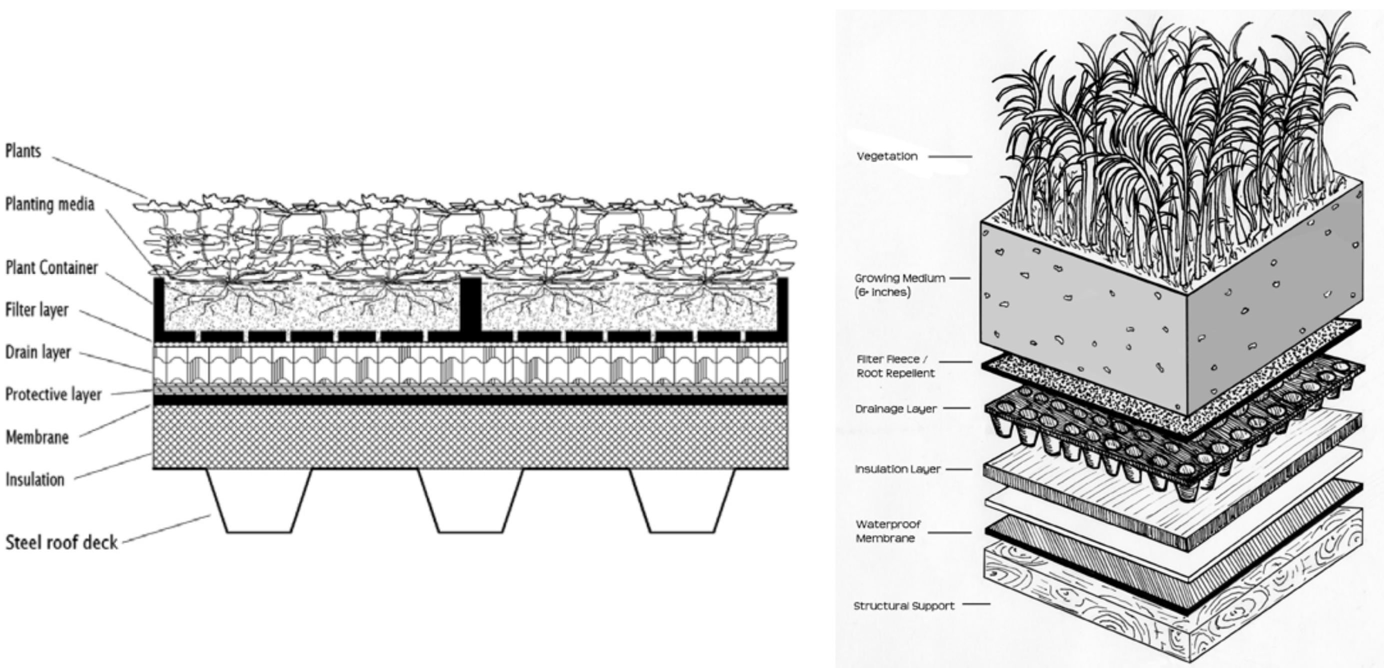

Figure 4-35. Extensive (L) and Intensive (R) Green Roof – Typical Sections (Source: Wark and Wark, 2003)

4.3.7.2. Green Roof Feasibility

Required Elements

- The system shall have a maximum slope of 20%, unless specific measures from the manufacturer are provided to retain the system on steeper slopes.
- Green roofs shall only be used to manage precipitation that falls directly on the rooftop area.

Design Guidance

- Extensive rooftops are commonly designed for maximum thermal and hydrological performance and minimum weight load while being aesthetically pleasing. Typically, only maintenance personnel have access to this type of roof. Extensive practices can be installed on either a flat or pitched roof.
- Intensive rooftops are designed with a deeper planting media, larger plants (trees and shrubs), and often incorporate public walkways and benches. These are installed on flat roofs.

4.3.7.3. Green Roof Conveyance

Required Elements

- Roof drain designs should include at least two outlets or an outlet and an overflow. Outlets must be kept clear of vegetation by installing a vegetation free zone around the outlet or overflow.
- The runoff exceeding the capacity of the green roof system shall be safely conveyed to a drainage system or another stormwater treatment practice without causing erosion. If an overland path is used, a stabilized channel shall be provided for erosive velocities (3.5 fps) for the 1-year storm event.
- The green roof system shall safely convey runoff from the 100-year storm away from the building (i.e, so as not to flood the building) and into a downstream drainage system.

Design Guidance

- Designers may incorporate a variety of measures to ensure waterproof conditions between the growing medium and the rooftop (refer to design guidance under “Green Roof Treatment” below).

4.3.7.4. Green Roof Pre-Treatment

Design Guidance

- Pre-treatment of runoff entering green roof facilities is not applicable. The practice shall only be applied to capture precipitation that falls directly on the roof surface.

4.3.7.5. Green Roof Treatment

Required Elements

- Green roofs shall be receive T_V credit equal to the void space of the planting medium (void spaces will be dependent on selection of media), above the drain layer and without bypass to the overflow system. The total volume managed about the drain layer without bypass to the overflow is credited toward HC_V and larger storms shall be calculated as follows:

$$Tv = Ag \times n \times dt$$

Where:

T_v = treatment volume credit (ft^3)

A_g = green roof surface area (ft^2)

n = porosity of planting medium, assumed to be 0.33

d_t = depth of planting medium (ft)

- Green roof storage shall not be credited towards the WQ_V or Re_V.

Design Guidance

- The following guidance from Wark and Wark (2003) and the Philadelphia Water Department (Philadelphia Stormwater Management Guidance Manual, 2011) offers considerations for the installation of green roof systems. Other options will be acceptable assuming they utilize similar design parameters:

Planting medium

- The planting medium is distinguished by its mineral content, which is synthetically produced, expanded clay. The clay is considerably less dense and more absorbent than natural minerals, providing the basis for an ultra-lightweight planting medium. Perlite is a common form of expanded clay and is found in garden nursery planting mix (not planting soil). The types of expanded clays used in green roofs are also used in hydroponics (Wark and Wark, 2003).
- The planting medium should be at least 3” deep (Philadelphia, Stormwater Guidance Manual, 2011). Green roof growing medium should be a lightweight mineral material with a minimum of organic material. See Appendix B3, VSMM, Vol. 2 for sample specifications for the planting media.

Filter layer

- The filter layer is an engineered fabric designed to prevent fine soil particles from passing into the drainage later of the green roof system. The filter fabric shall allow root penetration, but prevent the growth medium from passing through into the drainage layer.
- See Appendix B3, VSMM, Vol. 2 for sample specifications for the filter layer.

Drain layer

- Between the planting medium and roof membrane is a layer through which water can flow from anywhere on the green roof to the building’s drainage system, this is known as the drain layer.
- The drain layer is needed to promote aerated conditions in the planting media and to convey excess runoff during larger storms. The drain layer also is intended to prevent ponding of runoff into the planting medium.
- The critical specification for a drain layer is the maximum volumetric flow rate, which is determined based on the design precipitation of 1 inch for the WQ_v. Minimum passage area should be standardized for various locations. Since the drain layer supports the planting medium and vegetation, the compression strength should be specified. See Appendix B3, VSMM, Vol. 2 for sample specifications for the drain layer.

- Many drain mat products are segmented or baffled to attain the necessary compression strength, and hence, have insulating qualities that should be considered.

Protective layer

- The roof's membrane needs protection, primarily from damage during green roof installation, but also from fertilizers and possible root penetration. The protective layer can be a slab of lightweight concrete, sheet of rigid insulation, thick plastic sheet, copper foil, or a combination of these, depending on the particular design and green roof application.
- Since current standards generally do not recognize the insulating qualities of green roofs, a local code variance may be needed to install one on an under-insulated roof. Rigid insulation can be used as a protective layer. Insulation may be above or below the rigid roof surface.

Waterproofing

- A green roof should be installed with in conjunction with the roof's waterproofing system.

4.3.7.6. Green Roof Landscaping and Vegetation

Required Elements

- A landscape plan shall be provided to specify plant species based on specific site, structural design, and hydric conditions present on the roof with a target achieving vegetative coverage of at least 75% of the green roof area within one year.

Design Guidance

- Plant materials should be chosen based on their ability to take up much of the water that falls on the roof and withstand micro-climate conditions.
- The ASTM E2400-06 *Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems* covers the criteria considered for the selection, installation, and maintenance of plants of a green roof system and applies to both intensive and extensive roof types.
- See Appendix B3, VSMM, Vol. 2 for additional guidance on green roof landscaping and vegetation.

4.3.7.7. Green Roof Construction Sequencing

Design Guidance

Construction of the green roof can occur at any time during site construction, but obviously following building construction. Installation should proceed following installation of the roof system as follows:

- Install waterproof membrane over prior constructed roof deck. Inspect to ensure watertight seal with either pressure test or water test.
- Install protective layer over membrane, note rigid insulation provides both protection from the waterproof membrane as well as additional insulation.
- Install drainage layer over protective layer; inspect to ensure drainage layer is properly secured to protective layer.

- Install filter layer of geotextile fabric treated with root inhibitor.
- Install planting medium to design depth; avoid excessive foot traffic resulting in compaction of planting medium. Moisten growing media prior to vegetation installation.
- Install vegetation per plan, provide initial fertilizer per landscape plan recommendations and water as necessary for 4 to 6 weeks during plant establishment stage.

4.3.7.8. Green Roof Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- Immediately after construction, inspect green roofs weekly until the vegetation has established. Water as needed to establish vegetation.
- After vegetation has established, inspect and fertilize extensive green roofs as necessary. Fertilization should be minimized and only applied according to soil tests in order to maintain soluble nitrogen levels between 1 and 4 ppm (Philadelphia Water Department). Replace dead vegetation as needed.
- Weed green roofs as needed.
- Water green roofs as needed during exceptionally dry periods.

4.3.7.9. Green Roof Maintenance – Annual

Green roofs typically take two to three years to fully establish. Items such as weeding and inspections are typically required at least twice per year.

Required Elements

- Inspect overflow drainage system (roof drains, scuppers and gutters) to ensure that they are not overgown or have organic matter deposits; clear drains of soil, vegetation or other materials that have the potential to clog inlet.
- Inspect green roof for leaks on a quarterly basis.
- Plant materials shall be maintained to provide 90% plant cover.
- Growing medium shall be inspected for evidence of erosion from wind or water; stabilize with additional growing medium as necessary.

Design Guidance

Extensive Green Roof Systems:

- Vegetation may need to be watered periodically during the first season and during exceptionally dry periods.
- Vegetation may need to be lightly fertilized and weeded at least once a year.

<u>Intensive Green Roof Systems:</u>

- Maintain intensive green roofs as any other landscaped area. This may involve mulching, weeding, irrigation, and the replacement of dead vegetation.

4.3.7.10. References

Environmental Protection Agency. Green Roofs. Fact Sheet: Innovative BMPs for Site Plans. 2006. Available at: http://water.epa.gov/polwaste/npdes/swbmp/Green-Roofs.cfm

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International Stormwater Best Management Practice Database (ISBD). January 2011. *Technical Summary: Volume Reduction.* Prepared by Geosyntec Consultants and Wright Water Engineers, Inc. Accessed at: http://www.bmpdatabase.org/%5CDocs%5CVolume%20Reduction%20Technical%20Summary%20Jan%202011.pdf on June 10, 2014.

4.3.8. Permeable Pavement and Reinforced Turf

Permeable pavements include a suite of hardscape surfaces with an underlying reservoir course that captures and temporarily stores precipitation before infiltrating into the underlying soil or conveying it elsewhere. These practices are typically most applicable to areas of low traffic, such as residential driveways, parking spaces, alleys, sidewalks, bike paths, courtyards, and residential streets.

Per the regulatory definition of "Impervious Surface" (see Glossary) permeable pavement surfaces can qualify as jurisdictionally pervious surfaces in certain cases. When a permeable pavement system meets the documentation and design requirements necessary to qualify as a jurisdictionally pervious surface, the surface is not directly regulated by a Stormwater Permit or Authorization to Discharge. However, the following section of this manual may nonetheless be useful for permeable pavement system design and maintenance, as failure to properly construct and maintain a permeable pavement surface can result in the surface becoming effectively impervious and thus subject to regulation and retrofit treatment requirements.

Under a restrictive set of circumstances, a permeable pavement system can be used to treat runoff from other jurisdictional impervious surfaces, and thus may become a creditable component of the stormwater management system. Given the potential for clogging, this treatment scenario is limited to rooftop runoff where the rooftop runoff is not expected to have elevated sediment and solids concentrations, and the rooftop runoff can be routed in such a way as to not accumulate additional solids (e.g., via pipe). In this scenario, the permeable pavement system must provide storage in excess of that required to qualify as a pervious surface, such that additional capacity exists for crediting toward rooftop treatment requirements. When used in this manner, the design requirements included in this section must be met in order to receive treatment credit.

There are a few categories of porous and permeable pavements, including porous asphalt, porous concrete or porous concrete slabs, permeable pavers and reinforced turf/gravel. The base materials often include a filter layer of sand between the surface course and underlying reservoir/sub-base material. Unreinforced gravel or dirt roads and parking lots are not considered permeable, as they are subject to compaction and thus possess minimal potential for infiltration.

Porous asphalt and pervious concrete look nearly the same as traditional asphalt or concrete pavement but have 10%-25% void space and are constructed over a base course that doubles as a reservoir for the stormwater before it infiltrates into the subsoil or is directed to a downstream facility. Construction specifications for porous asphalt and pervious concrete are located in Appendix B4, VSMM, Vol. 2.

In addition to porous asphalt and pervious concrete, several paver configurations are also acceptable, including:

Permeable solid blocks or reinforced turf: This type of permeable paving surface includes permeable solid blocks (where the blocks have a minimum void ratio of 15%) and contain open-cell grids filled with washed aggregate (for paving blocks) or sandy soil planted with turf (for reinforced turf applications), set on a prepared base course of washed aggregate.

Solid blocks with open-cell joints > 15% of surface: This type of paver surface includes interlocking impermeable solid blocks or open grid cells that must contain permeable void areas (between the impermeable blocks) exceeding 15% of the surface area of the paving system. Permeable void areas are filled with washed aggregate and compacted to required specifications. Pavers are set on prepared base course materials of washed aggregate.

Solid blocks with open-cell joints < 15% of surface: This type of paver surface includes interlocking impermeable solid blocks or open grid cells that contain permeable void areas (between the impermeable blocks) less than 15% of the surface area of the paving system. In order to meet the recharge and water quality treatment requirements, these types of systems must be designed to provide one inch of surface storage above the permeable pavement system.

Permeable pavements can be applied as infiltration practices or for detention storage:

Infiltration Facilities are designed to temporarily attenuate runoff in the reservoir course before draining into underlying soil. There are no perforated drain pipes at the bottom of the base or reservoir courses; however, they may have overflow pipes for saturated conditions and extreme storm events.

Detention Facilities are designed to include an impermeable liner at the bottom of the base aggregate, which then flows to a downstream facility for additional treatment and storage. This category is useful in sites with high groundwater, bedrock, hotspots, and areas with fill soils. If designed as a detention system, infiltration restrictions noted below do not apply.

Permeable pavement practices, especially those designed for detention rather than infiltration, may not be able to provide overbank flood control (Q_P) storage. Combine with other practices to handle runoff from large storm events, when required.

4.3.8.1. Design Summary

Criteria	Element	Requirements
Feasibility	Slope	Maximum slope of 5%
	Soils	Infiltration rate of at least 0.2 inches per hour for infiltrating systems
	Max. Contributing Drainage Area	1000 ft^2 of rooftop area
Conveyance	Underdrains	Required only if pavement is designed as detention; add one cleanout at the end of each separate drain line
	Overflow	Catch basins or an "overflow edge" connected to stone reservoir below pavement recommended as emergency backup in case of surface clogging
Pre-treatment	Pre-treatment sizing	N/A (pre-treatment not required for precipitation falling directly on permeable pavements, or for rooftop runoff routed in such a way as solids accumulation is unlikely)
Treatment	Depth of Practice	Varies based on design storm
	Pavement Surface	See Appendix B4, VSMM, Vol. 2 for asphalt and concrete specifications
	Choker Course	2" depth (or enough to lock up with underlying reservoir course during paving operations)
	Filter Course	Optional: 8 to12 inches
	Reservoir Course	Varies, based on design storm, minimum 6 inches
	Credit Towards Standards	Permeable pavement systems designed to store and infiltrate the 1 year design storm are jurisdictionally pervious, and may be counted as such throughout an application. Permeable pavement systems designed to store and infiltrate both rooftop runoff and incident rainfall from the 1 year design storm may be credited for the rooftop volume infiltrated toward Re_v, WQ_v and HC_v. .
Other	Construction	Protect permeable surfaces from construction site sediment contamination
	Maintenance	Monitor regularly to ensure that the paving surface drains properly after storms Regular vacuum sweeping (regenerative air vacuum system recommended) Minimize salt use in winter months; no sanding. Snow must not be stockpiled on permeable pavement. Stockpile where snow melt does not drain to permeable pavement. Keep adjacent landscape areas well maintained and stabilized Mow or re-seed pavers planted with grass as needed Clogging or deterioration may render the surface as effectively impervious, and thus subject to regulation as an impervious surface

Figure 4-36. Porous Asphalt in a Low-Density Residential Area in Pelham, NH (Source: UNHSC

Figure 4-37. Pervious concrete roads in Sultan, WA (Source: Washington Aggregates and Concrete Association)

Figure 4-38. Reinforced Turf - Westfarm Mall, Harford, CT (source: HW file photo)

4.3.8.2. Permeable Pavement Feasibility

Required Elements

- The bottom of infiltrating permeable pavement practices must be located in the soil profile, if the practice is being used to meet the water quality standard. Alternatively, a filter course is required where the bottom of an infiltrating permeable pavement practice cannot be located above the parent materials.
- To be suitable for infiltration, underlying soils shall have an in-situ infiltration rate of at least 0.2 inches per hour, as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests (Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements)
- The bottom of an infiltrating permeable pavement practice cannot be located in fill. An exception will be made for strictly residential land uses, for which the bottom may be located in up to 2 feet of fill consisting of material suitable for long-term infiltration after placement, as confirmed by field geotechnical tests (Appendix C1, VSMM, Vol. 2). Practices for non-residential sites that must be placed in fill require a 12 inch minimum filter course (refer to specifications, Appendix B4, VSMM, Vol. 2).
- Runoff from designated hotspot land uses or activities must not be directed to permeable pavements unless they are designed as a detention facility (with an impermeable liner).
- Permeable pavements are only suitable for use on slopes less than 5%. The bottom of the reservoir course shall be designed to be close to 0% slope as possible (i.e., < 0.5%); terrace the bottom layers as necessary to maintain this maximum slope of 0.5%
- The bottom of an infiltrating permeable pavement practice shall be separated by at least 3 feet vertically from the seasonal high groundwater table or ledge (when treating WQ_v), as documented by on-site soil testing.
- Permeable pavements shall not be installed where road sanding is performed in the winter, and strong consideration should be given to areas where tracking of sand from other roadways by vehicles will contaminate permeable pavement.

Design Guidance

- Permeable pavements are not appropriate for high traffic/high speed areas (≥ 1,000 vehicle trips/day and/or speeds above 35 miles per hour) due to the increased potential for system failures. These surfaces should not be used adjacent to areas subject to significant wind erosion or excessive tree leaf litter. Permeable pavements are also not suitable for areas where rapid changes in deceleration will occur (traffic lights, or intersections where drivers may rush up and stop quickly).
- Care should be taken to investigate all potential sources of pavement clogging materials, such as offsite stormwater runoff directed to the pavement, vehicle tracking of sand and soil from adjacent sites or businesses, sanding of sidewalks, and flood water contamination potential (i.e., creeks, streams, floodplains, etc.).

4.3.8.3. Permeable Pavement Conveyance

Required Elements

- In rare instances where runoff is directed onto the permeable pavement surface, an Erosion Prevention and Sediment Control (EPSC) Plan should be provided to address any run-on and specify at a minimum:

- how sediment will be prevented from entering the pavement area;
- a construction sequence;
- drainage management; and
- vegetative stabilization

Design Guidance

- Designers may incorporate catch basins or an "overflow edge" (a trench surrounding the edge of the pavement) connected to the stone reservoir below the surface of the pavement as a temporary emergency backup in case the surface clogs. These are typically seen in parking lot applications but are a favorable practice in any application.
- Permeable pavements should only be used to manage precipitation that falls directly on the permeable pavement area to protect the surface from clogging. Contributing drainage areas located outside the permeable pavement surface should be kept to a minimum (i.e., runoff from up-gradient impermeable or permeable surfaces should be minimal).
- Permeable pavement systems should have an observation well similar to those used in other infiltration practices. In general, one observation well is needed for every acre of permeable pavement.
- Where an underdrain system is proposed, cleanouts are recommended at the end of each drainage line.

4.3.8.4. Permeable Pavement Pre-Treatment

Design Guidance

- Pre-treatment of runoff entering permeable pavement facilities is often not applicable since the practice frequently captures only incident precipitation.
- When designed as a rooftop runoff treatment system, pre-treatment is not required provided rooftop runoff is collected and routed in such a way that it is unlikely to accumulate or convey a substantial sediment load.

4.3.8.5. Permeable Pavement Treatment

Required Elements

- Permeable pavements used for infiltration of rooftop runoff shall be designed to exfiltrate the entire T_v through the floor of each practice (sides are not considered in sizing).
- The base course (reservoir layer) shall be a minimum 6 inches, but is generally 12 to 24 inches or greater (function of storage needed and frost heave resistance). Base material must be washed and clean, uniformly sized material (poorly graded), must maintain adequate bearing capacity, depending on the use, and compaction effort per specifications in Appendix B4, VSMM, Vol. 2. The base course may also include a filter course above the reservoir layer (2 to 6 inches of sand). See Appendix B4, VSMM, Vol. 2 for more information on material specifications.
- For permeable pavements designed to infiltrate rooftop runoff, design infiltration rates (f_c) shall be determined based on the soil texture of the underlying soil. Design infiltration rates shall be based on field in-situ testing results (Appendix C1, VSMM, Vol. 2). Pervious pavement is credited toward Re_v, WQ_V and HC_V of the

contributing rooftop area based on the treatment volume provided. The total storage volume (V_{Total}) for the infiltrating permeable pavement will first be calculated as follows:

$$V_{Total} = A_p \left(\frac{n \times d_t + f_c \times t}{12}\right)$$

Where:

V_{Total} = total storage volume within the permeable pavement system (ft^3)

A_p = permeable pavement surface area (ft^2)

n = porosity of gravel fill; the accepted porosity of gravel is 0.33

d_t = depth of aggregate base (ft)

f_c = design infiltration rate of the underlying soil (in/hr)

t = time to fill (hours) (assumed to be 2 hours for design purposes)

The maximum creditable treatment volume (T_v) is the difference between total storage (V_{Total}) and the volume that must first be provided to satisfy the jurisdictional pervious requirements:

$$T_v = V_{Total} - \left(\frac{A_p \times P_{1yr}}{12}\right)$$

Where:

T_V = maximum design volume (ft^3)

P_{1yr} = 1 year design storm depth (inches)

Where rooftop runoff can be routed to a permeable pavement system with available treatment capacity (T_v), the surplus treatment capacity can be allocated to contributing rooftop Re_v, WQ_v, and HC_v treatment requirements.

- For permeable paving practices used for detention only (e.g., systems with an underdrain), no credit is given toward WQ_v or HC_V and impermeable CNs shall be used in hydraulic and hydrologic models when calculating CP_V and Q_P. For permeable paving practices with a gravel sump beneath an underdrain system, credit is limited to the void space within the sump.

Design Guidance

- To avoid frost heave, design base to drain quickly (depth > 24 inches and drain time of 24 hours or less).
- ANR may reduce horizontal setbacks or vertical separation distances for infiltrating permeable pavements on a case-by-case basis in residential and non-vehicle surface (e.g., walkways/plazas) applications.
- Typically, the reservoir course should consist of uniformly sized washed and clean crushed stone (no more than 0.25% passing the number 200 sieve in large projects, and 0.15% for smaller projects, sensitive sites, and slowly infiltrating sites), with a depth sufficient to store the difference between rainfall and infiltration volume from the design storm.

- Permeable paving practices generally should be designed with an impermeable liner when subsurface contamination is present, due to the increased threat of pollutant migration associated with increased hydraulic loading from infiltration systems, unless contaminated soil is removed and the site is remediated, or if approved by the Agency on a case-by-case basis.
- Non-woven fabric should be used on the bottom and sides of the design section, and the fabric should be brought up and out of the full depth of the excavation. During construction this practice ensures that side wall contamination of the courses does not occur, and prevents collapse of the sides from soil migrating into the reservoir course and undermining an adjacent sidewalk or slope.

4.3.8.6. Permeable Pavement Landscaping and Vegetation

Required Elements

- In rare instances where pervious up-gradient "run-on" is proposed, such as pedestrian plazas or lawns, the up-gradient area must be fully stabilized and consisting of turf (i.e., absent bare soil). Trees that have the potential to shed leaf litter should not be planted immediately adjacent to pervious pavements (mature tree drip lines should not overhang permeable pavement surface).

4.3.8.7. Permeable Pavement Construction Sequencing

Design Guidance

Construction of permeable pavements should begin after the entire surrounding area has been stabilized with robust vegetation. Significant failure potential exists if construction site sediment is allowed to be tracked onto or if runoff flows into these areas. Also, during construction, the location of construction haul roads and activities should be kept away from the infiltrating permeable pavement areas to prevent soil compaction by heavy equipment. Areas where infiltrating permeable pavement practices are proposed shall not serve as a temporary sediment control device during site construction phase.

The following is a typical construction sequence to properly install permeable pavement:

- Temporary erosion and sedimentation controls are installed and kept in place during construction of the permeable pavement areas to divert stormwater away from the area until it is completed.
- Native materials must be protected from over compaction during construction.
- Stone storage layers are installed per the design plan cross section in lifts not more than 8 inches thick to a MAXIMUM of 95% standard proctor compaction. (See Appendix B4, VSMM, Vol. 2 for construction specifications). Proper compaction of select subbase materials is essential. Improper compaction of subbase materials will result in either 1) low pavement durability from insufficient compaction, or 2) poor infiltration due to over-compaction of subbase. Care must be taken to assure proper compaction.
- The density of subbase courses is tested in accordance with the specified methods as directed in Appendix B4, VSMM, Vol. 2.
- The mixing, hauling, and placement of open graded asphalt are critical to the success of permeable systems. Variation from the material specifications identified in Appendix B4, VSMM, Vol. 2 can result in failure of the permeable surface course. Elements such as contact with non-permeable perimeter features (e.g., curbs, gutters, manholes) requires special treatment, hauling temperatures and times must be within very narrow limits, and

the asphalt must be placed in a single lift. Final compaction of the surfaces also requires strict adherence to the technical specifications.

- No traffic shall be permitted on permeable asphalt until the material has been thoroughly compacted and has been permitted to cool to below 38 °C (100°F). The use of water to cool the pavement shall not be permitted. Roadways shall remain vacant for 24 hours, unless it can be documented that the internal temperature is 100°F or less. Parking lots shall remain vacant for 10 to 14 days to develop full stability (earlier traffic will result in scuff marks from vehicles with power steering).
- Remove temporary erosion and sedimentation controls only once the surrounding area and any contributing drainage areas have been fully stabilized.

4.3.8.8. Permeable Pavement Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- Inspect the facility every six months and immediately after events greater than or equal to 1.0 inches of rainfall to verify the surface is draining and for signs of pavement/paver failure. If corrective actions are required, document likely source contributing to poor infiltration; remedial measures may include vacuuming, replacement of sections of pavement/pavers, or a complete facility overhaul. Sweeping of any type shall not be permitted. The use of a regenerative air vacuum system is strongly recommended.

4.3.8.9. Permeable Pavement Maintenance – Annual

Required Elements

- Permeable paving surfaces require regular vacuuming or hosing (minimum every three months or as recommended by manufacturer for permeable solid blocks or reinforced turf) to keep the surface from clogging. Maintenance frequency needs may be more or less depending on the traffic volume and de-icing practices at the site.
- Minimize use of salt in winter months. No sanding is permitted.
- Snow must not be stockpiled on permeable pavement. Identify stockpile areas on design plans and in maintenance specifications and contracts to prevent unintentional stockpiling on permeable pavement. Stockpile in a location such that snow melt does not drain to the permeable area.
- Attach rollers to the bottoms of snowplows to prevent them from catching on the edges of pavers.
- Keep adjacent landscape areas well maintained and stabilized (erosion gullying quickly corrected). Grade adjacent landscape areas such that stormwater runoff from these areas is conveyed away from permeable surfaces.
- Do not blow cut grass clippings onto the permeable areas.
- Pavers planted with grass need mowing and often need reseeding of bare areas.

- Monitor regularly to ensure that the paving surface drains properly after storms.
- Inspect the surface annually for deterioration or spalling.
- Post signs identifying permeable pavement.
- Do not repave or reseal with impermeable materials.

4.3.8.10. References

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4.3.9. Rainwater Harvesting

Rainwater harvesting practices, when designed to temporarily store stormwater runoff for detention or re-use through retention, may assist in meeting stormwater runoff reduction goals and will be credited to a site's HCv.

Rainwater harvesting is the capture, conveyance, and storage of precipitation from impervious surfaces – typically rooftops – primarily for re-use, rather than infiltration or release into a waterway. Rainwater harvesting has minimal site requirements compared to other stormwater management practices and may be used in residential and industrial settings for any volume of rooftop runoff, if sized appropriately. Rainwater harvesting may be used on sites where dense development, pollutant hotspots, or soil conditions preclude the use of infiltration or other stormwater management practices. The use of rainwater harvesting reduces the amount of stormwater runoff entering the drainage system and/or local receiving waters as well as reducing or delaying peak flow rates. It is important to have well-defined operation and maintenance procedures for any rainwater harvesting system, in order to provide adequate storage capacity for subsequent storm events.

Storage tanks for harvested rainwater may be sited above or below ground, indoors or outdoors, or on rooftops of buildings that have been designed to bear the load of rainwater storage. The main components of a rainwater harvesting system include: a contributing rooftop surface, a conveyance system (gutter/downspouts/pipes), screening or pre-treatment filter and clean-out, a watertight storage container, an overflow pipe, an access hatch, and an extraction system (e.g., spout or pump). Additional components may include a first flush diverter, pressure tank, and backflow prevention device.

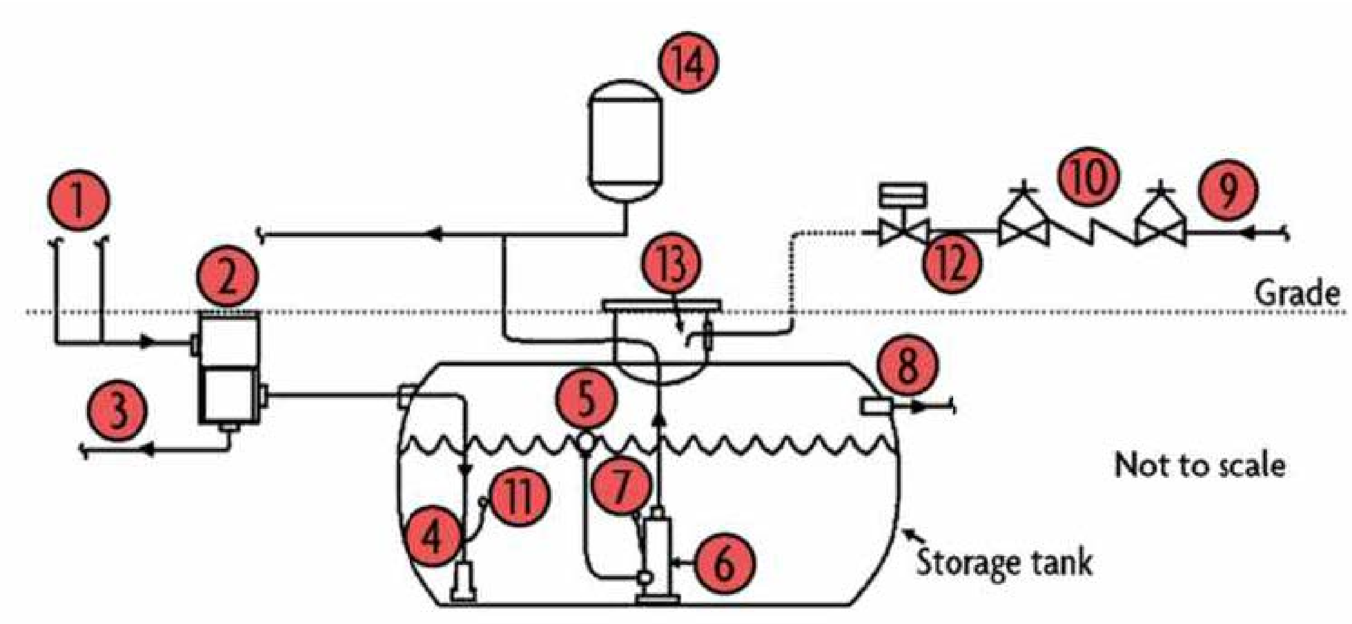
Rain barrels are commonly used to store harvested rainwater in small-scale residential settings, while above- or below-ground cisterns are more commonly used in larger-scale industrial settings. Rain barrels are above ground storage tanks generally holding 50-80 gallons, but may hold up to 200 gallons. Cisterns are sealed tanks, which may be above or below ground and generally hold 200-10,000 gallons (BASMAA 2012). While carefully managed rain barrels can be a viable means of stormwater runoff volume reduction for very small volumes of rainwater, this standard is intended to be applied to the larger storage volumes and more robust management strategies that are possible only with cisterns. For more information about how to use rain barrels, please see the *Vermont Rain Garden Manual* (http://www.uvm.edu/seagrant/sites/uvm.edu.seagrant/files/vtraingardenmanual.pdf).

Harvested rainwater is often well-suited for reuse in landscape irrigation and other non-potable uses, including in toilets and urinals, as well as HVAC make-up water, topping off swimming pools, and washing cars. In Vermont, reuse of harvested rainwater for purposes other than irrigation is largely unaddressed by current state regulations or local codes. Neither the Uniform Plumbing Code (UPC) nor International Plumbing Code (IPC) directly addresses rainwater harvesting in their potable or stormwater sections (EPA 2008). Because of this lack of specific rainwater harvesting guidance, some jurisdictions have regulated harvested rainwater as reclaimed water, resulting in stringent requirements that make reusing harvested rainwater challenging. The practicality of rainwater reuse will need to be evaluated on a case-by-case basis.

4.3.9.1. Design Summary

Criteria	Element	Requirements
Feasibility	Runoff source	Rooftop runoff only
	Contributing drainage area	Storage must be sufficient capture at least 0.2" from the contributing drainage area
	Application area/Reuse requirement	Area must be sufficient to handle an application rate of 1"/week
Conveyance	Gutters	Gutters shall be sized to contain and convey the 1-inch storm event at a rate of 1-inch/hour
	Overflow	Must demonstrate overflow runoff can be safely conveyed to a suitable, down-gradient location or secondary practice
Pre-treatment	Pre-treatment sizing	N/A for rooftop runoff Filter or screen for trapping leaves, sediment and coarse debris shall be provided
Treatment	Sizing	Total system must hold at least 0.2" of runoff from the contributing drainage area Water budget analysis and reuse plan required to ensure storage capacity for subsequent runoff events
	Credit Towards Standards	Volume credited toward WQ_V and HC_V based on storage volume
Other	Vegetation	Overflow conveyance/application area stabilized with vegetation before runoff directed to cistern
	Maintenance	Routinely monitor storage levels; manage water levels to provide adequate storage capacity Inspect annually for consistency with annotated design plan Clean filters and screens as needed Flush out accumulated sediment as needed

Figure 4-39. Rainwater harvesting schematic. Source: Virginia DCR 2013; www.rainwaterresources.com



1. Rooftop surface and rainwater collection system (roof drains, gutters, etc.)
2. Pre-treatment (screening, first flush diverters, filters, etc.)
3. Discharge of excess or diverted first flush to overflow or downstream practice
4. Flow calming inlet
5. Floating (outlet) filter
6. Submersible pump
7. Low water cut off float switch
8. Overflow to secondary runoff reduction drawdown practice, downstream runoff reduction or pollutant removal BMP, or conveyance system
9. Municipal back-up water supply
10. Back flow preventer
11. Float switch to control water levels
12. Solenoid valve
13. Air gap
14. Pressure tank

4.3.9.2. Rainwater Harvesting Feasibility

Required Elements

The following design elements are required when implementing rainwater harvesting practices to capture and re-use stormwater runoff.

- Rainwater harvesting shall be limited to rooftop runoff.
- Rainwater storage shall be designed to capture at least 0.2 inches of rainfall from the contributing rooftop.
- An application area or water reuse must be identified that is sufficient to reuse the stormwater volume stored within a week at an application rate of 1”/week over the irrigation period from May through September.
- For underground storage tanks, the bottom of the tank must be above groundwater level, and the top of the tank must be below the frost line. Storage tanks that are above ground or not able to be buried below the frost line shall be appropriately insulated or disconnected during the winter months in order to protect the system from freezing.

Design Guidance

- Rainwater harvesting systems can be used in areas with steep terrain where other stormwater treatments are inappropriate. However, systems must be designed in a way that protects slope stability. Cisterns need to be located in level areas where soils have been sufficiently compacted to bear the load of a full storage tank.
- Full cisterns can be very heavy, the bearing capacity of the soil beneath the cistern must be considered. Storage tanks should only be placed on native soils or on fill in accordance with the manufacturer's guidelines, or in consultation with a geotechnical engineer. A concrete base or aggregate may be appropriate.

4.3.9.3. Rainwater Harvesting Conveyance

Required Elements

- Gutters shall be hung at a minimum of 0.5% for 2/3 of the length and at 1% for the remaining 1/3 of the length, and shall be set and sized to properly capture, contain, and convey the 1-inch storm event at a rate of 1-inch/hour for credit.
- Overflow runoff must be safely conveyed to a suitable, down-gradient location such as a buffer area, open yard, grass swale, or secondary treatment practice as applicable.
- Overflow conveyance and tank siting shall be designed to prevent ponding or soil saturation within 10 feet of building foundations, and underground cisterns shall be sited at least 10 feet from building foundations.
- Systems shall be designed around a water budget analysis that identifies how water will be used to ensure that storage capacity in the system will be available for subsequent runoff events.

Design Guidance

- Topography of the site should be considered as it relates to inlet and outlet invert elevations for the system, as well as size and slope of the conveyance components and any pumping that may be necessary to get water to its intended re-use location.
- Aluminum, round-bottomed gutters and round downspouts are recommended.

4.3.9.4. Rainwater Harvesting Pre-Treatment

Required Elements

- Pre-treatment shall be provided in the form of a filter or screen to prevent leaf litter, sediment, and other debris from entering the storage tank. First flush diverters, vortex filters, roof washers, and leaf screens all represent acceptable forms of pre-treatment. The pre-treatment shall be installed either in the gutter or downspout or at the inlet to the storage tank, with proper design for clean-out. Depending on the desired use for the rainwater, additional filtration may be needed or desired.
- Mosquito screening (1 mm mesh size) shall be installed at openings to prevent mosquitos from entering the storage tank.

Design Guidance

- Diversion of the "first flush" (the first 0.02-0.06 inches of rainfall) may be desired for larger systems to reduce pollutants and debris accumulation in the storage tanks. In this case, the "first flush" must be diverted to an acceptable pervious flow path that will not cause erosion during a 2-year storm, or to an appropriate practice on the property, for infiltration. Examples of acceptable pervious flow paths can be found in the Simple Disconnection practice standard (Section 4.2.2).

4.3.9.5. Rainwater Harvesting Treatment

Required Elements

- A water budget analysis must be provided that identifies how water will be used, to ensure that the system will be available for subsequent runoff events.
- Storage tanks shall be watertight and shall be composed of and sealed with water safe, non-toxic substances.
- Different rooftop materials contribute different substances/pollutants to rainwater, which may impact potential reuse. Generally, asphalt shingle and painted metal roofs are well-suited for rainwater harvesting. Rainwater shall not be harvested from the following roof types: tar and gravel, asbestos shingle, and treated cedar shakes. In addition, rainwater shall not be collected from roofs with metal flashing that contains lead.
- Rainwater harvesting is sized and credited toward WQ_V and HC_V based on the storage volume (T_V), and is calculated as follows:

$$T_v = \frac{(DA)(R_v)(12)}{P}$$

Where:

T_v = design storage volume (ft^3)
DA = drainage area (rooftop area captured for rainfall harvesting) (ft^2)
R_v = runoff coefficient = 0.95
P = target rainfall event, minimum of 0.2 inches

Design Guidance

- Water budget analysis should consider the size of the catchment area, local precipitation patterns, and anticipated water use (U.S. EPA 2013). Local precipitation patterns are best determined by using a long-term, continuous record of hourly or daily precipitation data (available from the National Climatic Data Center) for a given location (Cabell Brand Center, 2009). The continuous record of precipitation can be analyzed in a spreadsheet along with anticipated demands to provide reliable estimates of water conservation and stormwater performance as a function of cistern volume for a given catchment area and demand scenario (U.S. EPA 2013).

- The State of Virginia's 2011 design specification for rainwater harvesting provides specific guidelines for ensuring reliable demand and offers a robust methodology for cistern sizing based on analysis of the 30-year continuous rainfall record and anticipated demand scenarios (VA DCR, 2011). VA DCR has developed a Cistern Design Spreadsheet as a companion to the specification that can be used to estimate the anticipated performance of the system – see http://www.vwrrc.vt.edu/swc/April2010_updates/RainwaterHarvestingSpreadsheet_march%202010_v1.6.xls (note file size is 215 MB).
- The pH of rainfall in the eastern United States tends to be low (4.5-5.0) which may lead to the leaching of metals from roof materials, conveyance components, or tank linings. Once rainwater leaves rooftops, pH tends to be somewhat higher (5.5-6.0). Buffering compounds may be added to tanks if desired.

4.3.9.6. Rainwater Harvesting Landscaping and Vegetation

Required Elements

- Stormwater shall not be diverted to the rainwater harvesting system until the overflow conveyance and/or application area has been stabilized with vegetation.

Design Guidance

- Above ground storage tanks should be UV resistant and opaque to prevent algae growth, and protected from sunlight where possible.
- An effort should be made to meet property owners' preference when providing attractive, above-ground rain barrels and cisterns. The likelihood of continued use of these practices is increased if they are an attractive part of the exterior setting.

4.3.9.7. Rainwater Harvesting Construction Sequencing

Design Guidance

- The following is a typical construction sequence to properly install a rainwater harvesting practice:
  - Choose the tank location on the site.
  - Properly install the tank accounting for site stability, slope and soil bearing capacity, and accounting for the level of the water table and frost line for below-ground tanks.
  - Install the pump (if needed) and piping to end-uses (indoor, outdoor irrigation, or tank dewatering release).
  - Route downspouts or roof drains to pre-screening devices and/or first flush diverters.

4.3.9.8. Rainwater Harvesting Maintenance – Year 1

Required Elements

- Applicants are required to submit, at the time of permit application, an annotated maintenance plan including: location of stormwater treatment practices; and, a description of associated year one and annual inspection and maintenance activities.
- Inspect gutters and downsp outs to check for leaks or obstructions.
- Inspect overflow lines and conveyance pathways, and verify vegetation in application area has established - reseeding as necessary.
- Verify that captured rainwater is utilized or discharged in a timely manner and inspect levels to ensure adequate storage is available for future rain events.

4.3.9.9. Rainwater Harvesting Maintenance – Annual

Required Elements

- Inspect practice for consistency with annotated design plan provided with permit, including any narrative inspection and maintenance requirements.
- Rainwater storage levels shall be routinely monitored and tanks must be either actively or passively drained as needed to provide adequate storage capacity for subsequent storm events.
- Underground storage tanks shall have secured manholes/covers, and above ground storage tanks shall have secured covers to prevent child entry.
- Annual maintenance inspection and cleanup shall be conducted for all rainwater harvesting practices each spring, and include the following:
  - Inspect roof catchments to ensure that minimal amounts of particulate matter or other contaminants are entering the gutter and downspout.
  - Inspect gutters and downspouts to check for leaks or obstructions.
  - Inspect diverters, cleanout plugs, screens, covers, and overflow pipes and repair or replace as needed.
  - Inspect inflow and outflow pipes, as well as any accessories such as connectors to adjacent storage containers or a water pump.
  - Inspect cistern for cracks, and inspect seals for leaks.
  - Flush out accumulated sediment.

Design Guidance

- To avoid freezing of components, un-insulated above ground systems should be drained, cleaned and disconnected at the start of the winter season (before November 30 of each year). Downspout piping will need to be reconnected and directed to a grassy area or a practice located away from the structure to prevent winter snowmelt from damaging building foundations. Systems should be re-connected in the spring no later than April 1 of each year.

- Underground systems should be checked for ice blockages or frozen lines before piping is reconnected in the spring.

4.3.9.10. References

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4.4. Alternative Stormwater Treatment Practices

The stormwater treatment field is rapidly evolving and new stormwater management technologies constantly emerge. A permit applicant may propose, and the Agency may allow, the use of STPs other than those presented in Sections 4.1 – 4.3 of this Manual if the permit applicant can demonstrate to the Agency's satisfaction that the proposed alternative STPs will attain the applicable treatment performance standards for groundwater recharge, water quality, channel protection, overbank flood protection, and extreme flood control. Proposals for use of alternative treatment systems will require consideration of the design through the use of the individual permit application process.

There are two methods by which a designer may propose an alternative system design evaluation: through consideration of an existing-alternative system, currently installed and being used for stormwater treatment in a similar climate; or through a new design-alternative systems proposed for use in Vermont.

4.4.1. Existing Alternative Systems

If an existing alternative STP is proposed, the permit applicant shall include scientific verification of its ability to meet the applicable treatment standards specified in Chapter 2, and a proven record of longevity in the field. There are several existing protocols that have been developed which provide a more uniform method for demonstrating stormwater treatment technologies and developing test quality assurance (QA) plans for certification or verification of performance claims. Several of the more widely used protocols, including participating states, are described briefly below. The Agency will accept as evidence of performance a successful demonstration conducted in a manner consistent with the most current version of one of the protocols identified below, assuming approval is being sought for a similar application of the technology:

- Technology Acceptance Reciprocity Partnership (TARP), with evaluations by UMass Amherst Massachusetts Stormwater Evaluation Project (MASTEP)
    - Endorsed by California, Massachusetts, Maryland, New Jersey, Pennsylvania and Virginia, validated performance data and technical information on STPs tested under this protocol are available at: http://mastep.net/database/data.cfm
    - As of January 2015, MASTEP is not currently funded. Until funding is secured, the information listed on the website will not be updated and no new BMP reviews will be conducted
- U.S. EPA's Environmental Technology Verification (ETV)
    - Program concluded operations in early 2014; no additional technologies will be evaluated. Information on the performance of STPs evaluated under this protocol is available at: http://www.epa.gov/etv/pubs/04_vp_stormwater.pdf
- Washington Department of Ecology's Technology Assessment Protocol (TAPE)
    - A peer-reviewed regulatory certification process, administered by the Washington Department of Ecology, with assistance from the Washington Stormwater Center. A list of STPs that have received a designation through the TAPE process is available at: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html

Completion of a demonstration consistent with an aforementioned protocol does not completely eliminate state review of the data or approval of the project proposing to use the technology. The Agency reserves the right to evaluate any application and request additional information, including evidence of long-term performance. A poor maintenance record or high failure rate is valid justification for the Agency's rejection of a STP.

4.4.2. New-Design Alternative Systems

The performance standard for any new-design alternative STP shall meet the applicable treatment standards specified in Chapter 2.0, and shall have the capability to achieve long-term performance in the field. For a new-design alternative STP to be submitted to the Agency for consideration, a designer's certification of compliance, including pertinent design information, must be provided. This certification must provide details, with a reasonable level of surety, on how the system will achieve the requisite performance standards. In addition, a plan of study to obtain the following should be provided:

- At least five storm events must be sampled;
- Storm events must be sampled under a varying and representative range of precipitation intensities and antecedent conditions;
- Concentrations reports in the study must be flow-weighted;
- The study and/or design may be independently verified by the Agency;
- The study must be conducted in the field, as opposed to a testing laboratory;
- The practice must have been in the ground for at least one year at the time of monitoring; and,
- The study must be completed within three years of construction of the STP.

If the Agency determines that the proposed new-design alternative STP does not meet the performance standards, and the applicant is not able to modify the system to correct the deficiency to the satisfaction of the Agency within a reasonable period of time, then the permit applicant shall replace the alternative system with an acceptable STP, or suite of STPs, as set forth in this Chapter. If a new-design alternative system is successfully approved by the Agency, then this alternative will be available for use by other permit applicants, if determined appropriate by the Agency.

5.0 STORMWATER TREATMENT PRACTICES WITH LIMITED APPLICABILITY

As previously described, there is a suite of stormwater management practices that have limited applicability either because they only provide water quantity control capabilities or because they have limited water quality treatment capabilities (i.e., current independent studies do not support their inclusion in the list of acceptable practices). Limited applicability practices may be used in series with one or more of the other practices described in the manual in order to achieve the required level of water quality treatment. Limited applicability practices include:

- Dry Detention Ponds
- Underground Storage Vaults
- Pocket Ponds

Design guidance is provided for these limited application practices, however, not at the same level of detail as the practices acceptable to meet water quality requirements. In cases where the practice is a proprietary product, specifications and design criteria can typically be obtained from vendors.

5.1. Dry Detention Ponds

Dry detention ponds are designed to provide channel protection (CP_v), overbank (Qp10), and extreme flood (Qp100) control only. They are not suitable for meeting water quality or recharge criteria as standalone stormwater treatment practices.

- Dry detention ponds shall be constructed with side slopes no steeper than 2:1.
- Outlets requirements shall conform to Section 4.3.6, except when the minimum orifice size is used and the center of mass detention time for the detained volume during the 1-yr storm under the Type II distribution is less than 500 minutes.
- Dry detention ponds shall conform to wet pond requirements related to construction sequencing and maintenance in Sections 4.3.6.7 through 4.3.6.9.

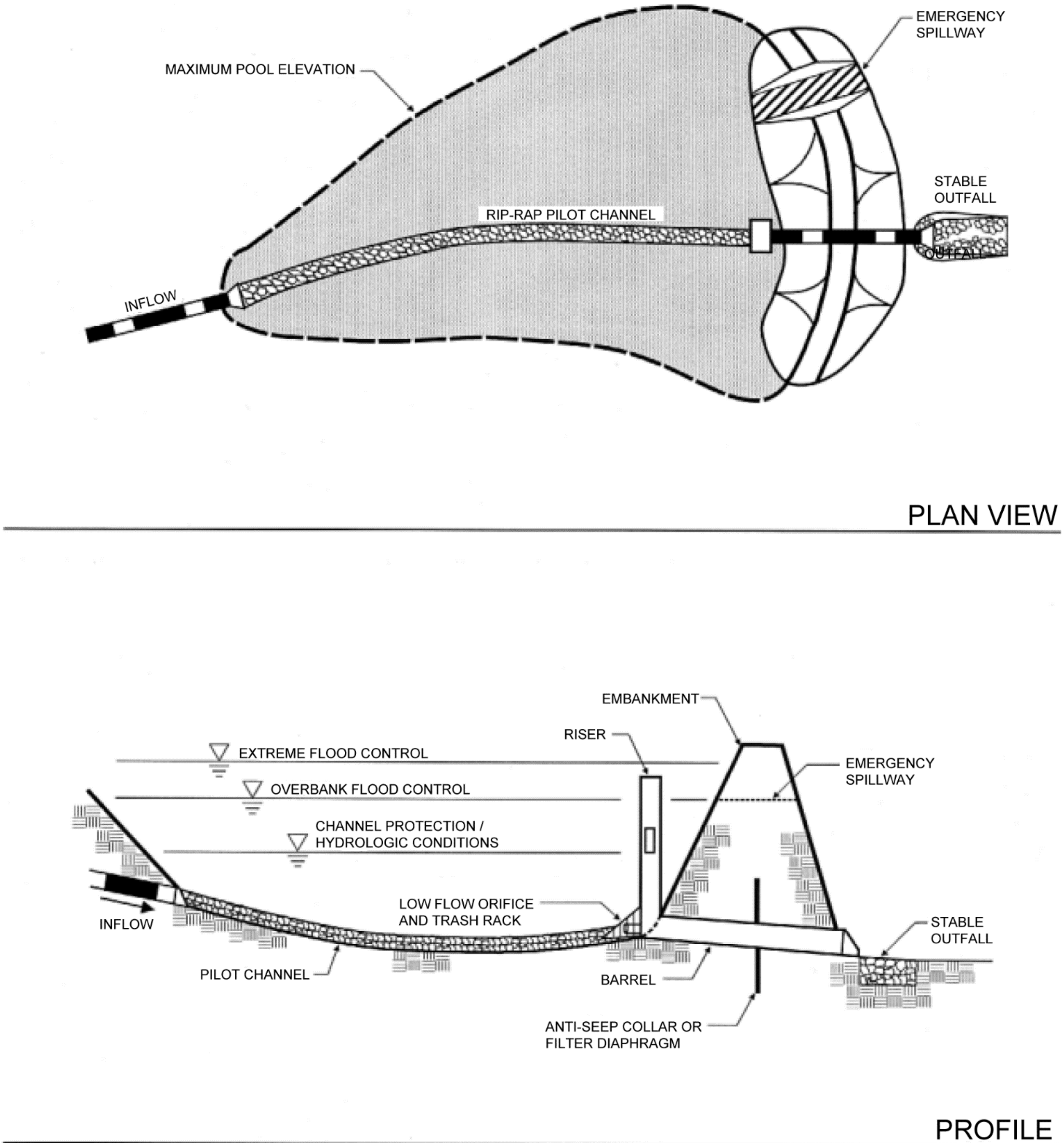


Figure 5-1. Dry Detention Pond

5.2. Underground Storage Vaults

Underground storage vaults are designed to provide channel protection (CP_v), overbank (Qp10), and extreme flood (Qp100) control only. They are not suitable for meeting water quality or recharge criteria as stand-alone stormwater treatment practices.

- Underground Storage vaults shall never serve as a sediment control device during site construction phase. In addition, the plan for the site shall clearly indicate how sediment will be prevented from entering the facility during construction.
- An observation well or access manhole shall be installed in every underground vault system for inspection and maintenance. Multiple observation wells (e.g., 1 well per 50 linear feet of chamber) may be required for large underground vault systems.
- The inlet and outlet of the vault shall be inspected periodically to ensure that flow structures are not blocked by debris. All pipes connecting vaults in series shall be checked for debris that may obstruct flow. It is important to design flow structures that can be easily inspected for debris blockage.

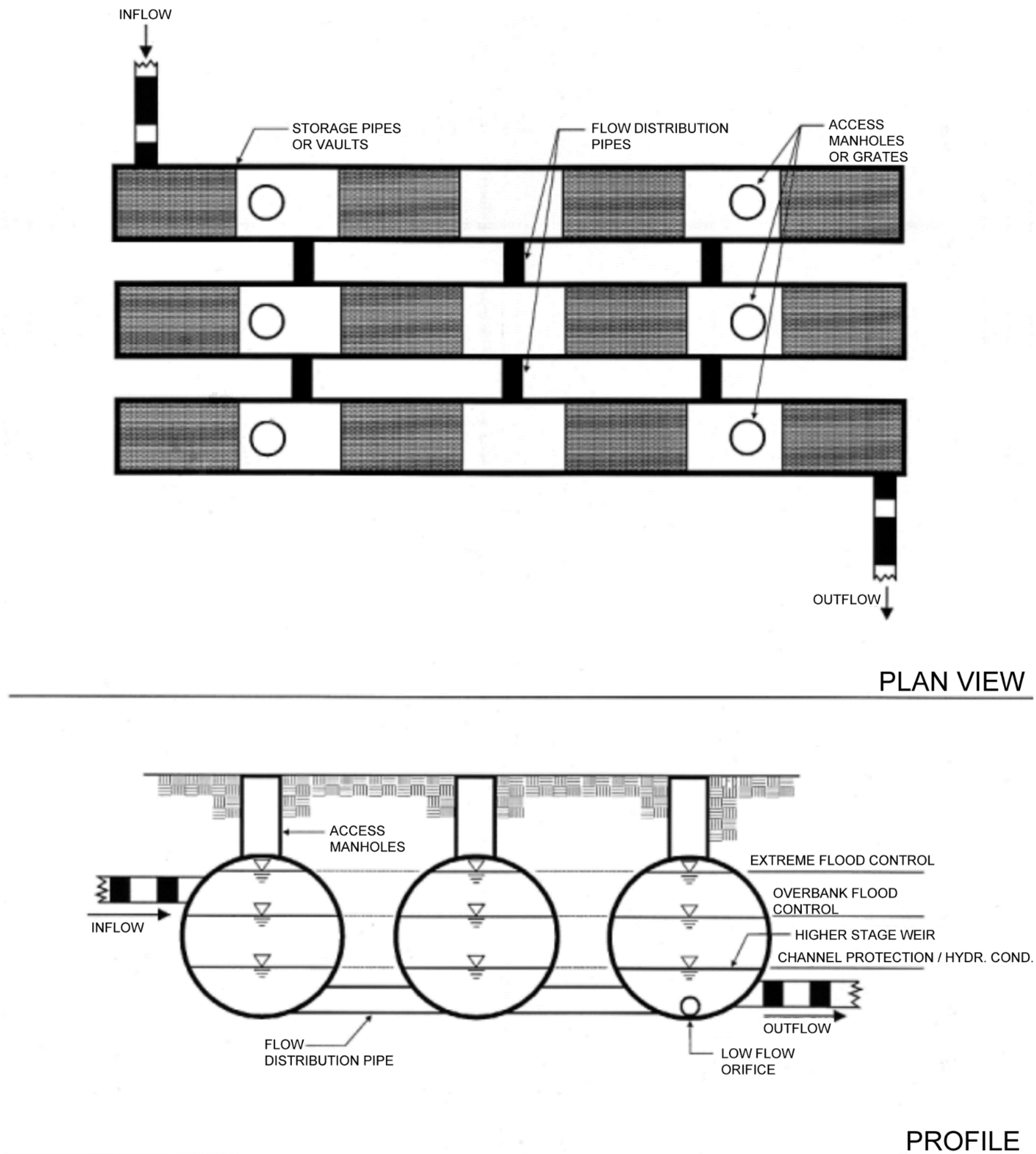
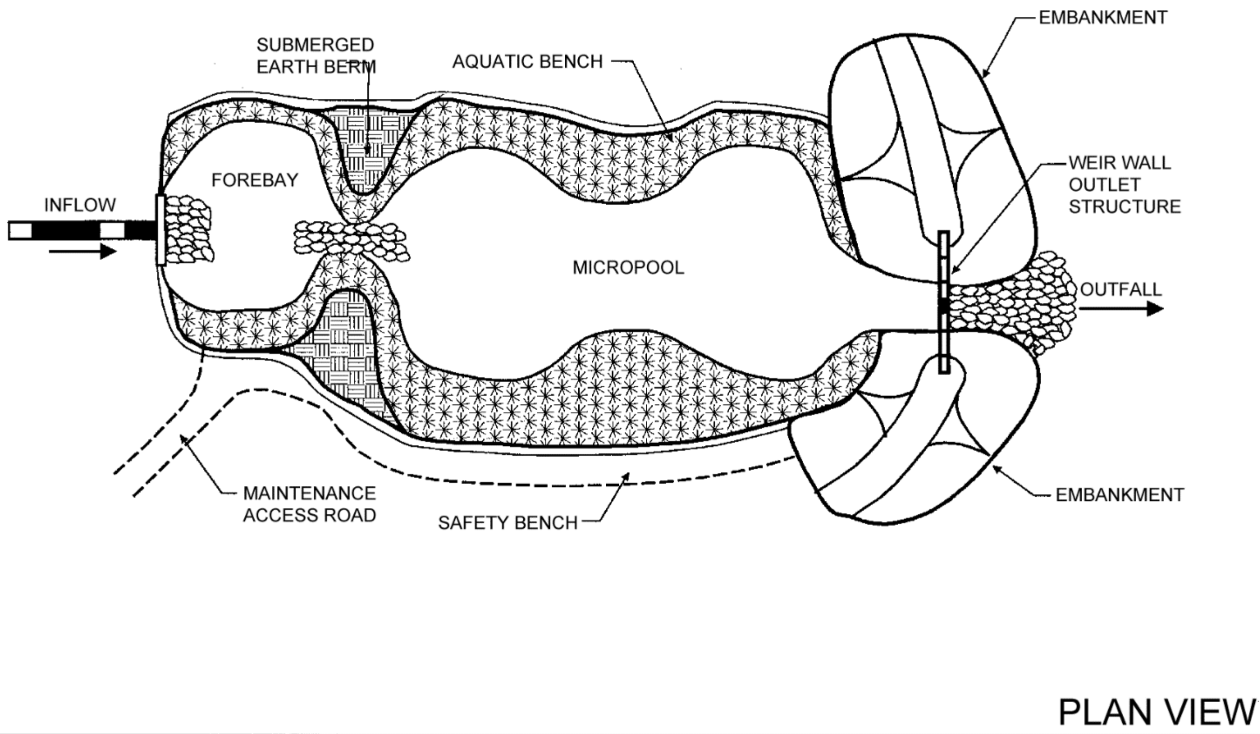


Figure 5-2. Underground Storage Vault

5.3. Pocket Ponds

Pocket ponds are not suitable for fully meeting water quality criteria as standalone best management practices, but may be allowed to provide channel protection (CP_v), overbank (Qp10), and extreme flood (Qp100) control. Pocket ponds are wet ponds that do not meet the full wet pond design requirements and perform the same functions as dry ponds, but due to interception of groundwater do have a permanent pool

- Pocket ponds with permanent pools equal to or greater than 4 feet in depth shall provide a safety bench in accordance with the safety bench requirements in Section 4.3.6.
- Pocket ponds shall also conform to the outlet requirements in Section 4.3.6, except when the minimum orifice size is used and the center of mass detention time for the detained volume during the 1-yr storm under the Type II distribution is less than 500 minutes.
- Pocket ponds shall conform to wet pond requirements related to construction sequencing and maintenance in Sections 4.3.6.7 through 4.3.6.9.



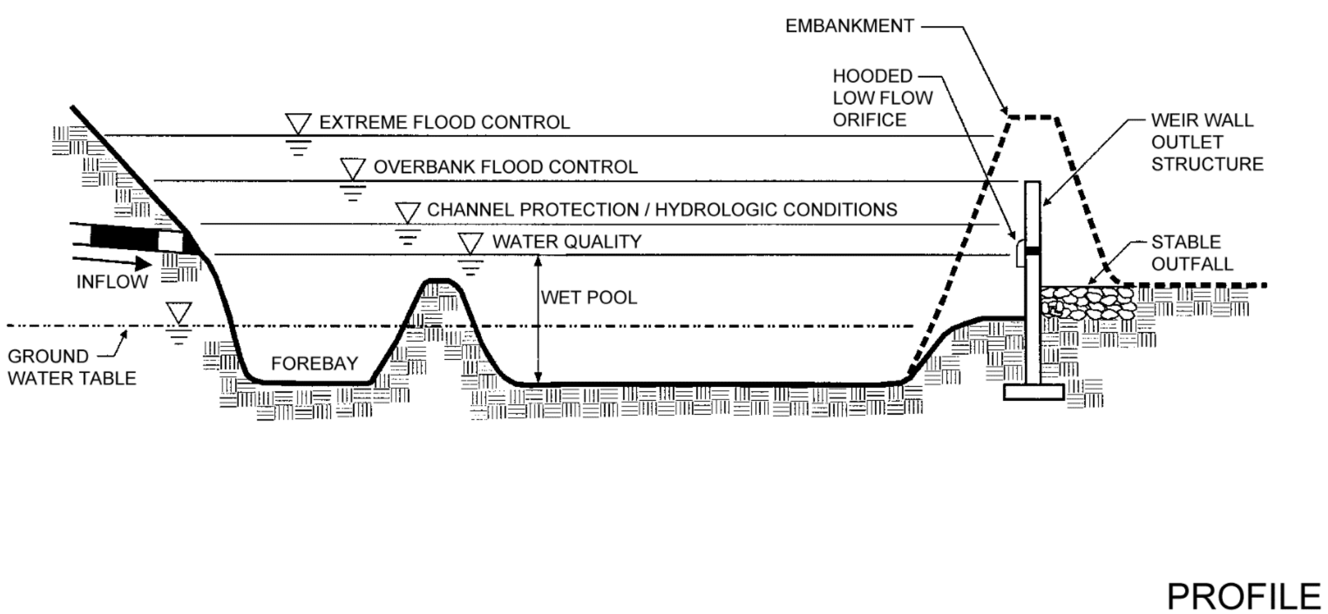


Figure 5-3. Pocket Pond

6.0 GLOSSARY

Agency - The Vermont Agency of Natural Resources.

Anti-seep Collar - An impermeable diaphragm usually of sheet metal or concrete constructed at intervals within the zone of saturation along the conduit of a principal spillway to increase the seepage length along the conduit and thereby prevent piping or seepage along the conduit.

Anti-vortex Device - A device designed and placed on the top of a riser or at the entrance of a pipe to prevent the formation of a vortex in the water at the entrance.

Applicant - A person applying for permit coverage. In some cases, more than one person may apply as co-applicants.

Aquatic Bench - A ten to fifteen foot wide bench which is located around the inside perimeter of a permanent pool and is normally vegetated with aquatic plants; the goal is to provide pollutant removal and enhance safety in areas using stormwater ponds.

Aquifer - A geological formation that contains and transports groundwater.

As-built - Drawing or certification of conditions as they were actually constructed.

Authorization to Discharge - An authorization to discharge issued by the Secretary pursuant to a general permit.

Baffles - Guides, grids, grating or similar devices placed in a pond to deflect or regulate flow and create a longer flow path.

Bankfull Flow - The condition where streamflow just fills a stream channel up to the top of the bank and at a point where the water begins to overflow onto a floodplain.

Barrel - The closed conduit used to convey water under or through an embankment: part of the principal spillway.

Base Flow - The stream discharge from ground water.

Berm - A shelf that breaks the continuity of a slope; a linear embankment or dike.

Best Management Practice (BMP) - A schedule of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce water pollution, including but not limited to the stormwater treatment practices (STPs) set forth in this Manual.

Bioretention - A water quality practice that utilizes landscaping and soils to treat stormwater runoff by collecting it in shallow depressions, before filtering through a fabricated planting soil media.

Channel - A natural stream that conveys water; a ditch or swale excavated for the flow of water.

Channel Protection (CPv) - A design criteria which requires either 12 or 24 hour detention of the one year post-developed, 24 hour storm event for the control of stream channel erosion.

Channel Stabilization - Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, structural linings, vegetation and other measures.

Check Dam - A small dam construction (i.e., vertical drop of 6 to 12 inches) in a gully, swale, or other small watercourse to decrease the stream flow velocity (by reducing the channel gradient), minimize channel scour, and promote deposition of sediment. Check dams can be constructed of wood, small diameter stone, concrete, or earth.

Chute - A high velocity, open channel for conveying water to a lower level without erosion.

Clay (soils) - 1. A mineral soil separate consisting of particles less than 0.002 millimeter in equivalent diameter. 2. A soil texture class. 3. (Engineering) A fine-grained soil (more than 50 percent passing the No. 200 sieve) that has a high plasticity index in relation to the liquid limit. (Unified Soil Classification System)

Clean Water Act - The federal Clean Water Act, 33 U.S.C.A. §1251 et. seq.

Coconut Rolls - Also known as coir rolls, these are rolls of natural coconut fiber designed for use in streambank stabilization.

Compaction (soils) - Any process by which the soil grains are rearranged to decrease void space and bring them in closer contact with one another, thereby increasing the weight of solid material per unit of volume, increasing the shear and bearing strength and reducing permeability.

Conduit - Any channel intended for the conveyance of water, whether open or closed.

Contour - 1. An imaginary line on the surface of the earth connecting points of the same elevation. 2. A line drawn on a map connecting points of the same elevation.

Core Trench - A trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

Cradle - A structure usually of concrete shaped to fit around the bottom and sides of a conduit to support the conduit, increase its strength and in dams, to fill all voids between the underside of the conduit and the soil.

Crest - 1. The top of a dam, dike, spillway or weir, frequently restricted to the overflow portion. 2. The summit of a wave or peak of a flood.

Crushed Stone - Aggregate consisting of angular particles produced by mechanically crushing rock.

Curve Number (CN) - A numerical representation of a given area's hydrologic soil group, plant cover, impervious cover, interception and surface storage derived in accordance with Natural Resources Conservation Service methods. This number is used to convert rainfall volume into runoff volume.

Cut - Portion of land surface or area from which earth has been removed or will be removed by excavation; the depth below original ground surface to excavated surface.

Cut-and-fill - Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

Cutoff - A wall or other structure, such as a trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

Dam - A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, sediment or other debris.

Detention - The temporary storage of storm runoff in a STP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Detention Structure - A structure constructed for the purpose of temporary storage of stream flow or surface runoff and gradual release of stored water at controlled rates.

Development – The construction of impervious surface(s) on a tract or tracts of land.

Dike - An embankment to confine or control water, for example, one built along the banks of a river to prevent overflow or lowlands; a levee.

Disturbance – Removal of stable surface treatment leaving exposed soil susceptible to erosion.

Disturbed Area - An area in which the natural vegetative soil cover has been removed or altered and, therefore, is susceptible to erosion.

Diversion - A channel with a supporting ridge on the lower side constructed across the slope to divert water from areas where it is in excess to sites where it can be used or disposed of safely. Diversions differ from terraces in that they are individually designed.

Drainage - 1. The removal of excess surface water or ground water from land by means of surface or subsurface drains. 2. Soils characteristics that affect natural drainage.

Drainage Area (watershed) - All land and water area from which runoff may run to a common (design) point.

Drop Structure - A structure for dropping water to a lower level and dissipating surplus energy; a fall. The drop may be vertical or inclined.

Dry Swale - An open drainage channel explicitly designed to detain and promote the filtration of stormwater runoff through an underlying fabricated soil media.

Emergency Spillway - A dam spillway designed and constructed to discharge flow in excess of the principal spillway design discharge.

Energy Dissipator - A designed device such as an apron of rip-rap or a concrete structure placed at the end of a water transmitting apparatus such as pipe, paved ditch or paved chute for the purpose of reducing the velocity, energy and turbulence of the discharged water.

Erosion - 1. The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. 2. Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion:

> **Accelerated Erosion** - Erosion much more rapid than normal, natural or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose base surfaces, for example, fires.
>
> **Gully Erosion** - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 1 or 2 feet to as much as 75 to 100 feet.
>
> **Rill Erosion** - An erosion process in which numerous small channels only several inches deep are formed. See rill.
>
> **Sheet Erosion** - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not subsequently be removed by surface runoff.

Erosive Velocities - Velocities of water that are high enough to wear away the land surface. Exposed soil will generally erode faster than stabilized soils. Erosive velocities will vary according to the soil type, slope, structural, or vegetative stabilization used to protect the soil.

Exfiltration - The downward movement of water through the soil; the downward flow of runoff from the bottom of an infiltration STP into the soil.

Existing Impervious Surface - An impervious surface that is in existence, regardless of whether it ever required a stormwater discharge permit.

Existing Stormwater Discharge - A discharge of regulated stormwater runoff which first occurred prior to June 1, 2002 and that is subject to the permitting requirements of 10 V.S.A. Chapter 47.

Expansion and expanded portion of an existing discharge - An increase or addition of new impervious surface to an existing impervious surface, such that the total resulting impervious surface is greater than the minimum regulatory threshold.

Extended Detention (ED) - A stormwater design feature that provides for the gradual release of a volume of water over a 12 to 24 hour interval in order to increase settling of pollutants and protect downstream channels from frequent storm events.

Extended Detention Method - A method for meeting the Channel Protection Standard for those sites where the practice or suite of practices is insufficient to achieve the HC Method for meeting Channel Protection Standard.

Extreme Flood (Q_{100}) - The storage volume required to control those infrequent but large storm events in which overbank flows approach the floodplain boundaries of the 100-year flood.

Filter Bed - The section of a constructed filtration device that houses the filter media and the outflow piping.

Silt Fence - A geotextile fabric designed to trap sediment and filter runoff.

Filter Media - The sand, soil, or other organic material in a filtration device used to provide a permeable surface for pollutant and sediment removal.

Filter Strip - A strip of permanent vegetation above ponds, diversions and other structures to retard flow of runoff water, causing deposition of transported material, thereby reducing sediment flow.

Fines (soil) - Generally refers to the silt and clay size particles in soil.

Flow Splitter - An engineered, hydraulic structure designed to divert a percentage of storm flow to a STP located out of the primary channel, or to direct stormwater to a parallel pipe system, or to bypass a portion of baseflow around a STP.

Forebay - Storage space located near a stormwater STP inlet that serves as pre-treatment, to trap incoming coarse sediments before they accumulate in the main treatment area.

Freeboard (hydraulics) - The distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions.

French Drain - A type of drain consisting of an excavated trench refilled with pervious material, such as coarse sand, gravel or crushed stone, through whose voids water percolates and flows to an outlet.

Gabion - A flexible woven-wire basket composed of two to six rectangular cells filled with small stones. Gabions may be assembled into many types of structures such as revetments, retaining walls, channel liners, drop structures and groins.

Gabion Mattress - A thin gabion, usually six or nine inches thick, used to line channels for erosion control.

Grade - 1. The slope of a road, channel or natural ground. 2. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction, like paving or laying a conduit. 3. To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

Swale - An open vegetated channel, also known as a grass channel, used to convey runoff and to provide pre-treatment by filtering out pollutants and sediments.

Gravel - 1. Aggregate consisting of mixed sizes of 1/4 inch to 3-inch particles that normally occur in or near old streambeds and have been worn smooth by the action of water. 2. A soil having particle sizes, according to the Unified Soil Classification System, ranging from the No. 4 sieve size angular in shape as produced by mechanical crushing.

Gravel Diaphragm - A stone trench filled with small, river-run gravel used as pretreatment and inflow regulation in stormwater filtering systems.

Gravel Filter - Washed and graded sand and gravel aggregate placed around a drain or well screen to prevent the movement of fine materials from the aquifer into the drain or well.

Gravel Trench - A shallow excavated channel backfilled with gravel and designed to provide temporary storage and permit percolation of runoff into the soil substrate.

Ground Cover - Plants that are low growing and provide a thick growth that protects the soil as well as providing some beautification of the area occupied.

Gully - A channel or miniature valley cut by concentrated runoff through which water commonly flows only during and immediately after heavy rains or during the melting of snow. The distinction between gully and rill is one of depth. A gully is sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lesser depth and would be smoothed by ordinary farm tillage.

Head (hydraulics) - 1. The height of water above any plane of reference. 2. The energy, either kinetic or potential, possessed by each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various terms such as pressure head, velocity head, and head loss.

Herbaceous Perennial - A plant whose stems die back to the ground each year.

High Marsh - A pondscaping zone within a stormwater wetland that exists from the surface of the normal pool to a six-inch depth and typically contains the greatest density and diversity of emergent wetland plants.

High Marsh Wedges - Slices of shallow wetland (less than or equal to 6 inches) dividing a stormwater wetland.

Hot Spot - Area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Hydraulic Gradient - The slope of the hydraulic grade line. The slope of the free surface of water flowing in an open channel.

Hypoxia - Lack of oxygen in a waterbody resulting from eutrophication.

Hydrograph - A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

Hydrologic Condition Volume (HC_v) – The difference between the pre-development and post-development site runoff for the 1-year, 24-hour storm.

Hydrologic Condition (HC) Method – A method for meeting the Channel Protection Standard, intended to determine a suite of practices, including the mandatory post-construction soil quality and depth standard, which when implemented, will approximate runoff characteristics of "woods in good condition" for the one-year, 24 hour storm event.

Hydrologic Soil Group (HSG) - A Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce much more runoff.

Hydroseed - Seed or other material applied to areas in order to revegetate after a disturbance.

Impervious Surface (I) - Those manmade surfaces, including, but not limited to, paved and unpaved roads, parking areas, roofs, driveways, and walkways, from which precipitation runs off rather than infiltrates; §1264(a)(6). For purposes of this Manual, pervious or porous pavement, concrete, pavers and similar materials are not considered impervious when design specifications demonstrate that the material in question has the capacity to infiltrate the one-year storm, under a type II distribution. In assessing the infiltrative capacity the designer shall account for factors related to the specific application, including the effect of base and sub-base materials, slope, and maintenance practices.

Infiltration Rate (f_c) - The rate at which stormwater percolates into the subsoil measured in inches per hour.

Inflow Protection - A water-handling device used to protect the transition area between any water conveyance (dike, swale, or swale dike) and a sediment-trapping device.

Level Spreader - A device for distributing stormwater uniformly over the ground surface as sheet flow to prevent concentrated, erosive flows and promote infiltration.

Manning's Formula (hydraulics) - A formula used to predict the velocity of water flow in an open channel or pipeline:

$$V = (1.486/n) * R^{2/3} * S^{1/2}$$

Where V is the mean velocity of flow in feet per second; R is the hydraulic radius; S is the slope of the energy gradient or for assumed uniform flow the slope of the channel, in feet per foot; and n is the roughness coefficient or retardance factor of the channel lining.

Micropool - A smaller permanent pool that is incorporated into the design of larger stormwater ponds to avoid resuspension or settling of particles and minimize impacts to adjacent natural features.

Microtopography - The complex contours along the bottom of a shallow marsh system, providing greater depth variation, which increases the wetland plant diversity and increases the surface area to volume ratio of a stormwater wetland.

Mulch - Covering on surface of soil to protect and enhance certain characteristics, such as water retention qualities.

Multi-Sector Permit - An individual or general NPDES permit issued to a commercial industry or group of industries that regulates the pollutant levels associated with industrial storm water discharges or specifies on-site pollution control strategies.

Municipality - An incorporated city, town, village or gore, a fire district established pursuant to state law, or any other duly authorized political subdivision of the state.

NPDES - Acronym for the National Pollutant Discharge Elimination System, for the issuance of permits under section 402 of the federal Clean Water Act and includes the Vermont-administered NPDES program authorized by the federal Environmental Protection Agency.

New Development - The construction of new impervious surface on a tract or tracts of land where no impervious surface previously existed.

New Impervious Surface – An impervious surface created after the effective date of Chapter 18 or Chapter 22 of the Vermont Environmental Protection Rules..

New Stormwater Discharge – A new or expanded discharge of regulated stormwater runoff, subject to the permitting requirements of 10 V.S.A. Chapter 47, which first occurs after June 1, 2002 and has not been previously authorized pursuant to 10 V.S.A. Chapter 47.

Nitrogen-fixing (bacteria) - Bacteria having the ability to fix atmospheric nitrogen, making it available for use by plants. Inoculation of legume seeds is one way to insure a source of these bacteria for specified legumes.

Normal Depth - Depth of flow in an open conduit during uniform flow for the given conditions.

Outfall - The point where water flows from a conduit, stream, or drain.

Off-line - A stormwater management system designed to manage a storm event by diverting a percentage of stormwater events from a stream or storm drainage system.

Off-site - Land within a project's drainage area that is not characterized as being part of the site.

On-line - A stormwater management system designed to manage stormwater in its original stream or drainage channel.

Offset or Offset Project – A state-permitted action or project within a stormwater-impaired water that a discharger or a third person may complete to mitigate the impacts that an existing or proposed discharge or discharges of regulated stormwater runoff has or is expected to have on the stormwater-impaired water.

Offset Charge – The amount of sediment load or hydrologic impact that an offset must reduce or control in the stormwater-impaired water in which the offset is located.

Offset Charge Capacity – The amount of reduction in sediment load or hydrologic impact that an offset project generates.

One Year Storm (Q_1) - A stormwater event which occurs on average once every year or statistically has a 100% chance on average of occurring in a given year.

One Hundred Year Storm (Q_{100}) - A extreme flood event which occurs on average once every 100 years or statistically has a 1% chance on average of occurring in a given year.

Open Channels - Also known as swales, grass channels, and biofilters. These systems are used for the conveyance, retention, infiltration, filtration, and pre-treatment of stormwater runoff.

Outlet - The point at which water discharges from such things as a stream, river, lake, tidal basin, pipe, channel or drainage area.

Outlet Channel - A waterway constructed or altered primarily to carry water from man-made structures such as terraces, subsurface drains, diversions and impoundments.

Peak Discharge Rate - The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Permanent Seeding - Results in establishing perennial vegetation that may remain on the area for many years.

Permeability - The rate of water movement through the soil column under saturated conditions

Permissible Velocity (hydraulics) - The highest average velocity at which water may be carried safely in a channel or other conduit. The highest velocity that can exist through a substantial length of a conduit and not cause scour of the channel. A safe, non-eroding or allowable velocity.

Person - Any individual, partnership, company, corporation, association, joint venture, trust, municipality, the state of Vermont or any agency, department or subdivision of the state, any federal agency, or any other legal or commercial entity.

pH - A number denoting the common logarithm of the reciprocal of the hydrogen ion concentration. A pH of 7.0 denotes neutrality, higher values indicate alkalinity, and lower values indicate acidity.

Piping - Removal of soil material through subsurface flow channels or “pipes” developed by seepage water.

Plugs - Pieces of turf or sod, usually cut with a round tube, which can be used to propagate the turf or sod by vegetative means.

Pocket Pond - A limited applicability stormwater pond designed for small drainage area (< 5 acres) runoff and which has little or no baseflow available to maintain water elevations and relies on ground water to maintain a permanent pool.

Pond Buffer - The area immediately surrounding a pond that acts as filter to remove pollutants and provide infiltration of stormwater prior to reaching the pond. Provides a separation barrier to adjacent development.

Pond Drain - A pipe or other structure used to drain a permanent pool within a specified time period.

Pondscaping - Landscaping around stormwater ponds that emphasizes native vegetative species to meet specific design intentions. Species are selected for up to six zones in the pond and its surrounding buffer, based on their ability to tolerate inundation and/ or soil saturation.

Porosity - Ratio of pore volume to total solids volume.

Pre-treatment - Techniques employed in stormwater STPs to provide storage or filtering to help trap coarse materials before they enter the system.

Principal Spillway - The primary pipe or weir that carries baseflow and storm flow through the embankment.

Project – New development, expansion, redevelopment and or existing impervious surface that the Secretary is considering for coverage under an individual or general permit or which has received coverage under an individual or general permit.

Waters of the State - All rivers, streams, creeks, brooks, reservoirs, ponds, lakes, springs, and all bodies of surface waters, artificial or natural, which are contained within, flow through or border upon the state of Vermont or any portion of it.

Recharge Rate - Annual amount of rainfall that contributes to groundwater as a function of hydrologic soil group.

Redevelopment - The reconstruction of an impervious surface where an impervious surface currently exists, when such reconstruction involves substantial site grading, substantial subsurface excavation, or modification of existing stormwater conveyance such that the total of impervious surface to be constructed or reconstructed is greater than the minimum regulatory threshold. Redevelopment does not mean management activities on impervious surfaces, including any crack sealing, patching, coldplaning, resurfacing, paving a gravel road, reclaiming, or grading treatments used to maintain pavement, bridges and unpaved roads. Redevelopment does not include expansions.

Regulated stormwater runoff - precipitation, snowmelt, and the material dissolved or suspended in precipitation and snowmelt that runs off impervious surfaces and discharges into surface waters or into groundwater via infiltration.

Retention - The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

Reverse Slope Pipe - A pipe which draws from below a permanent pool extending in a reverse angle up to the riser and which determines the water elevation of the permanent pool.

Right-of-Way - Right of passage, as over another's property. A route that is lawful to use. A strip of land acquired for transport or utility construction.

Rip-Rap - Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves); also applies to brush or pole mattresses, or brush and stone, or similar materials used for soil erosion control.

Riser - A vertical pipe that extends from the bottom of a pond STP and houses the control devices (weirs/orifices) to achieve the discharge rates for specified designs.

Runoff Coefficient (hydraulics) - A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.

Runoff (hydraulics) - That portion of the precipitation on a drainage area that is discharged from the area in the stream channels. Types include surface runoff, ground water runoff or seepage.

Runoff Coefficient (Rv) - A value derived from a site impervious cover value that is applied to a given rainfall volume to yield a corresponding runoff volume.

Safety Bench - A flat area above the permanent pool and surrounding a stormwater pond designed to provide a separation from the pond pool and adjacent slopes.

Sand - 1. (Agronomy) A soil particle between 0.05 and 2.0 millimeters in diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System, a soil particle larger than the No. 200 sieve (0.074mm) and passing the No. 4 sieve (approximately 1/4 inch).

Secretary - the Secretary of the Agency of Natural Resources or the Secretary's duly authorized representative.

Sediment - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Seepage - 1. Water escaping through or emerging from the ground.2. The process by which water percolates through the soil.

Seepage Length - In sediment basins or ponds, the length along the pipe and around the anti-seep collars that is within the seepage zone through an embankment.

Setbacks - The minimum distance requirements for location of a structural STP in relation to roads, wells, septic fields, other structures.

Sheet Flow - Water, usually stormwater runoff, flowing in a thin layer over the ground surface.

Side Slopes (engineering) - The slope of the sides of a channel, dam or embankment. It is customary to name the horizontal distance first, as 1.5 to 1, or frequently, 1 ½: 1, meaning a horizontal distance of 1.5 feet to 1 foot vertical.

Silt - 1. (Agronomy) A soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System a fine-grained soil (more than 50 percent passing the No. 200 sieve) that has a low plasticity index in relation to the liquid limit.

Site - Either the drainage area that includes all portions of a project contributing stormwater runoff to one or more discharge points; or, the area that includes all portions of disturbed area within a project contributing stormwater runoff to one or more discharge points. The choice of either of these two methods of calculating the site area shall be at the discretion of the designer. In cases where there are multiple discharges to one or more waters, "site" shall mean the total area of the sub-watersheds. For linear projects, including but not limited to highways, roads and streets, the term "site" includes the entire right of way within the limits of the proposed work, or all portions of disturbed area within the right of way associated with the project. The method of calculating the site area for linear projects shall be at the discretion of the designer. Calculations of a site are subject to the Secretary's review.

Soil Test - Chemical analysis of soil to determine needs for fertilizers or amendments for species of plant being grown.

Spillway - An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled to regulate the discharge of excess water.

Stabilization - Providing adequate measures, vegetative and/or structural that will prevent erosion from occurring.

Stage (Hydraulics) - The variable water surface or the water surface elevation above any chosen datum.

Stand-alone offset project – An offset project that is implemented by a person independent of the permitting of a discharge of regulated stormwater runoff.

Stand-alone Offset Project NPDES permit – A NPDES permit issued by the Secretary for a stand-alone offset project that is not completed prior to the initiation of the first discharge to which the offset charge capacity is assigned. A stand-alone offset project NPDES permit will be issued by the Secretary pursuant to the Agency's federally-authorized NPDES program under 10 V.S.A. Section 1258.

Stilling Basin - An open structure or excavation at the foot of an outfall, conduit, chute, drop, or spillway to reduce the energy of the descending stream of water.

Stormwater Discharge Permit or Stormwater Permit - A permit issued by the Secretary for the discharge of regulated stormwater runoff to waters that are not stormwater-impaired waters.

Stormwater Filtering - Stormwater treatment methods that utilize an artificial media to filter out pollutants entrained in urban runoff.

Stormwater Impact Fee – The monetary charge assessed to a permit applicant for the discharge of regulated stormwater runoff to a stormwater-impaired water that mitigates a sediment load level or hydrologic impact that the discharger is unable to control through on-site treatment or completion of an offset on a site owned or controlled by the permit applicant.

Stormwater-impaired Water - A state water listed as being impaired principally due to stormwater runoff on the EPA-approved State of Vermont 303(d) List of Waters.

Stormwater-Impaired Watershed – The total area of land contributing runoff to a stormwater-impaired water.

Stormwater Ponds - A land depression or impoundment created for the detention or retention of stormwater runoff.

Stormwater Runoff - Precipitation and snowmelt that does not infiltrate into the soil, including material dissolved or suspended in it, but does not include discharges from undisturbed natural terrain or wastes from combined sewer overflows.

Stormwater Treatment Practices (STPs) - Devices that are constructed to provide temporary storage and treatment of stormwater runoff.

Stormwater Wetlands - Shallow, constructed pools that capture stormwater and allow for the growth of characteristic wetland vegetation.

Stream Buffers - Zones of variable width that are located along both sides of a stream and are designed to provided a protective natural area along a stream corridor.

Structures – Buildings such as houses, businesses, pump houses, and storage sheds and infrastructure such as roadways, culverts, bridge abutments, and utilities.

Subgrade- The soil prepared and compacted to support a structure or a pavement system.

Substantially Deteriorated - The condition of a stormwater treatment practice that would necessitate repair or reconstruction beyond that which would be considered routine, periodic maintenance for a system of similar design.

Tailwater - Water, in a river or channel, immediately downstream from a structure.

Technical Release No. 20 (TR-20) - A Soil Conservation Service (now NRCS) watershed hydrology computer model that is used to compute runoff volumes and route storm events through a stream valley and/or ponds.

Technical Release No. 55 (TR-55) - A watershed hydrology model developed by the Soil Conservation Service (now NRCS) used to calculate runoff volumes and provide a simplified routing for storm events through ponds.

Temporary Seeding - A seeding which is made to provide temporary cover for the soil while waiting for further construction or other activity to take place.

Ten Year Storm (Q_{10}) - The peak discharge rate associated with a 24 hour storm event which exceeds bankfull capacity and occurs on average once every ten years (or has a likelihood of occurrence of 10% in a given year).

Time of Concentration (t_c)- Time required for water to flow from the most remote point of a watershed, in a hydraulic sense, to the outlet.

Toe (of slope) - Where the slope stops or levels out. Bottom of the slope.

Toe Wall - Downstream wall of a structure, usually to prevent flowing water from eroding under the structure.

Topsoil - Fertile or desirable soil material used to top dress road banks, subsoils, parent material, etc.

Total Maximum Daily Load or TMDL – The calculations and plan for meeting water quality standards approved by the U.S. Environmental Protection Agency (EPA) and prepared pursuant to 33 U.S.C. 1313(d) and federal regulations adopted under that law.

Total Suspended Solids (TSS) - The total amount of soils particulate matter that is suspended in the water column.

Tract or Tracts of Land - A portion of land with defined boundaries created by a deed. A deed may describe one or more tracts.

Trash Rack - Grill, grate or other device at the intake of a channel, pipe, drain or spillway for the purpose of preventing oversized debris from entering the structure.

Two Year Storm (Q_2) - The peak discharge rate associated with a 24 hour storm event which exceeds bankfull capacity and occurs on average once every two years (or has a likelihood of occurrence of 1/2 in a given year).

Ultimate Condition - Full watershed build-out based on existing zoning. Where zoning has not been established, ultimate condition should reflect reasonable professional judgment that considers the likely nature of land use for the subject lands projected out over a 30 to 40 year planning period. Review authorities should be consulted where zoning has not been established.

Ultra-urban - Densely developed urban areas in which little pervious surface exists.

Velocity Head - Head due to the velocity of a moving fluid, equal to the square of the mean velocity divided by twice the acceleration due to gravity (32.16 feet per second per second).

Vermont Stormwater Management Manual (VSMM) - The Agency of Natural Resources' stormwater management manual.

Water Quality Remediation Plan (WQRP) – A plan, other than a TMDL or sediment load allocation, designed to bring an impaired water body into compliance with applicable water quality standards in accordance with 40 C.F.R. 130.7(b)(1)(ii) and (iii).

Water Quality Volume (WQ_V) - The storage needed to capture and treat 90% of the average annual stormwater runoff volume.

Water Surface Profile - The longitudinal profile assumed by the surface of a stream flowing in an open channel; the hydraulic grade line.

Watershed - The total area of land contributing runoff to a specific point of interest within a receiving water.

Wedges - Design feature in stormwater wetlands, which increases flow path length to provide for extended detention and treatment of runoff.

Wet Swale - An open drainage channel or depression, explicitly designed to retain water or intercept groundwater for water quality treatment.

Wetted Perimeter - The length of the line of intersection of the plane or the hydraulic cross-section with the wetted surface of the channel.

Wing Wall - Sidewall extensions of a structure used to prevent sloughing of banks or channels and to direct and confine overfall.

303(d) List - The EPA-approved State of Vermont 303(d) List of Waters prepared pursuant to 33 U.S.C. 1313(d).