2017 Vermont Stormwater Management Manual Rule

Environmental Protection Rule Chapter XX

Vermont Agency of Natural Resources

Effective ~~[Month] [Day], [Year]~~July 1, 2017

Acknowledgements

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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 PURPOSE

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Introduction. Effective stormwater management must include both water quality and water quantity controls. Since the Vermont Stormwater Management Manual (VSMM or Manual) was first published in 2002, substantial advances in the design and range of best management practices (BMPs) 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. These methodologies include 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. Collectively these BMPs that involve both structural and non-structural measures are referred to in this Manual as stormwater treatment practices (STPs).

This Manual more fully integrates approaches for designing and sizing STPs for water quality treatment, groundwater recharge, downstream channel protection, and flood protection under the umbrella of runoff reduction through the Hydrologic Condition Method to ensure runoff volumes delivered to local receiving waters after site development more closely mimics pre-development conditions. In addition, this Manual provides instruction on a range of site planning and ~~GSI~~green stormwater infrastructure design practices for minimizing the generation of runoff from the developed portions of Vermont's landscape, including requirements for restoring healthy soils as part of development activity.

In the sections that follow, this Manual expands and retools the unified approach for designing and sizing STPs that was presented in the 2002 VSMM. State-of-the-art BMPs for stormwater management are incorporated 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. In addition, this Manual includes site planning and design considerations for the siting of stormwater infrastructure to protect the natural landscape.

The 2017 VSMM is a key component of Vermont's program to protect waters from the impacts associated with developed land. The standards in this Manual, when applied pursuant to a stormwater permit, are effective in managing stormwater from new development and redevelopment. The 2017 VSMM is also an important strategy associated with Total Maximum Daily Load (TMDL) implementation in impaired waters, such as Lake Champlain. When the practices in the 2017 VSMM are applied to new development in the Lake Champlain watershed, the Vermont Agency of Natural Resources (ANR or Agency) estimates that the phosphorus load from new development will be reduced by at least 70%, on average. Act 64 of 2015, also known as the Vermont Clean Water Act, directs the Agency to regulate all existing parcels with three or more acres of impervious surface and gives the Agency the authority to designate smaller parcels if the Secretary of Natural Resources (Secretary) determines treatment is necessary to reduce adverse impacts to water quality; the 2017 VSMM will serve as the design standard for these statutory provisions. The 2017 VSMM and the associated operational stormwater permit program ~~is~~ applied in conjunction with ~~a~~the ~~range of~~state stormwater programs, including construction, industrial, municipal, and the newly-created municipal roads permitting authority will serve to protect, maintain, and restore Vermont's waters.

Purpose. The purpose of this Manual is:

- To protect, maintain, and improve the waters of the State of Vermont in conformance with the Vermont Water Quality Standards, by minimizing the risk of potential adverse impacts of stormwater runoff.
- To require the most effective STPs for new development and redevelopment, 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.

Manual Review. Because of the importance of the VSMM, the Agency's goals to ensure the standards in the VSMM remain the highest and best, and the understanding that the field of stormwater management continues to evolve, the Agency shall review the standards in the VSMM at least every five years to determine if the VSMM needs be revised to incorporate changes.

1.1. Regulatory Authority and Applicability

Authority. This Rule establishes the post-construction stormwater treatment standards for projects subject to stormwater discharge permitting in Vermont, and is adopted pursuant to 10 V.S.A. § 1264.

Applicability. The standards established in this Rule shall be applied by the Agency, pursuant to the Agency's Stormwater Management Rules, through general and individual permits.

Key Words. Designers are required to adhere to the applicable stormwater treatment standards and required performance criteria in this Manual. Specific words are used to indicate whether a particular design standard or criterion is required or optional. For purposes of this Manual, these terms and their meanings are as follows:

- **"Must," "shall," and "required"** mean the design standard or criterion is required; it is not optional. ~~The designer shall provide a written technical justification that is acceptable to the Agency, if the standard or criterion is not used or achieved.~~
- **"Should"** means a design standard or criterion is a well-accepted practice or a satisfactory and an advisable option or method, but is optional; it is not required.
- **"May"** means a design standard or criterion is recommended for consideration by the designer, but is optional; it is not required.

1.2. Anti-degradation

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The 2017 VSMM is adopted in conformance with the Anti-Degradation Policy of the Vermont Water Quality Standards and the Department's Interim Anti-Degradation Implementation Procedure (October 2010).

The development of the 2017 VSMM was informed by an extensive stakeholder process and review of existing stormwater standards in place nationally. As a result of this process, this Manual includes the highest level of cost-effective STPs. Additionally, the 2017 VSMM development process took into account anti-degradation requirements and the socioeconomic effects of requiring certain practices.

The practices in the Manual will be reviewed in cycles not to exceed five years to ensure that the required practices remain the highest level of cost-effective STPs. Where warranted based on this review, the

Agency will revise the 2017 VSMM to add, remove, or modify practices to ensure ongoing compliance with the anti-degradation requirements of the Vermont Water Quality Standards.

In the vast majority of cases, application of the practices and BMPs in this Manual will maintain and protect the higher quality of the State's high quality waters, will prevent limited reductions in the existing higher quality of those waters, and will minimize risk to the existing and designated uses of those waters.

Therefore, compliance with the 2017 VSMM affords a rebuttable presumption of compliance with the Anti-Degradation Policy. The overall presumption of compliance with anti-degradation requirements for projects designed in conformance with this Manual may be rebutted on a case-by-case basis if warranted by credible and relevant project- or site-specific information available to the Agency during the review of an application for a proposed discharge.

1.3. Protection of Groundwater

Commented [SE4]: Section added

The 2017 VSMM applies the best available treatment and disposal technologies for the management of stormwater, for ensuring that groundwater is not depleted by development, and for the protection of groundwater quality.

During development of the 2017 VSMM, the Agency relied upon the best available information and a public stakeholder process to evaluate the use of STPs and design strategies for the protection groundwater. An extensive review of available data suggests that unmanaged stormwater is unlikely to exceed primary groundwater enforcement standards. Consequently, the infiltration of stormwater managed in conformance with this Manual is unlikely to violate primary groundwater enforcement standards at any applicable point of compliance.

Stormwater that is infiltrated in conformance with the 2017 VSMM receives pre-treatment, treatment, and is subject to source controls and seasonal-high groundwater table separation requirements that are likely to mitigate potential contamination. Further, this Manual specifies the established set backs for structural infiltration STPs from source water protection areas, drinking water sources, and wastewater disposal areas. In addition, the 2017 VSMM prohibits use of infiltration-based STPs to treat stormwater runoff that comes in contact with "hotspot" land uses or activities that may present a greater risk to groundwater quality. Finally, the Groundwater Recharge Standard set forth in this Manual ensures that groundwater recharge will be maintained at pre-development levels based upon prevailing mapped hydrologic soil groups (HSGs).

The 2017 VSMM will be reviewed and, if necessary, revised every five years to assure that the VSMM continues to apply the best treatment and control technologies. The Agency reserves the right to disallow the infiltration of stormwater or to require additional protective measures on a case-by-case basis if warranted by credible and relevant information available to the Agency during the review of an application.

Based on the foregoing, permitted stormwater discharges to groundwater managed in accordance with a stormwater system designed to the standards of the 2017 VSMM are compliant with the State's policy regarding the protection of groundwater as contained in 10 V.S.A. §§ 1390, 1392, 1410, the Groundwater Protection Rule and Strategy (Environmental Protection Rules, Chapter 12), and the Underground Injection Control Regulations (Environmental Protection Rules, Chapter 11), including section 11-301 "Prohibitions."

1.4. Effective Date and Transition

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Effective Date. This Rule shall take effect on July 1, 2017.

Transition. The standards in the 2017 VSMM may be applied, at the discretion of the applicant, to a project if the construction, redevelopment, or expansion is a public transportation project, and as of the effective date of this Rule, the Agency of Transportation or the municipality principally responsible for the project has initiated right-of-way valuation activities or determined that right-of-way acquisition is not necessary for the project, and substantial construction of the project commences within five years of the effective date of this Rule.

2.0 SITE DESIGN AND STORMWATER TREATMENT PRACTICE SIZING CRITERIA

Introduction. 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 STPs.

Pervious surfaces. For purposes of this Manual, pervious or porous pavement, concrete, pavers, and similar manmade materials are not "impervious surface," as defined in this Manual, when design specifications demonstrate that the material in question has the capacity to infiltrate the 1-year 24-hour storm event, 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.

2.1. Site Planning and Design

Commented [ME6]: All of Section 2.1 and 2.1.1 may be included in guidance, but are not appropriate for rule.

For the purposes of this mManual, "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, lake shorelands, wetlands, floodplains, river corridors, 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 maximizethe retention of forest cover, natural areas, stream equilibrium, and undisturbed soils, will reduce stream instability and the generation of stormwater runoff from the site that will ultimately need to be managed and will reduce stream instability. Further, all disturbed areas of the site will be subject to a post-construction soil depth and quality standard (see Sectionubchapter 3.0), whereas undisturbed areas are presumed to comply with the standard without additional interventionsrequirements.

2.1.1. Minimizing Impervious Cover and Conserving Natural Vegetation

In the 2002 Vermont Stormwater Management Manual (VSMM), several of the site-design approaches described below were offered as optional "credits" that could be applied to reduce the required water quality and groundwater 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 generallycan result in smaller development footprints that will reduce the need for building and maintaining stormwater treatment practices structural STPs in order to meet the treatment standards in Section 2.22-7. Section 2.1.1. is for guidance purposes only and is not required, however other local, state, or federal regulatory requirements may apply.

Natural Area Conservation

- Consider ~~C~~conserving~~e~~ trees and other existing vegetation at each site or establishing new natural areas by planting additional vegetation, establishing no-mow zones, 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 such as shorelands and riparian areas.~~

Natural Drainage, Buffer and Floodplain Protection

- Where possible, ~~E~~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%), lake shorelands, and wetlands.
- Preserve or restore riparian stream buffers with native vegetation. Buffers are most effective when maintained in an undisturbed condition, mowing and brush hogging should not take place within a buffer.
- 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~~develop, 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~~catch basins.
- Consider options to "go vertical" reducing the area of land required for parking with multi-story parking structures or underground parking.

~~2.1.1.~~2.1.2. Setbacks for Water Resource Protection and Restoration

Commented [SE7]: Section added. This section is guidance (not part of the rulemaking version) as the information contained here is already contained in other rules and permits.

Since the 2002 Vermont Stormwater Management Manual (VSMM) was released there have been substantive statutory revisions and rulemaking requiring the protection of wetlands, lake shorelands, floodplains, and river corridors. Public policy has evolved with the science that explains the environmental and societal importance of the physical, chemical, and biological processes that occur when these landscape features remain intact. The physical incursions that may adversely affect or disrupt these processes include not only hydrologic modification, which STPs are designed to avoid, but the physical encroachments into these features that change natural processes and may lead to undesirable loss of water resource function and value, such as vital wildlife habitat. This is particularly true in higher energy river systems, where stability and equilibrium conditions may not only be disrupted by changes in flow quantity, but by encroachments into the system that cause the displacement of flow and energy attenuation. Failure to avoid these disruptions and displacements may result in altered flow patterns, systemic instability, erosion and loss of habitat.

Wetlands naturally store and filter sediments and nutrients as an ecosystem process, but these functions are reduced when wetland systems are overwhelmed by artificially high water inputs and pollution loads. The loss of wetland acreage for the purpose of stormwater infrastructure may result in a net loss of the water storage and water quality protection functions in the landscape. Additionally, lakeshores are very sensitive areas and some STPs could cause disturbance to and degradation of the lake ecosystem if not installed in the appropriate place on the lakeshore.

The siting of STPs may fall under the local, state, and/or federal jurisdictions. It is the responsibility of the designer to obtain any required land use permits, as this manual will not attempt to comprehensively list, explain, or duplicate their requirements. It is important, however, to recognize that the improper siting of STPs may undo the very water quality gains they were meant to achieve and that the following statutorily-required Vermont Department of Environmental Conservation (DEC or Department) programs have co-evolved with the Stormwater Program to avoid these conflicts. The following site planning guidance is included here with the goal of increasing the efficiency of the site planning process and to guide designers regarding state policies for restoring and protecting wetlands, lake shorelands, floodplains and river corridors.

Wetlands

- The siting of STPs within wetlands or wetland buffers must meet the No Undue Adverse Impact Standard as set in the Vermont Wetland Rules by following the mitigation sequencing (VWR §9.5), the first step of which is avoidance. The mitigation sequencing requires that activities as much as possible, in sequence: avoid wetland and buffer, minimize impacts, restore short-term impacts, and compensate for the remainder of impacts.
- Non-structural STPs utilizing undisturbed natural vegetated areas for treatment, such as disconnection, may be compatible with wetland buffer functions and therefore undisturbed disconnection areas may be sited within wetland buffers.
- Many wetlands are not mapped on the Vermont Significant Wetland Inventory maps. Some indicators of wetlands are hydric soils, flood hazard zones, saturated soils, and vernal pools. Only a qualified wetland scientist may determine the absence or presence of a wetland and the boundaries for regulatory purposes. An on-site evaluation of wetlands is a necessary step before project design in order to effectively avoid wetland resources.
- It is possible that older stormwater infrastructure is located within a wetland or wetland buffer. Expansion of such infrastructure may require a Vermont Wetlands Permit, which may be obtained if the expansion is determined tonot further compromise the wetland function. Designers should have a qualified wetland scientist review the site for wetland constraints before considering expansion or modifications to existing stormwater infrastructure.

Lake Shorelands

- The Shoreland Protection Act (Chapter 49A of Title 10 §1441 *et seq.*) establishes a state regulation for guiding development within Protected Shoreland Area, encompassing land within 250 feet of the mean water level, of all lakes greater than 10 acres in size. The intent of the Act is to prevent degradation of water quality in lakes, preserve habitat and natural stability of shorelines, and maintain the economic benefits of lakes and their shorelands. For a project that proposes to create new cleared area or impervious surfaces in the Protected Shoreland Area, with some exemptions, the Shoreland Protection Act requires all shoreland owners to either register or apply for a permit from the Agency's Lakes & Ponds Management and Protection Program. Depending on the scope of the project and its proximity to the mean water level, STPs could be conditions of the permit. Non-structural STPs utilizing undisturbed natural vegetated areas for treatment, such as disconnection, may be compatible with lake shoreland buffer functions and therefore undisturbed disconnection areas may be sited within lake shoreland buffers.

Floodplains and River Corridors

- The siting of STPs within floodplains and rivers corridors must meet the No Adverse Impact Standard as set in the DEC Flood Hazard Area and River Corridor Protection Procedure (FHARCPP, Sections 7.0(a)(1) and (2)). In summary, new STPs shall not be placed in the:
    - Floodway without certification that base flood elevations or velocities will not be increased;
    - Flood fringe without compensatory storage unless the Agency determines there to be no more than a minimal effect on floodwater storage and floodwaters are not diverted onto adjacent properties;
    - River corridor unless the River Corridor Performance Standard is achieved and new or future channel management would not be required to protect it from erosion.
- Specific to non-structural STPs that are comprised of natural vegetation, such as disconnection, the River Corridor Performance Standard would be met when these STPs are sited within the outer 50-foot buffer component of the State River Corridor.
- Further guidance in defining, mapping, and protecting floodplains and the siting of STPs in or adjacent to floodplains and river corridors may be found in the DEC Flood Hazard Area and River Corridor Protection Procedure or by contacting the Agency's Rivers Program.
- While all but the steepest or bedrock confined streams rely on the function of adjacent floodplains to remain stable, many streams and rivers in Vermont are incised and therefore disconnected from their floodplain. In many cases, the important function of these abandoned floodplain areas are not accurately captured by FEMA floodplain maps. Most Vermont streams are not mapped at all by FEMA. Therefore, the State has mapped river corridors for all streams and rivers to keep open not only those areas necessary for the achievement of a stable meander geometry but for the restoration of floodplains. Both of these components are essential to the achievement of least erosive, equilibrium conditions. Keeping new encroachments out of rivers corridors will protect and restore Vermont floodplains.

~~2.1.2.~~2.1.3. Optional Design Strategies for Meeting Applicable Treatment Standards on Already Developed Sites

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Introduction. Due to the wide variety of existing physical site constraints that may be present on an already developed site, control and treatment of stormwater runoff from the complete extent of proposed expanded or redeveloped impervious surfaces may not always be achievable. This Manual includes two strategies, Site Balancing and Net Reduction, that designers may use to meet the applicable treatment standards when expanding or redeveloping an already developed site.

In addition, this Manual has a subchapter specific to public transportation projects (Subchapter 6.0), which includes a suite of additional options available to this unique category of projects. Public transportation projects are often confined by right-of-way and other site constraints, but at the same time may present tremendous opportunities for maximizing stormwater treatment and control and water resource protection when given additional flexibility. The public transportation specific subchapter was developed in consideration of both state and local public transportation projects through a collaborative effort between the Agency and the Vermont Agency of Transportation.

Consultation with the Agency. Prior to applying either of the following design strategies to a project, the designer shall discuss the use of site balancing or net reduction with the Agency's Stormwater Program, in the specific context of the project under development and prior to stormwater permit application submittal. The Agency may deny a permit application if site balancing or net reduction do not provide equivalent treatment or control or present risks to water quality, in consideration of impervious surface proximity to water resources, existing site conditions, or other factors.

I. Site Balancing.

(a) Site balancing may be used for expansion and redevelopment projects, if the designer demonstrates that control or treatment of runoff from expanded or redeveloped impervious surfaces is not reasonably feasible or has marginal benefit due to site constraints.

(b) The designer shall clearly specify in the permit application that site balancing is being proposed and shall provide the required explanation and justification for its use, as outlined below.

(c) The designer shall demonstrate that treatment or control of the impervious surfaces to be expanded or redeveloped is not reasonably feasible or has marginal benefit due to physical, topographical, or environmental constraints. Examples of infeasibility include instances where control or treatment for the expanded or redeveloped impervious surfaces would require the applicant to acquire new land, pump the stormwater in question, remove existing impervious surface or other infrastructure, construct stormwater treatment or control systems in wetlands or other surface waters or riparian buffer zones, or result in other negative impacts on waters. Examples of marginal benefit include instances where control or treatment for expanded or redeveloped impervious surfaces would provide less volume reduction or water quality benefit than control or treatment of other existing impervious surfaces discharging to the same point, or to another point within the same watershed.

(d) The designer shall demonstrate that "equivalent treatment" will be achieved by:

(1) providing additional stormwater control or treatment beyond what is required for the existing impervious surfaces to be redeveloped, that is not otherwise required under an operational stormwater discharge permit; or

(2) providing additional stormwater control or treatment of impervious surfaces that is not otherwise required under an operational stormwater discharge permit; and

(3) demonstrating that the requirements for treatment or control on the impervious surfaces to be used for site balancing are equal to or greater than the treatment or control requirements on the expanded or redeveloped impervious surfaces for which treatment is not reasonably feasible.

(e) Prohibition. Non-rooftop impervious surfaces, including roads, driveways, and parking lots, shall not be balanced with treatment or control of rooftop impervious surfaces.

(f) Additional requirements.

(1) The applicant must own or control the impervious surfaces and required STPs that will be used for site balancing.

(2) Any area to be used for site balancing shall discharge to the same receiving water, or the same watershed, as the impervious surface being expanded or redeveloped. The "same receiving water" or "same watershed" shall be determined by the Agency during pre-application review, required under Section 2.1.3~~2.1.2~~ of this Rule, on a case-by-case basis.

II. Net Reduction.

(a) Introduction. Existing developed sites that pre-date modern stormwater design requirements, may present unique opportunities to greatly improve stormwater treatment and control. Expansion and redevelopment projects often involve reconfigurations of parking, drives, or buildings that can result in a net reduction in impervious surface, despite the creation or redevelopment of impervious that triggers the need for a stormwater discharge permit. A net reduction of impervious surface can have both stormwater quality and volume reduction benefits. While the Water Quality Treatment Standard applicable to redevelopment allows for credit towards removal, an overall net reduction in impervious is not specifically considered.

(b) Projects involving a combination of expansion and redevelopment that will result in a five percent or more net reduction in total resulting impervious surface, may achieve compliance with the VSMM by complying with the following alternative requirements:

(1) Expanded portions of impervious surfaces, or expanded equivalent as allowed under Site Balancing, shall be treated to achieve the Water Quality Treatment Standard, adjusted for net reduction. The percent treatment required for all expanded impervious surfaces shall be reduced by the overall percent of net impervious surface reduction. For example, a 25 percent net reduction in total resulting impervious surface, pre- vs. post-, equates to 75% WQ_V applied to expanded impervious surfaces. Under this standard, expanded impervious surfaces shall not be subject to the Channel Protection Standard, Overbank Flood Protection Standard, or Extreme Flood Protection Standard.

(2) Redeveloped impervious surfaces shall be treated, or redeveloped equivalent as allowed under Site Balancing, to achieve 50 percent of the Water Quality Treatment Standard (50% WQ_V). When using this strategy to meet treatment standards, impervious areas removed shall not be counted toward meeting the required Water Quality Treatment Standard for redevelopment.

(3) Impervious surfaces that are removed shall be subject to the Post-Construction Soil Depth and Quality Standard, as applicable.

(4) Existing impervious surfaces subject to a greater treatment and control requirement shall maintain the required level of treatment and control and shall not be used for meeting the above requirements.

(5) The areas in which impervious surfaces are removed shall discharge to the same receiving water or be located within the same watershed as the expanded or redeveloped impervious surfaces. The "same receiving water" or "same watershed" shall be determined by the Agency during pre-application review, required under Section 2.1.32.1.2 of this Rule, on a case-by-case basis.

2.2. Treatment Standards

Introduction. After consideration (guidance) of appropriate site planning and design strategies, the designer willshall select one or more stormwater treatment practices (STPs) presented in Subchapter 4.0 or, for public transportation projects, Subchapter 6.0 to meet the specified treatment standards for gGroundwater rRecharge, wWater qQuality, cChannel pProtection, oOverbank fFlood pProtection, and eExtreme fFlood cControl. In addition, the designer will need toshall design for compliance with the requirements of the Post-Construction Soil Depth and Quality Standard. 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**
Post-Construction Soil Depth and Quality Standard	Maintain or restore healthy on-site soils
Groundwater Recharge Standard	Infiltrate a portion of the post-developed runoff based on hydrologic soil group
Water Quality Treatment Standard	Treat the runoff from the 90th percentile (1.0 inch) 24-hour storm event
Channel Protection Standard	Control the post-developed runoff from the 1-year 24-hour storm by one of or a combination of the following methods: • Hydrologic Condition Method – Match the post-development runoff volume to the pre-development runoff volume from the 1 year 24-hour storm. • Extended Detention Method – Provide 12 or 24-hour detention of the 1-year 24-hour storm. • Alternative Extended Detention Method – Demonstrate that the 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 of the 1-year 24-hour storm were provided.
Overbank Flood Protection Standard	Control the post-developed peak discharge from the 10-year storm to 10-year pre-development peak rates
Extreme Flood Protection Standard	Control the peak discharge from the 100-year storm to the 100-year pre development peak rates

Under this manual, STPs are grouped in three Tiers as described in detail in Section 2.2.4.1. Tier 1 Practices that are considered to be the highest performing practices, those that provide treatment by reliance upon infiltration shall be first considered to meet the Water Quality Treatment Standard.

Because Tier 1 Practices rely upon infiltration, they also have the highest stormwater runoff reduction capability. Following consideration of Tier 1 Practices, designers may consider Tier 2 Practices, Tier 3 Practices, and existing stormwater infrastructure, in that order to meet the applicable Water Quality Treatment Standard. The details for evaluating use of priority practices is described in detail in Section 2.2.4.1. Following an evaluation for use of priority practices to meet the Water Quality Treatment Standard, the designer may consider use of all other practices for meeting all of the other STPs contained within Chapters 4.0 and 5.0, as applicable for meeting the requirements. 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 extreme flooding (see 2.2.7). Groundwater recharge typically occurs during the majority of individual storm events, those generally totaling less than 1 inch, and therefore, as depicting in Figure 2-1 are nested within the water quality storms.

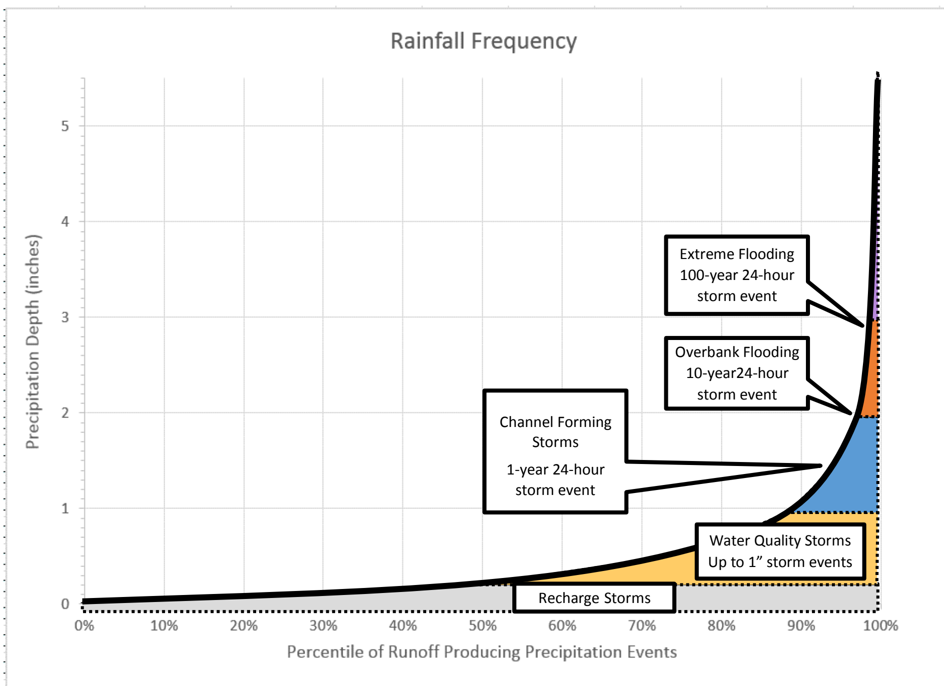

Figure 2-1. Approximate Ranges for Storms Comprising Treatment Standards Sizing Criteria

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

Commented [SE9]: Moved to Subchapter 4

~~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 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 can be lost when development removes native vegetation, removes or compacts native soil, and replaces it with minimal topsoil or 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 healthy soil quality plays in water quality issues, this ~~m~~Manual establishes a mandatory Post-Construction Soil Depth and Quality standard designed to retain greater stormwater functions in the post-development landscape, provide increased treatment of pollutants and sediments that result from development, 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 on slopes less than or equal to 33% 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. The details and requirements of the Post-Construction Soil Depth and Quality Standard are presented in ~~Sections~~Subchapter 0.

2.2.2. Runoff Reduction Framework

All of the treatment standards described in this ~~m~~Manual, with the exception of the Post-Construction Soil Depth and Quality Standard, may be met wholly or partially ~~by~~through 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~~may be assessed in terms of the treatment volume (T_v) credit that can be calculated for each STP that provides some level of runoff reduction. T_v credit is essentially a stormwater volume that can be applied to all treatment standards. Table 2-2 lists the STPs ~~that can receive~~eligible for 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 (unlined)	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~~are not eligible for T_v credit and cannot be used to meet the Groundwater Recharge Standard. Furthermore, structural STPs that do not infiltrate at least the calculated recharge volume (Re_v) do not meet the Groundwater Recharge Standard as detailed in Section 2.2.3. However, these practices may be able to meet some or all of the remaining standards through alternative methods. The methods for meeting each treatment standard are described in the sections that follow. Methods for calculating the credit ~~of~~for each practice ~~is~~are described in ~~Chapters~~Subchapter 4.0.

2.2.3. Groundwater Recharge Standard (Re_V)

To comply with the Groundwater Recharge Standard, 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 volume (Re_v) is determined as a function of annual pre-development recharge for a given soil group, average annual rainfall volume, and amount of impervious cover at a site. The calculated Re_v shall be infiltrated or disconnected using practices acceptable for meeting the Groundwater Recharge Standard.

A list of practices acceptable for meeting the Groundwater Recharge Standard is presented in Table 2-3; all practices are described in detail in ~~Chapters~~Subchapter 4.0~~ of this manual~~. All STPs that meet the Groundwater Recharge Standard may receive T_v credit towards subsequent standards through the runoff reduction framework, specifically the Hydrologic Condition Method of the Channel Protection Standard described in Section 2.2.5.1.

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 volume isshall be calculated as follows:

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

where:

Re_v = Recharge volume (acre-feet)

F = Recharge factor (dimensionless), see **Error! Reference source not found.**

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 volume shall be calculated separately for each drainage area. Re_v is nested within the water quality volume (WQ_v) and therefore can be credited toward the water quality volume and provides T_v credit toward all other applicable treatment standards.

The Groundwater Recharge Standard shall be waived for:

- Site drainage areas where stormwater runoff contributes fromcomes in contact with a hotspot land use or activity (, as described in Section 2.3).
- Site drainage areas comprised entirely of HSG D soils.

The Groundwater Recharge Standard may also be waived, prohibited, or otherwise restricted within certain areas, ~~such as~~including groundwater source protection areas~~,~~ within specified proximity to groundwater supply sources, wastewater disposal systems, or where features may exist such as karst topographic areas or areas of documented slope failure. Requirements and restrictions for the siting of structural infiltrating STPs are detailed in ~~Cs~~Subchapter 4.0~~ and designers must identify the location of groundwater source protection areas, groundwater supplies, and wastewater infrastructure, relative to any proposed infiltrating STPs~~. Designers are also advised to consult with the Agency's Drinking Water and Groundwater Protection Division for all applicable restrictions.

2.2.4. Water Quality Treatment Standard (WQTS)

~~The objective of~~Except for redevelopment which shall comply with Section 2.4, to comply with 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, shall be captured and treated. This runoff contains the majority of pollutants.

The following equation shall be used to determine the water quality volume (WQ_v) 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)

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 shall be treated with ~~stormwater treatment practice (~~STP~~)~~s in accordance with Section 2.2.4.1~~ of this manual~~.
- The ~~recharge volume (~~Re_v~~)~~ is contained within the WQ_v and shall be count~~s~~ed towards the ~~water quality standard~~WQTS in the drainage area where it is provided.
- The sizing of water quality STPs shall be based on the drainage area contributing 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~~surfaces draining to them.

- If off-site runoff is rerouted, the designer ~~must~~shall ensure that such rerouting will not cause erosion or flooding problems in the area where the water is discharged.

2.2.4.1. Water Quality Practice Selection

Commented [SE10]: Section added

(a) Practices for meeting the WQTS are divided in this Manual into Tier 1, Tier 2, and Tier 3 Practices. The STPs have been organized by order of design preference, and based upon pollutant removal efficiencies and potential for runoff reduction; with Tier 1 Practices providing the greatest degree of water quality treatment and runoff reduction and Tier 3 Practices providing the minimum required level of water quality treatment and runoff reduction.

(b) Designers shall use permit application materials provided by the Agency when evaluating what tier of STPs shall be used on a site and shall certify in the permit application to the evaluation and analyses, and, if required, justification that they provide pursuant to the requirements of this Section 2.2.4.1.

(c) When no STPs already exist on a site, the designer shall first evaluate use of Tier 1 STPs, pursuant to permit application requirements. If, based upon completion of the permit application materials, use of Tier 1 STPs is not possible or is infeasible, then the designer shall evaluate use of Tier 2 Practices. Tier 3 Practices may only be used if Tier 1 STPs cannot be used and the designer provides a detailed justification for why Tier 2 Practices cannot be used. The designer's detailed justification shall explain the site or design constraints that require use of Tier 3 Practices; cost may not be used as a justification.

(d) When an STP already exists on a site, and the designer proposes to use the pre-existing STP, the designer shall evaluate whether the STP can be modified in-line or off-line of pre-existing infrastructure to meet the Tier 1, 2, or 3 Practice pollutant reduction levels. If the pre-existing STP can be modified, the STP shall be modified to the highest Tier pollutant reduction level that the STP can accommodate. If the pre-existing STP cannot accommodate modifications to meet 2017 STP design requirements, but the STP meets the 2002 Manual STP design requirements, and is identified as an acceptable STP for meeting the WQTS in the 2017 VSMM, then the project shall continue implementing the pre-existing STP. The 2002 STP shall be modified, if necessary, to accommodate applicable treatment standards for new and redeveloped impervious surfaces. If the pre-existing STP cannot accommodate modifications and does not meet the STP design requirements of the 2002 VSMM, then the designer shall follow the STP evaluation process in 2.2.4.1(c).

Tier 1 Practices

Tier 1 Practices are the practices that can be designed to provide water quality treatment and infiltrate the water quality volume (WQ_V), and include practices such as infiltration basins, unlined bioretention cells, and other practices that treat and infiltrate stormwater runoff. These practices, when properly constructed and maintained, are expected to achieve the highest pollutant removal and runoff reduction of all the practices identified in this Manual; generally exceeding 80% TP and 98% TSS removal (USEPA BMP Performance Curves, National Stormwater Database, International Stormwater Database). In addition, T_V credit towards the Hydrologic Condition Method (HCM) under the Channel Protection Standard is equivalent to the volume of stormwater infiltrated, which can exceed the WQ_V when designed to accommodate larger volumes. Infiltration feasibility and soil testing requirements for infiltrations are specified in Section 0.

Tier 1 Practices[1]
Infiltration Basins, Trenches, Chambers
Dry Wells
Unlined Bioretention
Unlined Dry Swales
Unlined Filters
Simple Disconnection
Disconnection to Filter Strip or Vegetated Buffer
[1] These STPs generally exceed 80% TP removal and generally achieve 98% TSS removal, and the T_V credit equivalent to volume infiltrated. (USEPA BMP Performance Curves, National Stormwater Database, International Stormwater Database)

Tier 2 Practices

When infiltration is not possible or is infeasible, a designer shall evaluate use of Tier 2 Practices to meet the WQTS. Tier 2 Practices include high performance practices, such as gravel wetlands and lined bioretention cells that may provide a sump with stormwater storage at the base of the practice. These practices will often be lined and underdrained due to a high seasonal groundwater table, hotspot land uses, or other design limitations. These practices, when properly constructed and maintained, are expected to achieve a high pollutant removal rate ranging from 60%-80% TP and 80-97% TSS removal (USEPA BMP Performance Curves, National Stormwater Database, International Stormwater Database).

Tier 2 Practices[2]
Lined Bioretention
Gravel Wetlands
[2] These STPs generally meet 60-80% TP removal and generally achieve 80-97% TSS removal, and the T_V credit equivalent to volume stored below the sump/underdrain. (USEPA BMP Performance Curves, National Stormwater Database, International Stormwater Database)

Tier 3 Practices

If a site or project design cannot accommodate the Tier 1 or Tier 2 Practices specified above because of site or design constraints, but excluding costs, then a designer may use Tier 3 Practices to meet the WQTS. Tier 3 Practices include lined dry swales, lined filters, wet ponds, and shallow surface wetlands. These practices, when properly constructed and maintained, are expected to achieve a pollutant removal rate ranging from 50-60% TP and approximately 80% TSS removal (USEPA BMP Performance Curves, National Stormwater Database, International Stormwater Database)..

Tier 3 Practices[3]
Lined Dry Swales
Lined Filters
Wet Ponds
Shallow Surface Wetlands
[3] These STPs generally meet 50-60% TP removal and achieve 80% TSS removal, and the T_V credit is equivalent to volume stored below the sump/underdrain, if applicable. (USEPA BMP Performance Curves, National Stormwater Database, International Stormwater Database)

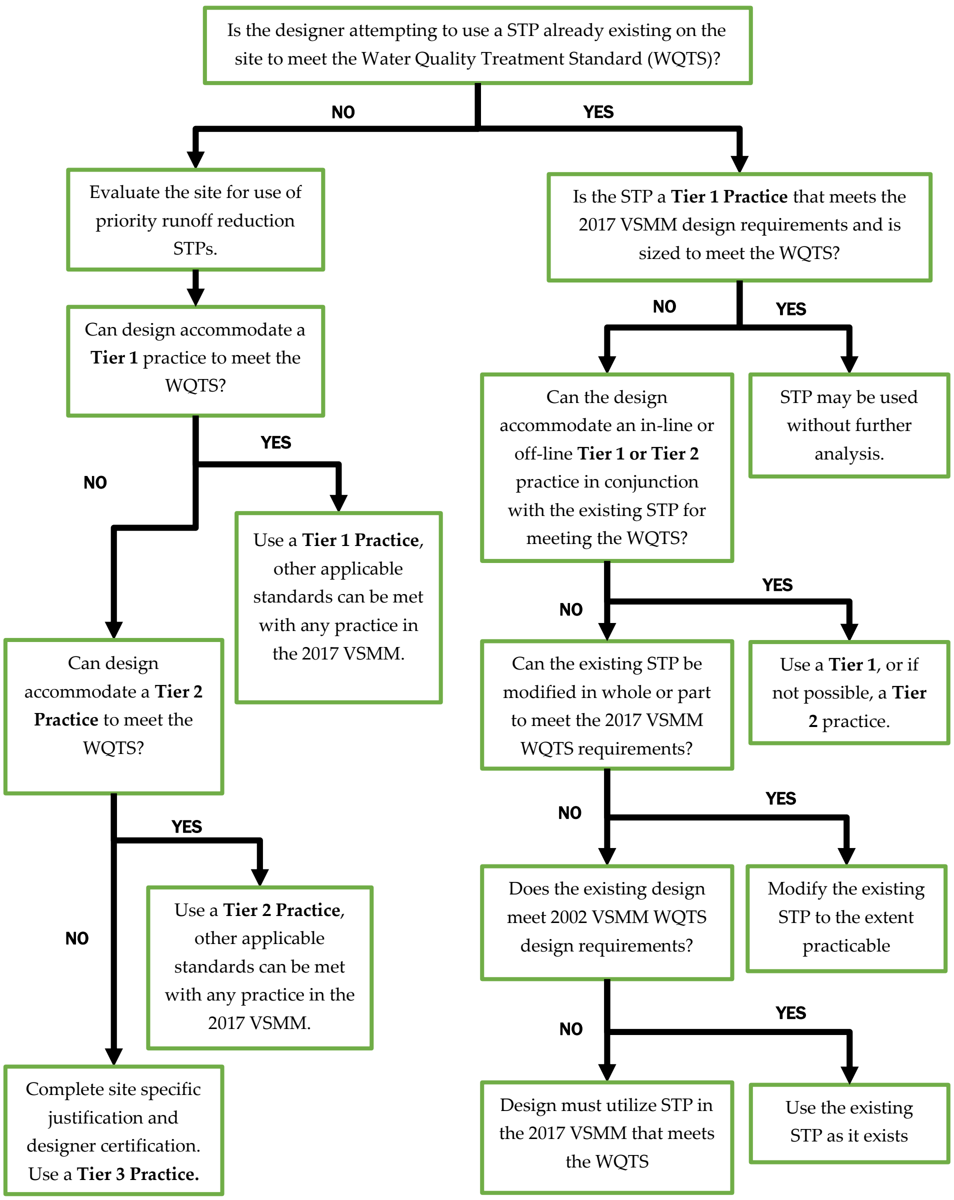

Figure 2-2: STP selection flowchart for Water Quality Treatment Practices

2.2.4.2. Water Quality Peak Flow Calculation

The peak rate of discharge for the water quality design storm (1 inch, 24-hour storm event) is neededrequired for the sizing of rate based treatment practices and off-line diversion structures. Conventional United State Department of Agriculture (USDA) 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 inches.

In order tTo 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 design storm, 1")
Q_a = runoff volume, in inches (equal to WQ_v ÷ area)

The calculated CN canshall be used to estimate the peak discharge rate of the water quality storm using a computer aided hydrologic model (TR-20 or an approved equivalent). Time of concentration shall be computed pursuant to Section 2.2.4.3.

2.2.4.3. Time of Concentration

Commented [SE11]: Moved from channel protection

To calculate peak rates for compliance with the requirements of this Manual, the time of concentration (T_c) shall 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 (hours)

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 flow path 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) may be determined a number of ways, including in AutoCAD, ArcGIS, or by the following relation:

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

where:

C = contour length (feet)

I = contour interval (feet)

Contour length (C) means the total length of all contour lines within the catchment, including all closed contours, as directly measured from a plan sheet.

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 shall 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 feet of sheet flow in the total flow path length.

2.2.5. Channel Protection Standard

~~It is not only t~~The pollutant load transported by stormwater runoff from the developed landscape ~~that has a~~ is not the only deleterious impact that stormwater has on receiving streams. Management of stormwater is also necessary to protect stream channels from scour and erosion.

~~Management of~~To comply with the Channel Protection Standard, the ~~one~~1-year, 24-hour storm ~~event is required for the protection of~~shall be managed to protect stream channels from the changes in timing, runoff volume, and peak flow rate of stormwater runoff that occurs as the result of development activities.

In Vermont the 1-year, 24-hour rainfall ranges between 1.8 and 3.0 inches (NOAA, Atlas 14, 2015). For purposes of compliance with the Channel Protection Standard, rainfall values from NOAA Atlas 14, or its replacement, shall be used unless specific data are available for a particular site location and prior approval has been obtained from the Agency.

The Channel Protection Standard shall be satisfied using the Hydrologic Condition Method, the Extended Detention Method, the Alterative Extended Detention Method, or by some combination of these methods. The Hydrologic Condition Method (HCM) and the Extended Detention Method are described in the following subsections, followed by the Alternative Extended Detention Method. For projects that will use distributed and non-structural treatment for the majority of a site, a designer may elect to use the Alternative Extended Detention Method to satisfy the Channel Protection Standard as identified in Section 2.2.5.4.

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~~discharge" ~~is~~means 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, however the overall common plan of development ~~is~~shall 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.

For a project that has more than one discharge point and that discharges to different receiving waters, ~~W~~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~~.~~uare miles.

2.2.5.1. Hydrologic Condition Method

The Hydrologic Condition Method (HCM) is ~~intended~~used to determine a suite of practices, including the mandatory post-construction Soil Depth and Quality Standard, which, when implemented, will approximate runoff characteristics of "woods in good condition" for the ~~one~~1-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.~~

Commented [SE12]: Moved to the Channel Protection Section

The ~~Hydrologic Condition Method (~~HCM~~)~~ is based on the curve number (CN) hydrology method developed by the ~~United States Department of Agriculture (~~USDA~~) Natural Resources Conservation Service (~~NRCS~~)~~. The hydrologic condition ~~treatment~~ volume (HCv) is the difference between the pre-development and post-development site runoff for the 1-year, 24-hour storm.

To comply with the HCM in acre-feet, ~~T~~the following equation shall be used to determine the ~~treatment volume~~HCv ~~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 ~~R~~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 2-5. 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
Woods in Good Condition	30	55	70	77

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

~~The Hydrologic Condition Method is met~~Compliance with the HCM shall be achieved 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~~HCM is presented in Table 2-6; all practices are described in detail in ~~C~~Subchapter 4.0 of this ~~m~~Manual.

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

Type	Practice	Crediting Notes
Non-Structural	Reforestation	
	Simple Disconnection	
	Disconnection to Vegetated Buffer or Filter Strip	
Structural	Infiltration Trenches/Basins/Chambers	
	Permeable Pavements	
	Sand Filter (unlined)	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 (unlined)	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 (unlined)	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	

Commented [SE13]: These

More information on how practices are credited toward the HCM is provided in the individual practice standards presented in ~~C~~Subchapter 4.0.

2.2.5.2. Extended Detention Method

For those sites where the practice or suite of practices ~~is insufficient to achieve the~~under the HCM are insufficient to achieve compliance with the Channel Protection Standard, additional STPs may need to be implemented to protect stream channels from degradation.

To comply with the Extended Detention Method, ~~S~~storage of the channel protection volume (CPv) shall be provided by means of extended detention (ED) storage for the ~~one~~1-year, 24-hour rainfall event. Extended detention time shall only be required down to the ~~one (~~1~~)~~ inch minimum orifice size. As noted previously, the ~~c~~Channel ~~p~~Protection Standard 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~~shall be provided, and if a stormwater discharge is to a warm water fish habitat, 24 hours of extended detention ~~is required~~shall be provided. Cold water fish habitats and warm water fish habitat designations are listed in the Vermont Water Quality Standards, Appendix A.

In evaluating a site for channel protection ~~by~~through 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 model~~s TR-55 and~~ TR-20 ~~(~~, or approved equivalent~~)~~, ~~will~~shall be used for determining peak discharge rates, and for routing detention ponds.
- Time of concentration (T_c) shall be computed pursuant to Section 2.2.4.3 of this Manual.
- Pursuant to Section 2.2.5.3, ~~A~~adjusted curve numbers ~~should~~shall 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~~shall 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 "existing condition" for the ~~one~~1-year storm event.
- Orifices less than ~~three~~3 inches shall be protected from clogging. The minimum allowable orifice size is ~~one (~~1~~)~~ inch.

2.2.5.3. Calculating Adjusted Curve Numbers

When the Channel Protection Standard is partially met ~~by the hydrologic condition method~~through the HCM, an adjusted CN ~~will need to~~shall be calculated for the project site. The adjusted CN (CN_{adj}) ~~is~~shall then be used to demonstrate compliance with the ~~c~~Channel ~~p~~Protection ~~s~~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 practice~~s~~, in acre-ft

The cumulative treated volume ~~should~~shall 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~~shall then be calculated as:

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

An adjusted CN for the impervious area ~~can~~shall 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~~1-year, 24-hour storm. For Q_{P10} and Q_{P100}, the ~~ten~~10-year and 100-year, 24-hour storm events ~~must~~shall 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 structural STPs ~~and/~~or other non-structural STPs for the majority of a site, a designer may elect to use the Alternative Extended Detention Method to satisfy the Channel Protection Standard.

~~In this case~~To comply with the Alternative Extended Detention Method, the designer shall demonstrate that the ~~one~~1-year 24-hour 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~~shall 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 24-hour storm event 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 compared to the site~~-~~-wide post-treatment ~~one~~1-year 24-hour storm peak outflow rate.

By demonstrating thatIf the post-development site with all proposed treatment produces a peak one1-year flow rate that is less than thise hypothetical pond peak outflow rate, the site willshall be presumed to meet the Channel Protection Standard.

2.2.5.5. Time of Concentration

Commented [SE14]: Moved to Water Quality section.

In order tTo calculate peak rates for compliance with the Extended Detention and flow attenuation standardsrequirements of this Manual, the time of concentration mustshall 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 flow path 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) canmay 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) ismeans the total length of all contour lines within the catchment, including all closed contours, as directly measured from a plan sheet.

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 willshall 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 feet. of sheet flow in the total flow path length.

2.2.6. Overbank Flood Protection Standard (Q_{P10})

To comply with the 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.

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.

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, shouldshall 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), willshall be used for determining peak discharge rates, and for routing detention ponds.
- Time of concentration (T_c) shall be computed pursuant to Section 2.2.4.3 of this Manual.
- The standard for characterizing pervious pre-development land use for on-site areas shall be "woods in good condition." Existing impervious may be characterized as impervious in the pre-development condition.
- Off-site areas shouldshall at a minimum be modeled as "existing condition."

- Safe passage of the 100-year, 24-hour storm event shall be provided for off-site areas that drain to the STP.
- ~~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 NOAA 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~~ Compliance with the ~~o~~Overbank ~~f~~Flood ~~p~~Protection Standard shall ~~be waived~~not be required if:

- A site ~~discharges~~ directly discharges to a 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~~reservoir, lake, or stream with a drainage area greater than or equal to 10 square miles; or
- ~~-~~A downstream analysis is completed ~~(see~~, pursuant to Section 2.5~~)~~, that indicates overbank flood control is not necessary for the site.

2.2.7. Extreme Flood Protection Standard (Q_{P100})

To comply with the Extreme Flood Protection Standard, ~~T~~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.

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.

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 model~~s TR-55 and~~ TR-20 ~~(~~, or approved ~~local~~ equivalent~~)~~, ~~will~~shall be used for determining peak discharge rates, and for routing detention ponds.
- Time of concentration (T_c) shall be computed pursuant to Section 2.2.4.3 of this Manual.
- The standard for characterizing pre-development land use for on-site areas shall be "woods in good condition." Existing impervious may be characterized as impervious in the pre-development condition.
- Off-site areas ~~should~~shall at a minimum be modeled as "existing condition."
- Safe passage of the 100-year 24-hour storm event shall be provided for off-site areas that drain to the STP.

- ~~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 NOAA 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~~Compliance with the ~~e~~Extreme ~~f~~Flood ~~control~~Protection Standard shall ~~be waived~~not be required 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~~in~~ a common plan of development ~~(~~, constructed after 2002~~)~~, is less than 10 acres; or
- A downstream analysis is completed ~~(See~~, pursuant to Section 2.5~~)~~, that indicates extreme flood control is not necessary for the site.

2.3. Stormwater Hotspots

~~A s~~Stormwater hotspots ~~is defined as a land use or activity that~~ generate~~s~~ higher concentrations of hydrocarbons, trace metals, ~~or~~and toxicants than are found in typical stormwater runoff~~, based on monitoring studies~~. ~~If a site, or a specific drainage area at a site, is designated as a hotspot, it may have implications for how stormwater is managed on the site. In addition, the Agency's Underground Injection Control (UIC) Rules prohibit infiltration of wastes, including stormwater runoff from certain activities.~~ Petroleum distribution centers, hazardous material loading~~/~~ and storage facilities, and other industrial sites may include drainage areas ~~considered to be~~that are stormwater hotspots. Hotspots may also include 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. Designers are encouraged to contact the Agency's Waste Management and Prevention Division in advance of proposing infiltration at a contaminated site prior to application submittal.

To prevent pollution of groundwater resources, ~~S~~stormwater runoff ~~contributing from~~that comes in contact with a hotspot ~~drainage areas~~ shall not ~~utilize a~~be treated with structural or non-structural ~~stormwater treatment practice (~~STP~~)~~s that reli~~es~~y upon infiltration ~~to meet applicable stormwater treatment standards. These STPs~~, include~~e~~ing infiltration basins, infiltration trenches, infiltration storage chambers, dry wells, unlined bioretention practices, unlined dry swales, unlined filters, and disconnection. ~~Other STPs not included within this manual may be reviewed by the Agency on case by case basis.~~

~~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.. Designers are encouraged to contact the Agency's Waste Management and Prevention Division in advance of proposing infiltration at a contaminated site prior to application submittal.~~

~~In drainage areas where infiltration is not appropriate, the~~To treat stormwater that comes in contact with a hotspot, other STPs identified in ~~the VSMM can~~this Manual may be used ~~as long as~~if they are lined (e.g., lined bioretention areas) when necessary. The intent of this section is to to reasonably prevent pollution from entering groundwater resources.

Many industrial sites are also subject to NPDES (National Pollutant Discharge Elimination System) Stormwater Multi-Sector General Permit (MSGP) coverage and these sites often include hotspot land uses and activities that areconsidered to generate higher potential pollutant loads and therefore may not be allowed to infiltrate stormwater runoff from these areas. Prior to incorporating stormwater infiltration STPs 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 drainage area would be identified as ais a hotspot land use or activity.

2.4. Redevelopment

This sSection establishes treatment standards 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 mManual affordsprovides redevelopment projects with additional flexibility in implementing STPs to meet the applicable standards.

Redevelopment is defined in 10 V.S.A. 1264, and applicable Stormwater Management Rules, and is included in the glossary of this manual. For areas of redevelopment, except for redevelopment of public transportation projects subject to Subchapter 6.0, the Water Quality Treatment StandardWQTS applies, whereby eitheris:

- The existing impervious surface area shall be reduced by 25% and restored to meet the Post-Construction Soil Depth and Quality Standard (, Section Subchapter 0), where applicable; or
- A STP or STPs shall be designed to capture and treat 50% of the WQ_V from the redeveloped impervious surface area; or
- A combination of water quality volume treatment (WQ_V) and impervious surface area reduction proportional to the aboveforegoing options isshall be provided.; reduction equal to 50% of the WQ_V where one percent of impervious reduction is equivalent to two percent of WQ_V, using the following equation.

$$WQ_{VR} = (50 - 2 \times I_{Reduced}) \times WQ_V$$

Where:

WQ_{VR} = Water quality volume for redeveloped site

$I_{Reduced}$ = Existing impervious reduced (%)

; or

- Redevelopment projects may consider use of other design strategies, including Site Balancing and Net Reduction pursuant to Section 2.1.3 of this Manual.
- If none of the aboveforegoing options are practicaltechnically feasible, 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 for

Tier 3 Practices in Section 2.2.4.1, provided designers have first justified the inability to utilize the acceptable Tier 1, Tier 2, and Tier 3 Practices, in that order, for meeting the Water Quality Treatment Standard as established in Section 2.2.4.1 of this manual. In such cases, it will be the responsibility of the designer toshall document, pursuant to the Section 4.4 documentation requirements, the site constraints or limitations and expected pollutant removal for any proposed alternative STP. Designers should refer to Alternative Design STPs (Section 4.4) in this manual for documentation requirements. This approach will not allow for higher performing practices, including those identified as Tier 1 through Tier 3 Practices, or approved equivalent to be use to "offset" treatment not provided elsewhere on site. Under this approach, Tier 1 through Tier 3 Practices and approved equivalent treatment required elsewhere on a site shall not be used to "offset" treatment that cannot be provided for redevelopment. The Agency reserves the right to not allow this approach where treatment and/or control is deemedProposed alternatives shall be subject to Agency approval. If the Agency determines that a proposed alternative will not provide inequivalent pollutant reduction and/or presents greater risks to water quality, in consideration of impervious surface proximity to water resources, existing site conditions, or other factors, the Agency shall deny the proposed alternative.

2.5. Downstream Analysis for Q_{P10} and Q_{P100}

Depending on the shape and land use of a watershed, it is possible that the upstream peak discharge may arrive at the same time a downstream structure is releasing its peak discharge, thus increasing the cumulative peak discharge Figure 2-3. 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.

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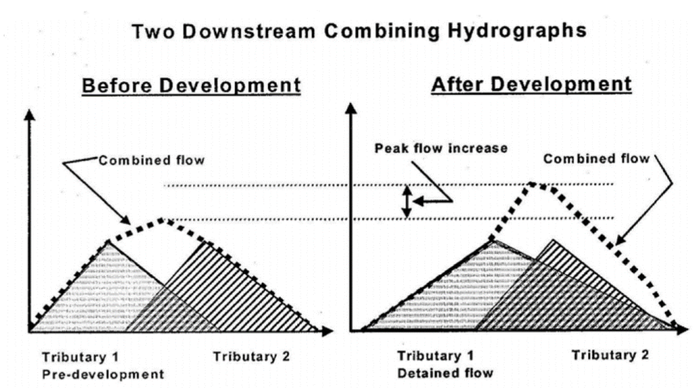

Figure 2-3: Graphical Depiction of Coincident Peak Phenomena (ARC, 2001)

A downstream analysis isshall be required when deemed appropriatenecessary by the Agency (e.g., known drainage problems; known flooding conditions) or, as required by the Overbank Flood Protection Standard (Section 2.2.6), or as required 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 2-7 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~~shall 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~~shall 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 Q_{P10} and Q_{P100}) without detention increase by less than 5% from the present condition, or as otherwise required by

Table 2-7 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 2-7 above, the designer ~~must~~shall 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.

Special caution ~~should~~shall be ~~employed~~used ~~where~~when the analysis shows that no detention structure is required. ~~Stormwater d~~Designers ~~must be able to~~shall 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 requireshall include, at a minimum, 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., and Aa 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 identificationying 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 stormwater runoff at the point of the 10% rule.

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

   a. Table 2-7 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 stormwater runoff at the point of the 10% rule.

   a. **If flows and velocities increase by less than 5%** at the analysis point, or as otherwise required by

   a.b. Table 2-7 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.

c. **If flows and velocities increase by 5% or greater** at the analysis point, or as otherwise required by

b. d. Table 2-7 above, then the designer mustshall 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 aboveTable 2-7, AND satisfyshall comply with Step 2.(a).(i) above.

3.0 POST-CONSTRUCTION SOIL DEPTH AND QUALITY

Introduction. 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.

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

To comply with the Post-Construction Soil Depth and Quality Standard, a project shall meet the requirements of this Subchapter 3.0.

Post-Construction Soil Depth and Quality Design Summary

Criteria	Element	Requirements
Feasibility	Slope	Less than or equal to 33% (3:1) Standard may be adjusted where existing mapped soils have less than 4 inches of naturally occurring topsoil
	Contributing Drainage Area	Applies to all site areas not covered by impervious surfaces, incorporated into a structural stormwater treatment practice, or engineered as structural fill or slope. .Required on fill soils and disturbed areas used for disconnection
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 104% 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 48 inches except where tree roots limit amendment incorporation or mapped soils show less than 4 inches of top soil. 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. Areas that are excluded from the standard shall be modeled in "poor condition" for the corresponding land cover.
Other	Vegetation and Landscaping	The Ssite specific plan for soil management during construction must be provided. plan shall identify all areas subject to the standard, and identify methods that the contractor may use to meet the standard, including construction details and notes. 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 (**Error! Reference source not found.**Table 3-1). Post-construction iInspection shall be completed prior to planting.
	Maintenance	General landscaping maintenance and annual inspections.

Key Elements
Feasibility: ▪ Applies to all disturbed areas within the site not covered by impervious surfaces, structural stormwater treatment, or engineered fill. ▪ Applies to slopes are ≤ 33% ▪ Areas subject to significant foot or vehicle traffic shall be modeled as "open space in poor condition"
Treatment: ▪ Retain duff layer and native topsoil to the maximum extent possible. ▪ Topsoil layer shall have a minimum organic matter content of 4% and depth of 4 inches, unless native mapped soils are less according to NRCS Official Soil Series Descriptions.
Treatment Options: ▪ **Option 1:** Leave native soils undisturbed and uncompacted during construction ▪ **Option 2:** Amend existing soils in place to meet depth and organic matter requirements. Till or scarify soils to a total depth of 8 inches. ▪ **Option 3:** Remove or stockpile existing soils and amend to meet depth and organic matter requirements. Scarify or till 4 inches of subsoil. Replace amended stockpiled soils prior to planting. ▪ **Option 4:** Scarify or till 4 inches of subsoil. Import topsoil to meet the depth and organic matter requirements.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the standard to be met.

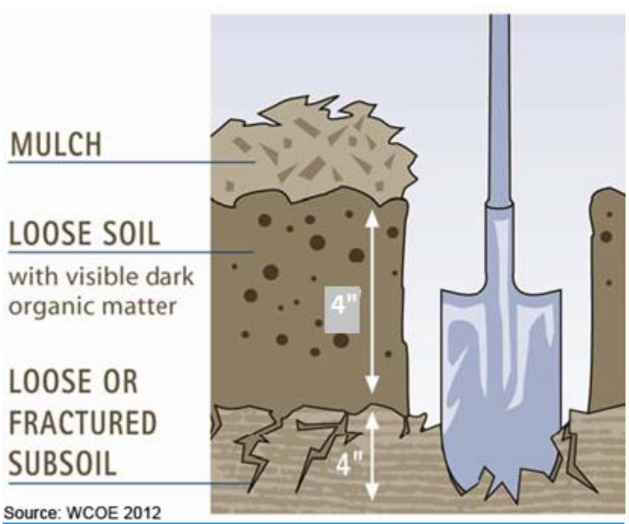

Figure 3-1. Typical Section, Verifying Post-Construction Soil Depth and Quality Using a Test Hole. Test holes should be about ~~one foo~~ 8 inches~~t~~ deep (after first scraping away any mulch) and about one ~~-~~foot square.

3.1. 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 ~~s~~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.
- The practice may be adjusted to reflect the mapped topsoil depth for soils that do not naturally have 4 inches or more of topsoil as indicated on the NRCS Official Soil Series Descriptions for the mapped soil types. In these cases, a copy of the Official Soil Series Description shall be included with the application. However, the practice standard of 4 inches shall apply on sites with fill soils that have replaced native soils, and sites where native topsoil was removed, regardless of whether or not existing soils ha~~d~~ve less than 4 inches of topsoil.
- Areas subject to significant regular foot or vehicle traffic may be waived from compliance with th~~e~~is ~~s~~Standard, but designers shall model the area in question as "open space in poor condition" rather than as "open space in good condition." ~~.~~ These areas ~~must~~shall be clearly identified on the plan

sheet. ~~Use of~~Requests for such ~~a~~ waivers ~~will~~shall be ~~determined~~reviewed on a case-by-case basis and ~~will be~~ subject to Agency approval.

- The ~~designation~~identification of areas exempt from the standard ~~as~~because of structural fill ~~or slope~~ shall be at the designer's discretion based on their best professional judgement, but will require certification that such areas are not able to meet th~~e~~is ~~s~~Standard. Areas exempt from the ~~s~~Standard ~~for this reason will not be available for~~because of structural fill ~~or slope~~ shall not be used as disconnection areas under Simple Disconnection or Disconnection to Filter Strips and Vegetated Buffers.

3.2. 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 topsoil shall be removed and stockpiled on site in a designated, controlled area, at least 50 feet. 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 structural STP or engineered as structural fill or slope shall, and that are less than or equal to 33% slope at project completion,~~ the Standard shall demonstrate the following:

- A topsoil layer with a minimum organic matter content of 4% dry weight in planting beds and turf areas. The topsoil layer shall have a minimum depth of 4 inches, except where tree roots limit the depth of incorporation of amendments needed to meet the criteria or where native mapped soils indicate less than 4 inches of naturally occurring topsoil on an NRCS Official Soil Series Description~~s~~. In th~~e~~ose cases in which native mapped soils indicate less than 4 inches of naturally occurring topsoil, restored top soil depth shall match that indicated on the NRCS Official Soil Series Description.

- ~~Subsoils below the topsoil layer shall be scarified to a depth of at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.~~

- Compost and other materials shall be used that meet the~~se~~ following organic content requirements:
    - The compost or other materials shall have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.
        - ~~The organic content for "pPre-approved" amendment rates can be met only using compost that~~If compost meets the definition of "compost" in the Agency's ~~Vermont~~ Solid Waste Management Rules, the compost's amendment rate shall be "pre-approved," and no further demonstration shall be required ~~§6-1102. This rule is available online at: http://dec.vermont.gov/sites/dec/files/documents/dec-solid-waste-management-rules-2012-03-15.pdf~~
        - ~~The compost must also have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.~~

- If compost or other materials do not meet the definition of "compost" in the Agency's Solid Waste Management Rules, the designer shall demonstrate that the compost or other materials shall comply with the required amendment rate and meet the contaminant standards in the Vermont Solid Waste Management Rules §6-1104(g)(6-7), §6-1105(e)(8-9), and §6-1106(e)(7-9). Calculated amendment rates may be met through use of composted materials that meet the aboveforegoing requirement;, Compost or other organic materials may be amended to meet the carbon to nitrogen ratioforegoing requirements, and. Such materials shall also meeting the contaminant standards ofin the Vermont Solid Waste Management Rules §6-1104(g) (6-7), §6-1105(e)(8-9), and §6-1106(e)(8-9).

  - Class A Biosolids may be used as a soil amendment, at a maximum proportion of 35% of the total soil volume, and shall be well mixed with existing soil before or during application.

- The resulting soil shall be conducive to the type of vegetation to be established.
- The soil quality requirements listed above canshall be met by using one or a combination of the following methods:

Commented [SE16]: The table previously under construction sequencing was merged with this list.

  - Option 1: Leave undisturbed native vegetation and soil, and protect from compaction during construction. 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. **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 in place either at default "pre-approved" rates, or at custom calculated rates based on tests of the soil and amendment.
    - Scarify or till subsoils to 4 inches of depth or to depth needed to achieve a total depth of 8 inches of uncompacted soil after calculated amount of amendment is added. Except for within the drip line of existing trees, the entire surface shall be disturbed by scarification.
    - Amend soil to meet organic content requirements:
      - PRE-APPROVED RATE: Place 1 inch of composted material and rototill into 3 inches of soil, or
      - CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of soil needed to achieve 4 inches of settled soil at 4% organic content.
    - Rake beds to smooth and remove surface rocks larger than 2 inches in diameter.
    - Water or roll to compact soil in turf areas to 85% of maximum dry density.
  - Option 3: StockpileRemove and stockpile existing topsoil during grading;.
    - sStockpile itsoil on site in a designated controlled area, at least 50 feet from surface waters, wetlands, floodplains, or other critical resource areas;.

- -Scarify or till subgrade to a depth of 4 inches. Except for within the drip line of existing trees, the entire surface shall be disturbed by scarification.
- and replace itthe topsoil, where feasible, prior to planting. Stockpiled topsoil mustshall 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.content requirements:
  - –PRE-APPROVED RATE: Compost shall be incorporated into the topsoil at a ratio 1:3, or
  - CALCULATED RATE: Incorporate composted material or approved organic material at a calculated rate to achieve 4 inches of settled soil at 4% organic content.
- Replace stockpiled topsoil prior to planting.
- Rake to level, and remove surface rocks larger than 2 inches in diameter.

- Option 4: Import topsoil mix of sufficient organic content and depth to meet the requirements.
  - Scarify or till subgrade to a depth of 4 inches. Except for within the drip line of existing trees, the entire surface shall be disturbed by scarification.
  - Place 4 inches of imported topsoil mix on surface. The imported topsoil mix shall contain 4% organic matter. Soils used in the mix shall be sand or sandy loam as defined by the USDA.
  - Rake beds to smooth and remove surface rocks larger than 2 inches in diameter.
  - Water or roll to compact soil in turf areas to 85% of maximum dry density.
  - 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.

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

Required Elements:

- A site--specific plan for soil management must be provided, that":
  - Identifies areas on the site subject to the sStandard;
  - Includes construction details and notes on the various methods the contractor couldmay use to meet the sStandard. Soil depth and quality shall be established towards the end of construction and once established, protected from compaction, such as from large machinery, vehicle traffic, and from erosion,; and;
  - Includes instructions for contractor verification of the sStandard, including a sampling scheme, for verification by the contractor;, that includes 9nine 8-inch deep test locationsholes per acre of area subject to sStandard. Test holes shall be excavated using

only a shovel driven solely by inspector's weight and shall be at least 50 feet apart from each other.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 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.

3.4. Post-Construction Soil Depth and Quality Construction Sequencing

Required Elements:

- Establish sSoil depth and quality shall be established towards the end of construction and once established, protected from compaction, such as from large machinery, vehicle traffic, 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 and documented by the contractor(s) responsible for site earthwork, preferably prior to planting, so that omissions can easily be corrected:. The inspection shall:
  - Verify that compost, mulch, topsoil and amendment delivery tickets match volumes, types, and sources needed to meet the standard. 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 8-inch deep test holes per acre of land subject to the standard (**Error! Reference source not found.**). Test holes must be excavated using only a shovel 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 sStandard.

    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 by the contractor indicates that an installation does not fulfill the Post Construction sSoil dDepth and qQuality sStandard, 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 sStandard. 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 and topsoil depth as described in the project specifications.
- Plant vegetation after installation is complete and inspection verifies the sStandard is met.

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

Commented [SE17]: Requirements from this section merged with treatment section.

Option	Construction Sequence	
OPTION 1: Leave native vegetation and soil undisturbed, and protect from compaction during construction.		
	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.**	
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.		
	Step 1: Scarification. Scarify or till subgrade to 4 inches of depth (or to depth needed to achieve a total depth of 8 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.	
	Step 2: Topsoil Application	
	A. Planting Beds 1. PRE-APPROVED RATE: Place 1 inch of composted material and rototill into 3 inches of soil. 2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of soil needed to achieve 4 inches of settled soil at 14% organic content. Rake beds to smooth and remove surface rocks larger than 2 inches in diameter.	**B. Turf Areas** 1. PRE-APPROVED RATE: Place 1 inch of composted material and rototill into 3 inches of soil. 2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of soil needed to achieve 4 inches of settled soil at 4% 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 2 inches in diameter.
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.		
	Step 1: Scarification. Scarify or till subgrade to a depth of 4 inches. 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.	
	Step 2: Topsoil Application	
	A. Planting Beds 1. PRE-APPROVED RATE: Place 1 inch of composted material and rototill into 3 inches of replaced soil. 2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of replaced soil needed to achieve 4 inches of settled soil at 4% organic content. Rake beds to smooth and remove surface rocks larger than 2 inches in diameter.	**B. Turf Areas** 1. PRE-APPROVED RATE: Place 1 inches of composted material and rototill into 3 inches of replaced soil. 2. CALCULATED RATE: Place calculated amount of composted material or approved organic material and rototill into depth of replaced soil needed to achieve 4 inches of settled soil at 4% organic content. Water or roll to compact soil to 85% of maximum dry density. Rake to level, and remove surface rocks larger than 2 inches in diameter.

Option	Construction Sequence	
OPTION 4: Import topsoil mix of sufficient organic content and depth to meet the requirements.		
	Step 1: Scarification. Scarify or till subgrade to 4 inches depth. Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.	
	Step 2: Topsoil Application	
	A. Planting Beds Use imported topsoil mix containing 4% organic matter. Soil portion must be sand or sandy loam as defined by the USDA. Place 4 inches of imported topsoil mix on surface Rake beds to smooth, and remove surface rocks over 2 inches in diameter.	B. Turf Areas Use imported topsoil mix containing 4% organic matter (. Soil portion must be sand or sandy loam as defined by the USDA. Place 4 inches of imported 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 2 inches in diameter.

3.5. 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.

3.6. 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 to ensure that no erosion is taking place and that soils are not becoming overly compacted. Note this does not include additional test pits on an annual basis.

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.

4.0 ACCEPTABLE STORMWATER TREATMENT PRACTICES

Introduction. This Subchapter presents detailed design requirements for the suite of STPs that ~~can~~may be utilized to meet one or more of the treatment standards identified in ~~Section~~ Subchapter 2.0 ~~of this manual~~. The STPs identified in the following sections specify the ability for the practice to meet the applicable treatment standards.

- **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. Pre-treatment is required for all STPs that will provide water quality treatment for non-rooftop stormwater runoff.
- **Section 0** presents a suite of **non-structural STPs** that are intended to shift stormwater design away from centralized management and focus instead on infiltrating and treating stormwater runoff close to the source. STPs discussed include: disconnections and reforestation. Designers are encouraged to exhaust opportunities to incorporate non-structural STPs 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 standards identified in Section 2.0. STPs discussed include: green roofs, permeable pavement, rainwater harvesting, bioretention~~/rain gardens~~, dry swales, infiltration trenches/basins, filtering systems, treatment wetlands, and wet ponds.
- **Section 4.4** presents an overview of **alternative STPs**, where a designer may consider the use of a STP that is proprietary or a STP that is otherwise not specifically included in this ~~m~~Manual for meeting applicable treatment standards. Alternative STPs are subject to Agency review and approval.

Each STP includes two sets of criteria—required elements and design guidance. **Required elements** are features that shall be used in all designs. If required design criteria for a particular practice cannot be met at a site, an alternative STP (Section 4.4) may be considered. **Design guidance** includes features that enhance practice performance, and are therefore optional and might not be necessary for all designs.

Each STP also includes a "Design Summary" table at the introduction to the practice. The design summary is meant to serve as a quick reference guide for frequent users of the manual. The required criteria and guidance featured within the summaries are not exhaustive, and important design requirements and design guidance 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 may be consistent with the schematic figures when using the STP described, but shall be completely detailed by the designer for site-specific conditions and construction purposes.

Commented [SE18]: Guidance not included in rulemaking version

Minor Variations from Numerical Design 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~~his or her best professional judgment to specify minor variations from numerical design criteria. ~~However, t~~These variations ~~must~~shall 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~~shall then have the option ~~of~~to either approv~~ing~~e the variation on a case-~~-~~specific basis ~~and allowing coverage under the general permit~~, or requir~~e~~ing the system to be ~~considered~~treated as an Alternative STP, as described in Section 4.4, subject to an individual permit. Designers are strongly encouraged to seek Agency approval for any minor variation prior to submittal of a stormwater permit application.

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4.1. Pre-Treatment Practices

Pre-treatment shall be provided for stormwater runoff, except for roof runoff that does not commingle with other stormwater runoff prior to treatment. Pre-treatment practices are designed to improve water quality and enhance the effective design life of ~~practices~~ STPs by consolidating the maintenance to a specific location. However, they do not meet pollutant removal ~~targets~~ goals or stormwater volume reduction standards on their own.

~~Pretreatment shall be provided for the entire~~ WQv~~WQ~~~~v, except for roof runoff that does not commingle with other runoff prior to treatment.~~WQv ~~P~~pre-treatment practices ~~must~~shall be combined with acceptable volume reduction~~/~~ and control, water quality, or storage practices to meet applicable standards. 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 device, specifications and design criteria can typically be obtained from vendors. As the Agency approves specific proprietary devices for pre-treatment, the Agency will maintain and update a list of these approved practices accessible to designers.

4.1.1. Pre-Treatment Swale

Pre-treatment swales ~~(or "~~, also known as 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 dry swale in that it is not intended to provide sufficient contact time for pollutant removal processes other than those associated with larger sediment particles and therefore can only be used for pre-treatment.

Pre-Treatment Swale Design Summary

Design Parameter	Requirements
Minimum Length	~~≥ 50 feet~~ Sufficient length for 5-minute minimum residence time for the peak discharge of the water quality storm (1", 24-hour event), with velocity no greater than 1 ft/s, depth no greater than 4"
Bottom Width	2 to 8 feet
Longitudinal Slope	0~~.5% -~~ 5~~2~~% without check dams >~~2% - 6~~5% with check dams
Maximum Side Slopes	2~~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~~

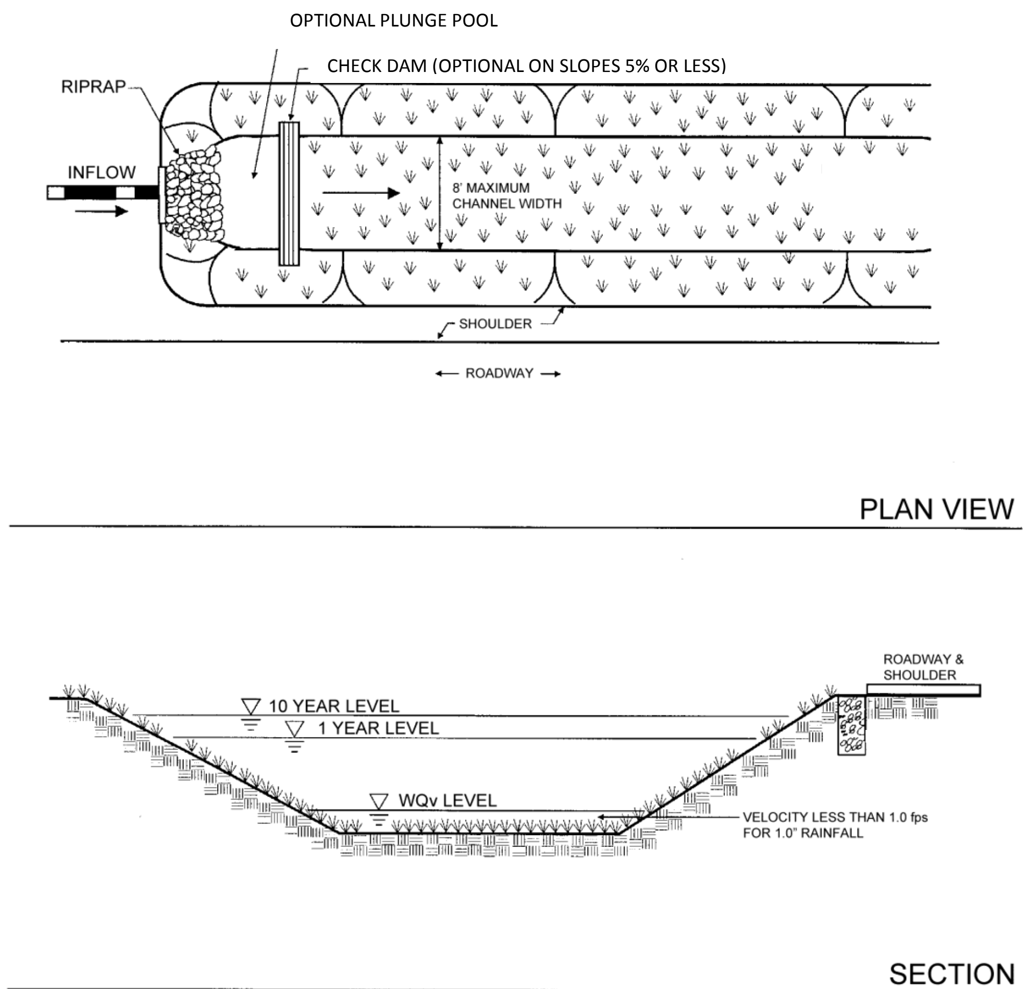

Figure 4-1~~4-1~~. Pre-~~T~~treatment Swale

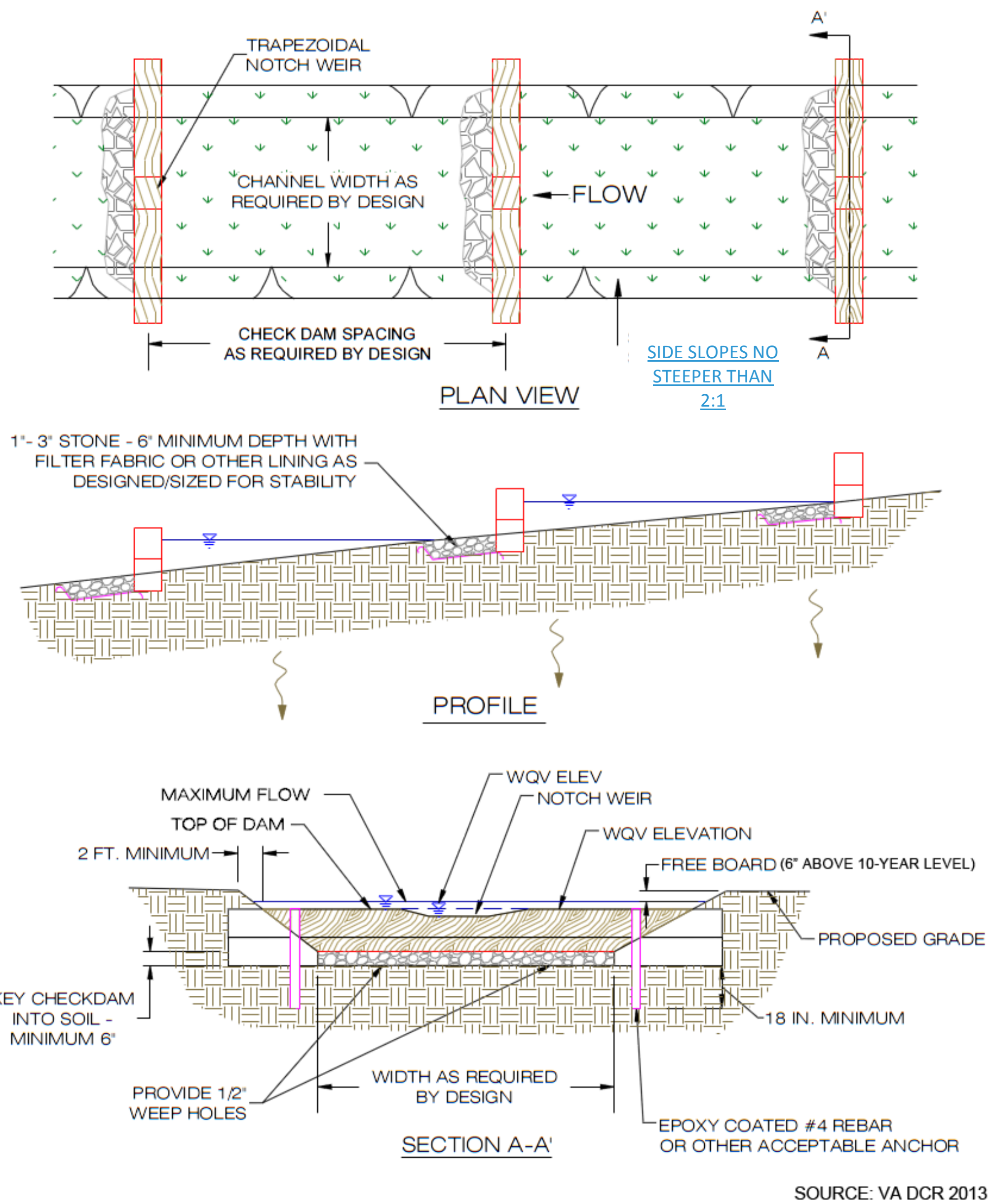

Figure 4-2. Pre-treatment Swale with Check Dams Shown for Swales >52%

4.1.1.1. Pre-Treatment Swale Feasibility

Required Elements:

- Pre-treatment swales constructed without check dams shall have a maximum longitudinal slope of 5%. Pre-treatment swales constructed on steeper slopes, >5% 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.

4.1.1.2. Pre-Treatment Swale Design

Required Elements:

- Pre-treatment swales shall be sized as follows:
    - Sizing of the pre-treatment swale width and length ~~is~~shall be based on the peak flow rate from the water quality storm (see Section 2.2.4.2) and shall be designed to ensure a minimum residence time of ~~five (~~5~~)~~ minutes at peak velocity for flow from the inlet to the outlet of the swale. For linear projects with no defined primary inflow location or similar projects with lateral contributing flow, adherence to the minimum 5-minute residence time ~~is~~shall be based on the peak flow rate from the water quality design storm as modeled for the contributing drainage area, and is ~~considered~~ sufficient for meeting pre-treatment swale design requirements.
    - Sufficient length for 5-minute minimum residence time for the peak discharge of the water quality storm (1.0~~"~~ inch, 24-hour event), with velocity no greater than 1 foot per ~~/~~second and peak runoff depth no greater than 4~~"~~ inches.
- The peak velocity for the 1-year storm within the pre-treatment swale must be non-erosive, in other words ~~(~~3.5-5.0 feet per ~~/~~second~~, see Appendix C7, VSMM, Vol. 2)~~.
- The bottom width of the swale shall be between 2~~two~~ and 8 ~~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.,~~less than or equal to 2H:1V ~~or flatter)~~.
- **Check Dams~~:~~.** Check dams or weirs shall be used to increase hydraulic residence time in the swale in steeper applications, >5% ~~(Figure 4-2)~~. Plunge pools or other energy dissipation may also be considered where the elevation difference between the tops of weirs to the downstream channel invert is a concern. The ~~D~~design requirements for check dams are as follows:
    - Check dams shall be composed of wood, concrete, stone, or other non-erodible material. The check dam ~~should~~shall be designed to facilitate easy maintenance and periodic mowing ~~(gravel check dams are discouraged)~~.

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- Check dams ~~must~~shall be firmly anchored into the side-slopes to prevent outflanking ~~;~~ ~~check dams must also be~~and anchored into the channel bottom a minimum of 6 inches.
- Check dams ~~must~~shall be designed with a center weir sized to pass the channel design storm peak flow (minimum 10-year 24-hour storm event if an on-line practice).
- Pre-treatment swales shall have the capacity to convey larger storms (minimum 10-year 24-hour storm event) safely with 6" of freeboard.
- Armoring ~~may be needed~~shall be provided at the downstream toe of the check dam, if necessary 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 level at a downhill check dam ~~should~~shall not extend above the elevation of the toe of the upstream check dam.
- Check dams composed of wood, concrete, or similar construction, shall have a weep hole or similar drainage feature so the check dam can dewater after a storm event.

Design Guidance:

- During construction, it is important to stabilize the swale promptly by~~until its turf cover has been~~ establishing vegetation. Applying a seed mix with both perennial and seasonal grasses, and mulch will ensure prompt stabilization. ~~ed, either with a temporary grass cover, or by using n~~Natural or synthetic erosion control ~~products~~matting may also aid in stabilization of the pre-treatment swale.
- Pre-treatment swales should not be designed to intercept groundwater. Swales may seasonally intercept seasonally high groundwater during periods of excessive precipitation and spring snow melt.~~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 distributed 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. With proper design and maintenance, filter strips can provide effective pre-treatment. Proper grading to ensure distributed flow throughout the length of the practice is necessary for a properly functioning filter strip.

~~4.1.2.1.~~ Pre-Treatment Filter Strip Design Summary

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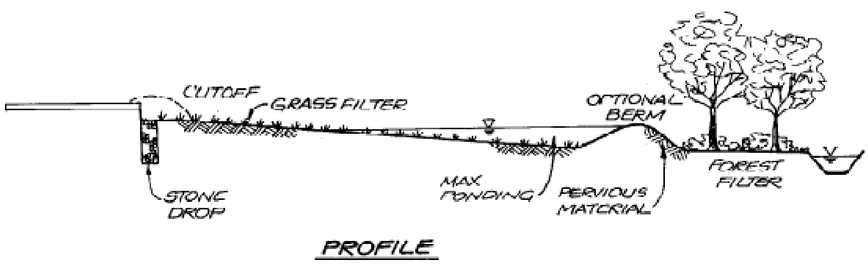
Parameter	Requirements			
Maximum Impervious Contributing Flow Path Length	35 feet		75 feet	
Filter Strip Slope (maximum 6%)	≤2%	>2%	≤2%	>2%
Filter Strip Minimum Length (feet)	10	15	20	25



Source: Claytor and Schueler, 1996

Figure 4-34-3. Filter Strip

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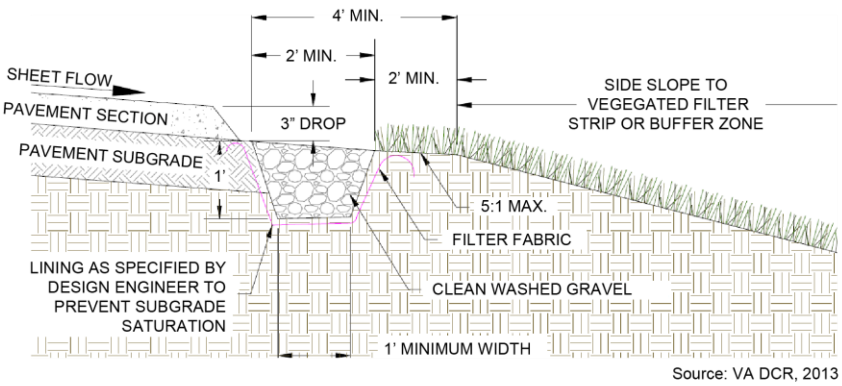


Figure 4-44-4. Stone Diaphragm

Commented [BK23]: Lose 3" drop from pavement section in graphic.

~~4.1.2.2.~~4.1.2.1. Filter Strip Feasibility

Required Elements:

- Filter strips designed for pre-treatment shall have a maximum average slope of 6%.
- The soils underlying the filter strip ~~must~~shall, at minimum, meet the criteria included in the Post-Construction Soil Depth and Quality Standard (~~Section~~Subchapter 3.0).

Design Guidance:

- Filter strips are best suited for~~to~~ pre-treatment of stormwater~~ing~~ runoff from driveway, roads and highways, roof downspouts, and small parking lots.

~~4.1.2.3.~~4.1.2.2. Filter Strip Design

Required Elements:

- The filter strip ~~must~~shall abut the entire length of the contributing area to ensure that runoff from all portions of the site are pre-treated.~~The side slopes of pre-treatment or treatment swales shall not be counted as filter strip pre-treat~~
- To limit the occurrence of concentration flow conditions, the maximum impervious contributing flow path length to a filter strip shall be limited to 75 feet 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 5%~~ (Figure 4-4)~~.
    - The roughly uniform clean stone diaphragm ~~is~~shall be 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.

Commented [SE24]: For guidance

- Flow shall travel over the impervious area and to the practice, including the stone diaphragm as distributed flow.
- A layer of filter fabric ~~should~~shall be placed between the stone and the underlying soil in the trench.
- If the contributing drainage area is steep (6% slope or greater), then larger stone 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.~~

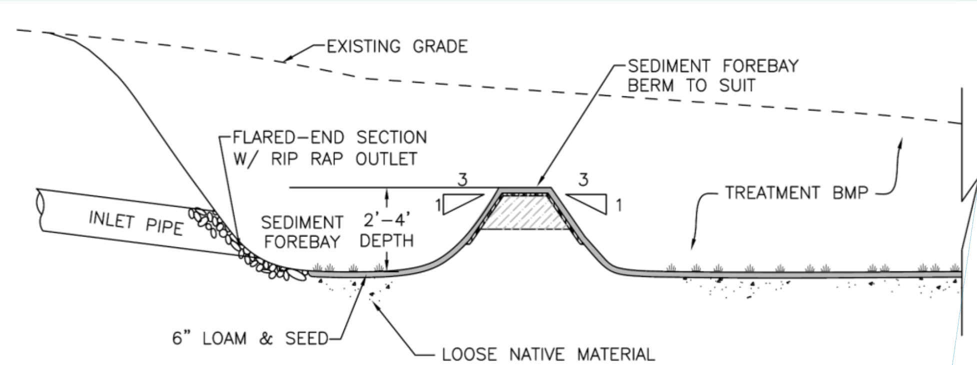
- ~~Filter strips provide a convenient area for snow storage and treatment. If used for this purpose, vegetation in the filter strip should be salt tolerant, (e.g., creeping bentgrass), and a maintenance schedule should include the removal of sand built up at the bottom of the slope.~~

4.1.3. Sediment Forebay

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

Sediment Forebay Design Summary

Design Parameter	Requirements
Forebay Volume	10% of the WQ_V~~WQ_v~~, at minimum. ~~See treatment practice for~~ Certain STPs will require sizing for more than 10% WQ_V~~WQ_v specific volume requirement~~, see specific STP requirements, Section 4.3.~~.~~
Minimum Depth	2 feet
Maximum Depth	6 feet
Safety	Bench required when peak design storm depth is greater than 4 feet and forebay side slopes are steeper than 4:1.
Maximum Side Slopes	2:1 or flatter



Source: RI DEM 2010

Figure 4-5~~4-5~~. Sediment Forebay

Commented [SE25]: Forebay depth is not consistent with requirements

Commented [BK26]: Update graphic for depth, "treatment BMP/STP", side slopes 2:1

4.1.3.1. Sediment Forebay Design

Required Elements:

- 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 STP) and be of an adequate depth to prevent re-suspension of collected sediments during the design storm, often 4 to 6 feet deep, but in no case less than 2 feet deep~~.~~. ~~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 STP, the bed and side slopes of the channel mustshall be armored.
- The outer perimeter of all deep permanent pool areas (four4 feet or greater) shall be surrounded by a safety bench that generally extends 15 feet outward (a 10-foot minimum bench is allowable on sites with extreme space limitations at the discretion of the DepartmentAgency) 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 mustshall be designed in a manner to prevent erosion of the embankment and primary pool.
- The outlet invert mustshall be elevated in a manner such that a minimum of 10% of the WQ_v can be stored below it. This outlet canmay be configured in a number of ways, such as a culvert, weir, or spillway channel. The outlet shouldshall be designed to convey the same design flow proposed to enter the structure.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition.

Direct access for appropriate maintenance equipment shallmust 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.

Design Guidance:

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

Sediment Forebay Maintenance & Maintenance Access

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 surface subject to treatment standards.

Sediment testing may be required prior to sediment disposal when stormwater runoff contributes from a hotspot land use or activityis 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.

Deep Sump Catch Basin Design Summary

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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

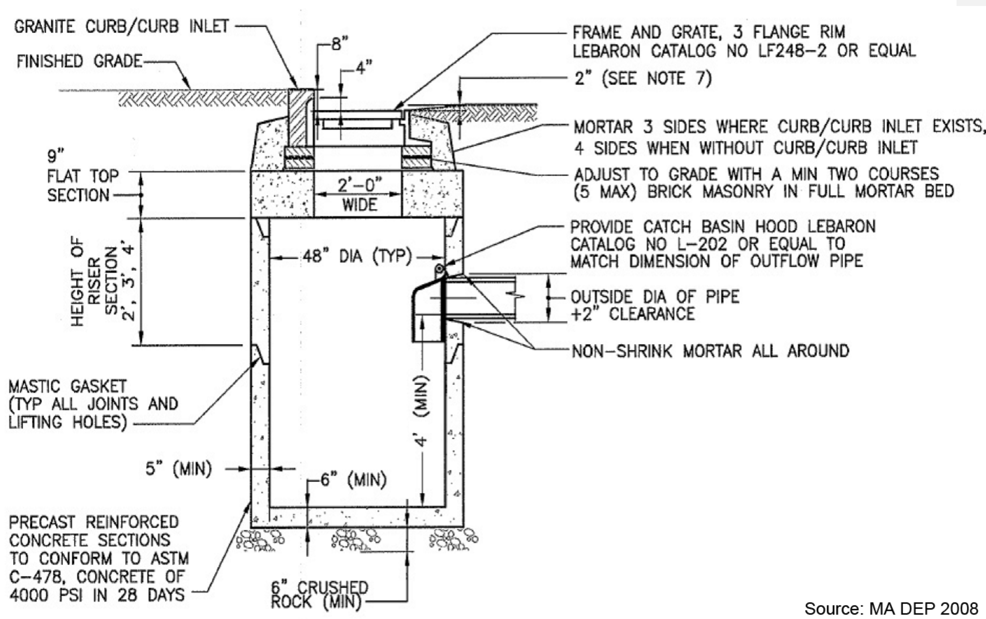


Figure 4-6: Typical Deep Sump Catch Basin

4.1.4.1. Deep Sump Catch Basin Feasibility

Required Elements:

- Deep sump catch basins used as pretreatment devices mustshall be located "off-line" – designed in a catch basin-to-manhole configuration with no inlet pipes (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 canmay not 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.

4.1.4.2 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.
- Inlet grates designed with curb cuts mustshall reach the back of the curb cut to prevent flow bypass.
- Hooded outlets shall be used.
- The inlet grate shall not be welded to the frame sSo that the sump can be easily inspected and maintained, the inlet grate shall not be welded to the frame.
- Sufficient maintenance access shall be provided when designing the geometry of deep sump catch basins.

Design Guidance:

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

4.1.4.2. Deep Sump Catch Basin Maintenance and Maintenance Access

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

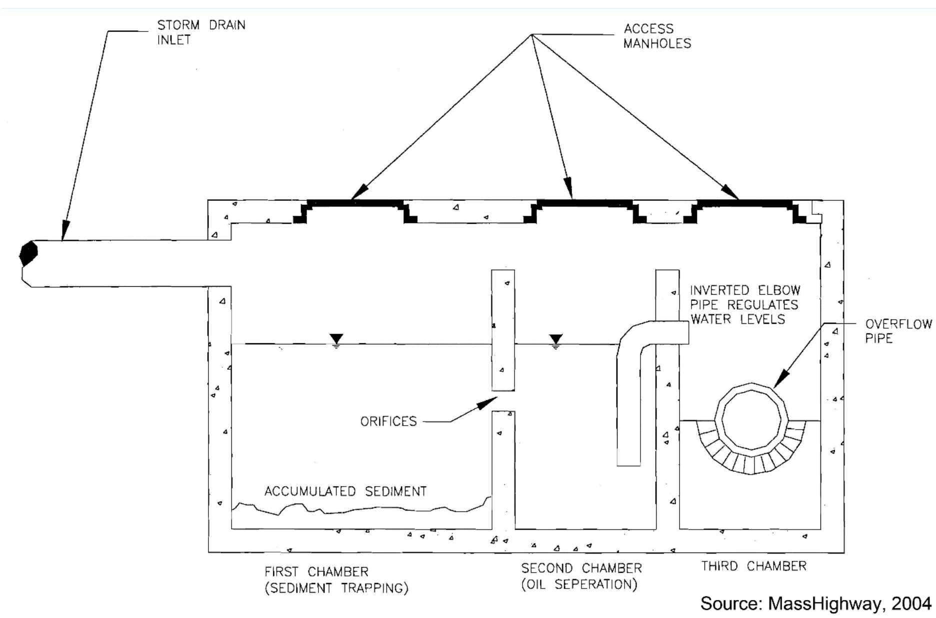
- Sediment testing may be required prior to sediment disposal when stormwater runoff contributes from a hotspot land use or activity is present.

Cleaning may require a vacuum-truck instead of "clam-shell" to avoid damage to the hood.

4.1.6. Proprietary Pre-Treatment 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, t~~These proprietary devices are ~~generally not capable~~ may not be able demonstrate~~of achieving~~ the level of water quality performance required by this M~~m~~anual ~~-~~ and as such, are only allowable for pre-treatment~~(Schueler, 2000; Claytor, 2000; UNHSC, 2007)~~ . ~~They may, however, provide pre-treatment for stormwater before it is directed to a downstream practice if~~ provided an independent third-party monitoring program ~~(e.g., ETV, TARP, TAPE)~~, such as one of the programs identified in Section 4.4.1, verifies that it removes a minimum of 50% TSS for the WQv~~WQ,~~ 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*~~

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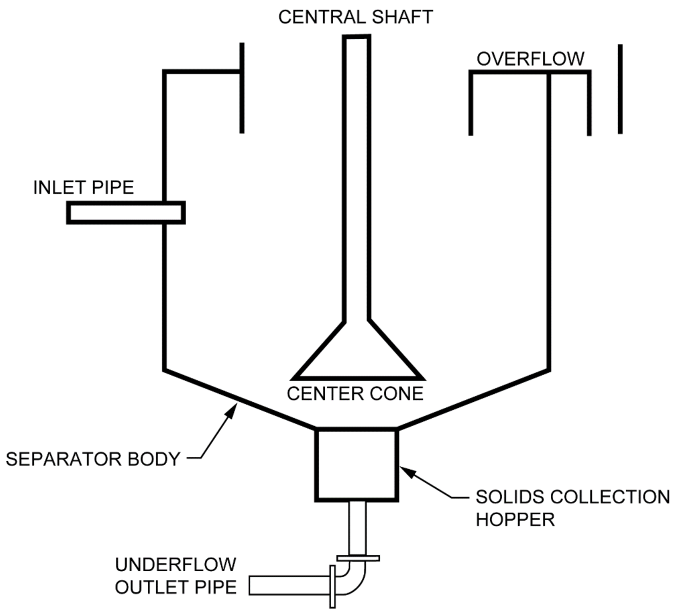

~~*Figure 4-8. Hydrodynamic Device*~~

4.1.6.1. Proprietary Device~~s~~ Feasibility

Required Elements:

- Proprietary devices shall be designed and installed ~~per~~in compliance with the manufacturer's recommendations.
- Proprietary devices ~~must~~shall be designed as off-line systems, or shall 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.~~

4.1.6.2. Proprietary Devices Design

Required Elements

- 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.
- Flow-through proprietary devices shall be designed to pass the entire WQvWQv. Peak flow of the Water Quality storm event shall be calculated in accordance with Section 2.2.4.2.. 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 WQvWQv).
- Flows higher than the design flow or that exceed the pre-treatment storage volume shall be configured to bypass the system, either by designing the practice as an off-line system or providing an internal bypass..
- For proprietary devices such as oil and /grit separators, all baffles shall be tightly sealed at sidewalls and at the roof to prevent the escape of oil.
- Proprietary devices shall be maintained in accordance with manufacturers' guidelines, and at a minimum when sediment has reached 50% of the designed storage capacity.
- Proprietary devices shall be located such that they are accessible for maintenance and emergency removal of oil or chemical spills.

Design Guidance

- Roof drains should bypass proprietary pre-treatment devices.

4.1.6.3. Proprietary Devices Maintenance and Maintenance Access

Required Elements

- Proprietary devices shall be maintained in accordance with manufacturers' guidelines, and at a minimum when sediment has reached 50% of the designed storage capacity.
- 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.

4.2. Non-Structural Practices

4.2.1. Reforestation and Tree Planting

Trees act as natural reservoirs by intercepting and storing rainfall, which can reduce stormwater runoff volume and mitigate its effects. Tree canopies intercept rainfall before it becomes stormwater runoff, and the uncompacted soil into which trees are ideally planted can also be used to capture and treat runoff. Trees may also be incorporated into bioretention and filter STP designs found in Section 4.34.2. Trees may also provide a host of wildlife and habitat benefits along with social and health benefits.

For the purposes of this Mmanual, credit for reforestation is given for three methods:

- **Active reforestation** involves planting a stand or block of trees at a project site, or individual trees with the explicit goal of establishing a mature forest canopy or distributed cover that will intercept rainfall, increase evapotranspiration rates, and enhance soil infiltration rates.
- **Passive reforestation** consists of protecting a portion of a project site from mowing and allowing native vegetation to reestablish.
- **Single tree credit** for the planting of individual trees.

The credits outlined in this sSection may be applied to site areas regardless of location on site. For reforested areas that receive runoff from impervious surfaces, credit may be sought under the requirements for Simple Disconnection (Section 4.2.2) or Disconnection to Filter Strips and Vegetated Buffers (Section **Error! Reference source not found.**).

Reforestation and tree planting may be considered in urban and suburban areas, as well as in rural situations where existing unforested areas are proposed for development, to provide shade and stormwater retention and to add aesthetic and natural habitat value.

~~4.2.1.1.~~ Reforestation and Tree Planting Design Summary

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Criteria	Element	Requirements
Feasibility	Minimum Required Area	Reforestation: Minimum contiguous area of 10,0002,500 ft² Minimum width of 2550 ft. Tree Planting: No minimum number of trees planted.
	Slope	Slope requirements not applicable for stand-alone reforestation. When reforested area is used in combination with disconnection STPss 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)
	Soils	Shall not be appliedApplication of STP in jurisdictional wetlands or jurisdictional wetland buffers may be subject to Vermont Wetlands Rules or other regulatory requirements.
Flow Control and Treatment	Conveyance	Impervious surfaces are not required to drain to reforested areas for use of STP, however when reforestation/tree planting is used in combination with disconnection, impervious surfaces must drain to reforested areas via sheetflow distributed flow and shall be/or consistent with Simple Disconnection or Disconnection to Filter Strip / Vegetated Buffer, as applicable.
	Pre-Treatment	Shall be provided for any contributing impervious surfaces consistent with Simple Disconnection and/or Disconnection to Filter Strip / Vegetated Buffer, as applicable.
	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, STP shall be consistent with Simple Disconnection or Disconnection to Filter Strip / Vegetated Buffer, as applicable.required treatment elements of that practice must also be satisfied
	Credit Towards Standards	Credited 0.1 watershed inches per square foot contiguous reforested area 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). Individual trees planted outside of reforested area credited cubic feet per tree.

Other	Vegetation and Landscaping	Reforestation and Tree Planting: Planting plan required Reforestation 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 Individual Tree Planting: Planting plan required 1 Large canopy tree equivalent to 2 small canopy trees 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.

Treatment Standard Applicability	
Recharge	Yes
Water Quality	Tier 1
Channel Protection	Hydrologic Condition Method
Q_{P10} and Q_{P100}	Hydrologic Condition Method. Partial credit through CN_{Adj}.

Key Elements

Feasibility:

- For active or passive reforestation credit: minimum area shall be 2,500 sq. ft. with a minimum width of 25 feet.
- No minimum areas for single tree plantings.
- Reforested areas may be used for Simple Disconnection (Section 4.2.2) or Disconnection to Filter Strips or Vegetated Buffers (Section 4.2.3)

Treatment:

- Tree species selected shall be well-suited to the site with consideration for natural species composition.

▪ Reforested areas are subject to the Soil Depth and Quality Standard (Subchapter 3.0) ▪ T_V credit, which can be credited towards Re_V, WQ_V, HC_V, Q_{P10} and Q_{p100}: ○ Active Reforestation: 0.1 inches x reforested area ○ Passive Reforestation: 0.05 inches x reforested area ○ Single tree plantings: 5 cubic feet per tree
Other: ▪ Planting plan shall include: delineation of the reforested area, plant species, plant locations, site preparation, and source of plant material.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

4.2.1.2. 4.2.1.1. Reforestation and Tree Planting Feasibility

Required Elements

- The minimum contiguous area of active or passive reforestation shall be a minimum of 10,000 2,500 square feet.
- The minimum width for reforested areas shall be 5025 feet.
- To receive credit towards HC_V, the reforested area shallmust 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 the same ownership/ or control as the site and shall be identified as protected from development and disturbance on the site plan.
- For reforested areas that are intended to will receive runoff from impervious surfaces, slope limitations shall be consistent with the requirements of Simple Disconnection (Section 4.2.2) or Disconnection to Filter Strips and Vegetated Buffers (Section 1.1.1.1).
- 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.
- Designers may consider designated foot traffic access to reforested areas by use of a path or trail. Impervious surface areas located within or across reforested areas shall not count toward reforestation credit.

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.

4.2.1.3. 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.

4.2.1.4. 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.

4.2.1.5.4.2.1.2. Reforestation and Tree Planting 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 mustshall meet the Post-Construction Soil Depth and Quality standard (SectionSubchapter 0).
- 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 1.1.1.1), the required elements of that practice must also be satisfied, taking steps necessary to eiensure that additional routed runoff does not cause erosion or degrade the quality of ground cover.
- Tv credit for **active reforestation** shall be equal to 0.1 inches multiplied by the reforested area (i.e. A reforested area of 1 acre equates to a THCv credit of 363 cubic feet).
- Tv credit for **passive reforestation** shall be equal to 0.05 inches multiplied by the practice area.
- Tv credit for **single tree plantings** shall be 5 cubic feet per tree planted.

~~4.2.1.6.~~4.2.1.3. Reforestation and Tree Planting 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. The plan shall include at a ~~M~~minimum the following 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.

- Active and passive r~~R~~eforestation areas shall not be maintained as landscaped areas. Forest leaf litter, duff, and volunteer sapling and understory growth shall not be removed.

- Trees planted for the single tree credit shall be at least 2-inch caliper for deciduous trees, or at least six feet tall for conifers.

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 recommended density of plantings for active reforestation 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 should 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 should be targeted to achieve 75% forest canopy within ten years.
- Selection of tree species for reforestation should 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 recommendation for trees is saplings 6-8 feet in height. The minimum size recommendation for shrubs is 18-24 inches in height, or 3-gallon size.
- New trees should 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 should only be performed when weather and soil conditions are suitable for planting.
- 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.
- New trees should 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.

4.2.1.7. 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 3.03.1) 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.

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4.2.1.8. 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.

4.2.1.9. 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. 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 and infiltration of the runoff through soil and vegetation, as well as chemical and biological activity within the soil.

~~4.2.2.1.~~ This practice is dependent on several site conditions (e.g., permeable flow path length, soils, slopes, and vegetative cover) ~~in order~~ to function properly.

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4.2.2.2. Simple Disconnection Design Summary

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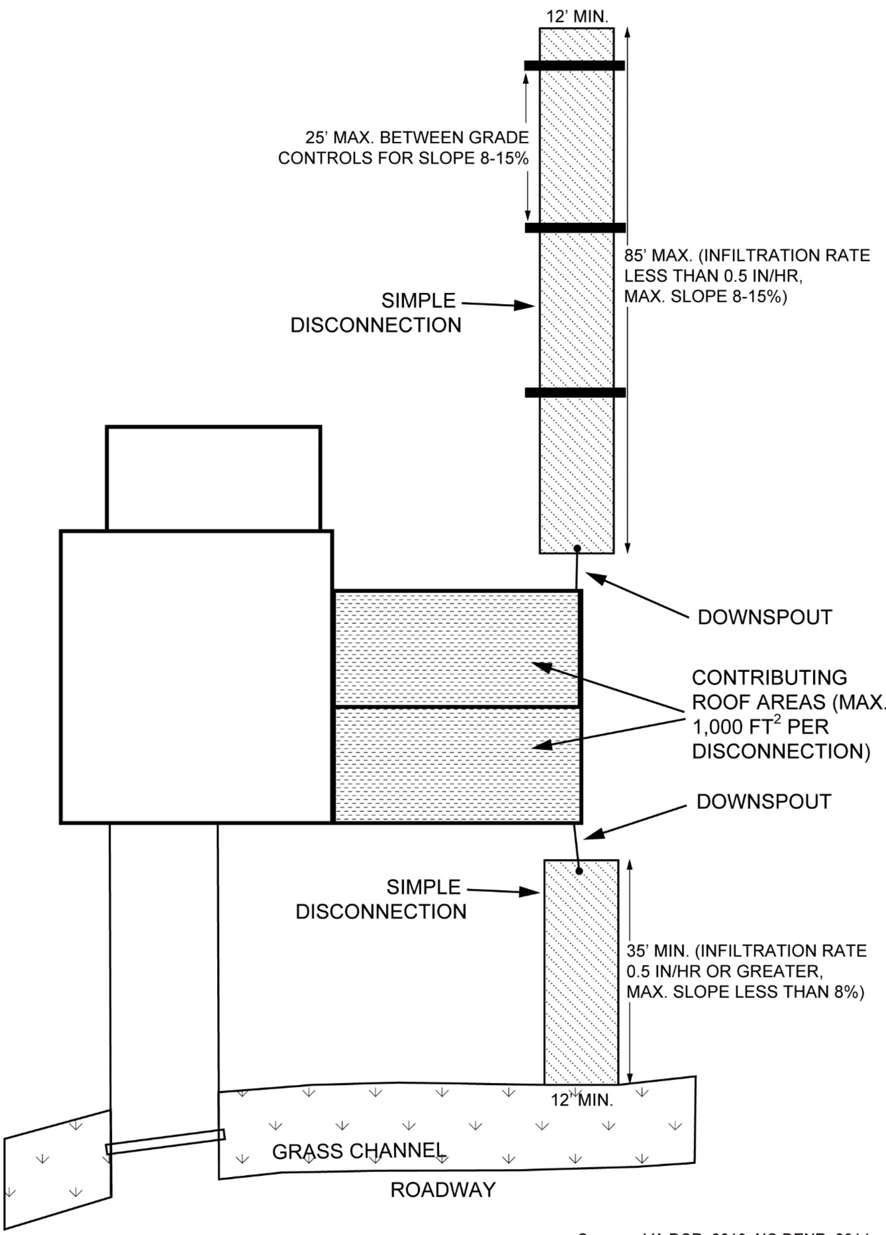
Criteria	Element	Requirements
Feasibility	Slope	15% or less (maximum slope in disconnection area) Terraces, berms, or other grade controls required every 20 feet if slope >8%
	Soils	Infiltration rate of 0.5 in/hr (HSG A/B) or greater for shortest disconnection flow path lengths, in less permeable soils (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 ft² 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 for downspouts, otherwise as wide as the disconnected surface
	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% Contributing lengths less than or equal to 10 ft. may match the contributing length on slopes less than 8% or double the length on slopes greater than or equal to 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, CP_v, Q_p10, and Q_p100.
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

Treatment Standard Applicability	
Recharge	Yes
Water Quality	Tier 1
Channel Protection	Hydrologic Condition Method
Q_{P10} and Q_{P100}	Hydrologic Condition Method. Partial credit through CN_{Adj}.
Key Elements	
Feasibility: ▪ Allowable for rooftops, sidewalks, recreation paths, and residential driveways only.	

- Maximum slope of 15%. Grade controls required if slope >8%. - Maximum contributing impervious length of 75 feet. - Contributing drainage area <1000 sq. ft. for downspouts.

Treatment:
- T_V credit is equal to the WQ_V of the disconnected site area. T_V can be applied to Re_V, HC_V, Q_{P10}, and Q_{P100}.
- Disconnection areas are subject to the Soil Depth and Quality Standard (Subchapter 3.0)
- Minimum 12 feet disconnection area width for downspouts, otherwise as wide as the disconnected surface.
- Disconnection area length (contributing area >10 ft wide):
  o Minimum 35 feet (HSG A/B) when slopes < 8%
  o Minimum 50 feet (HSG A/B) when slopes ≥ than 8%
  o Minimum 65 feet (HSG C/D) when slopes < 8%
  o Minimum 85 feet (HSG C/D) when slopes ≥ 8%
- Contributing lengths less than or equal to 10 ft. may match the contributing length on slopes less than 8% or double the length on slopes greater than or equal to 8%

Other: - Dense and vigorous vegetative cover shall be established over the receiving areas.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.



Sources: VA DCR, 2013; NC DENR, 2014

Figure 4-7~~4-9~~. Example of Simple Disconnection (Plan View)

Commented [GC29]: Figure says 25' max between structures, requirement says 20'.

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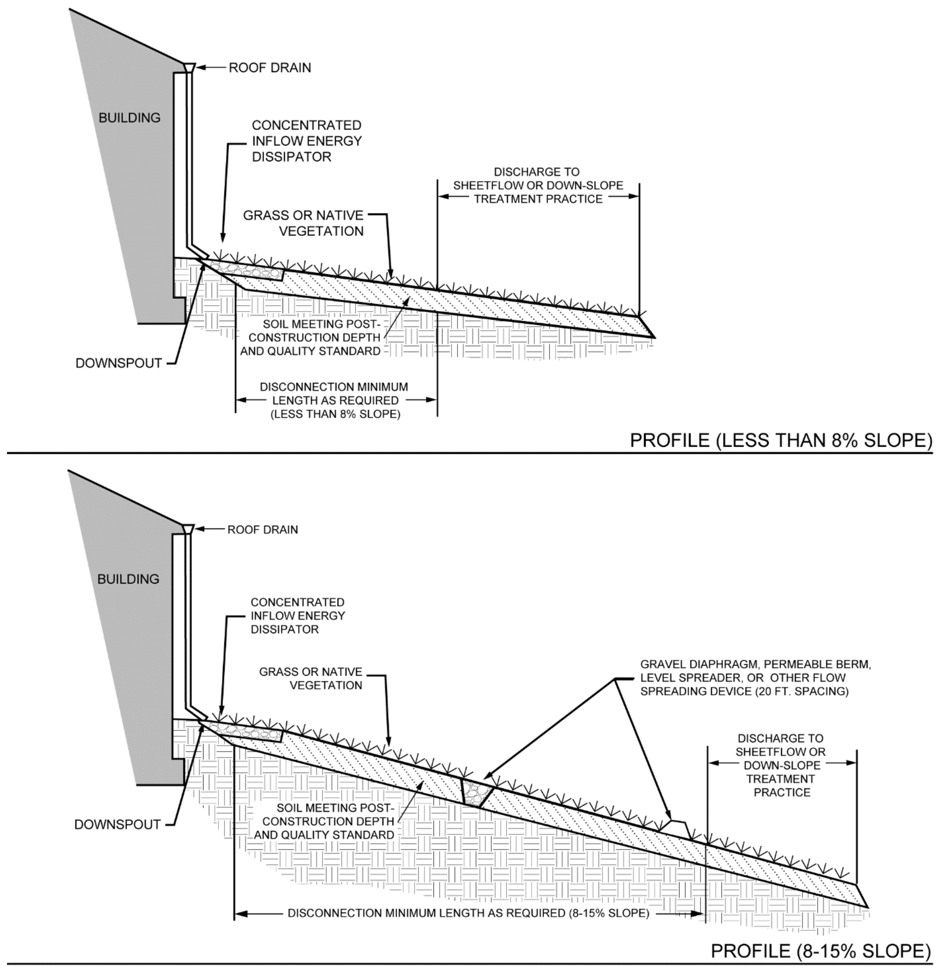
Do we want to try to find some figures from a driveway or sidewalk? We will not need a parking lot figure as they won't qualify under simple disconnect.



Source: Modified from VA DCR, 2013

Figure 4-8~~4-10~~. Simple Disconnection (Cross Section and Profiles)

~~4.2.2.3.~~4.2.2.1. Simple Disconnection Feasibility

Required Elements

- A permeable, vegetated treatment flow path equal in length to the minimum flow path length needed for treatment (see **Error! Reference source not found.**, below) ~~must~~shall be available down gradient (downslope) of the qualifying impervious surface~~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 for slopes less than 8% or double the contributing length for slopes greater than or equal to 8%.

- The width of the disconnection area shall be at least 12 feet for disconnected rooftops that discharge via downspouts, or equal to the contributing width for all other surfaces.
- ~~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 (Subchapter~~Section~~ 0).
- The contributing surface impervious area to any one discharge location must not exceed 1,000 square feet~~2~~. The contributing rooftop area to an individual downspout shall not exceed 1,000 square feet~~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 (Section 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 meet or 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 4.2.2.4, 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.

~~4.2.2.4.~~4.2.2.2. 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/ and downspout system is not used, runoff mustshall 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.

4.2.2.5.4.2.2.3. 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.

4.2.2.6.4.2.2.4. 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) and as wide as the disconnected surface mustshall 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 or equal 8% or twice the contributing length on slopes between 8 and 15%, and as wide as the disconnected surface.

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, Channel Protection Standard, Overbank Flood Protection Standard, and Extreme Flood Protection Standard. ~~where it applies.~~

~~4.2.2.7.~~4.2.2.5. 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.

~~4.2.2.8. 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.

4.2.2.9. 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.

4.2.2.10. 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. 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 vegetated buffers ~~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. Vegetated ~~B~~buffers ~~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 vegetated buffers ~~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 vegetated buffers ~~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 vegetated buffer's ~~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 vegetated 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.

4.2.3.1. Disconnection to Filter Strips and Vegetated Buffers Design Summary

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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 longer. 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 and is applied to all applicable standards.
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

Treatment Standard Applicability	
Recharge	Yes
Water Quality	Tier 1
Channel Protection	Hydrologic Condition Method
Q_{P10} and Q_{P100}	Hydrologic Condition Method. Partial credit through CN_{Adj}.
Key Elements	

Feasibility: ▪ Maximum slope of 15%. Grade controls required if slope >8%. ▪ Maximum contributing impervious length of 75 feet. ▪ Contributing drainage area <1000 sq. ft. for downspouts.
Treatment: ▪ T_V credit is equal to the WQ_V of the disconnected site area. T_V can be applied to Re_V, HC_V, Q_{P10}, and Q_{P100}. ▪ Disconnection areas are subject to the Soil Depth and Quality Standard (Subchapter 3.0) ▪ Minimum 12 feet disconnection area width for downspouts, otherwise as wide as the disconnected surface. ▪ Disconnection area length (contributing area >10 ft wide): ○ Minimum 35 feet (HSG A/B) when slopes < 8% ○ Minimum 50 feet (HSG A/B) when slopes ≥ than 8% ○ Minimum 65 feet (HSG C/D) when slopes < 8% ○ Minimum 85 feet (HSG C/D) when slopes ≥ 8%
Other: ▪ A clean stone diaphragm or level spreader shall be provided from the disconnected area to the vegetated area. ▪ Dense and vigorous vegetative cover shall be established over the receiving areas.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

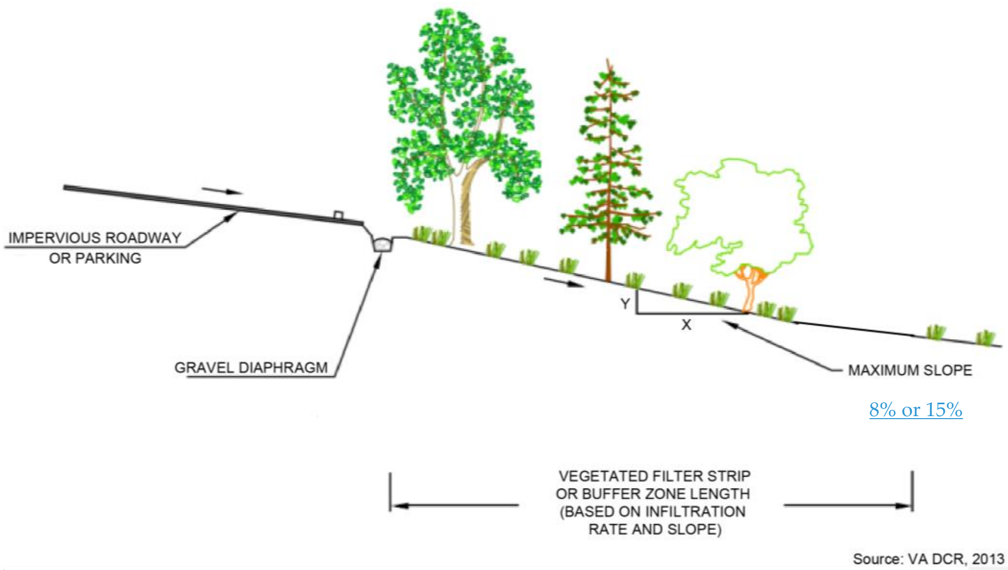

Figure 4-9~~4-11~~. Typical Section, Disconnection to Filter Strip or Buffer Zone via Sheet Flow

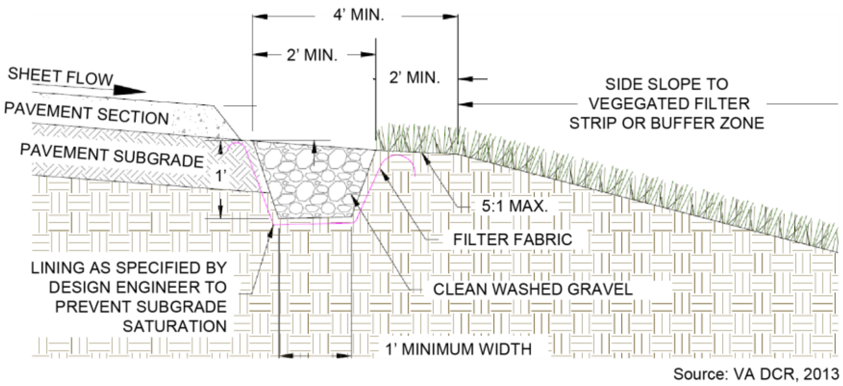

Figure 4-10~~4-12~~. Stone Diaphragm – Sheet Flow Pre-treatment

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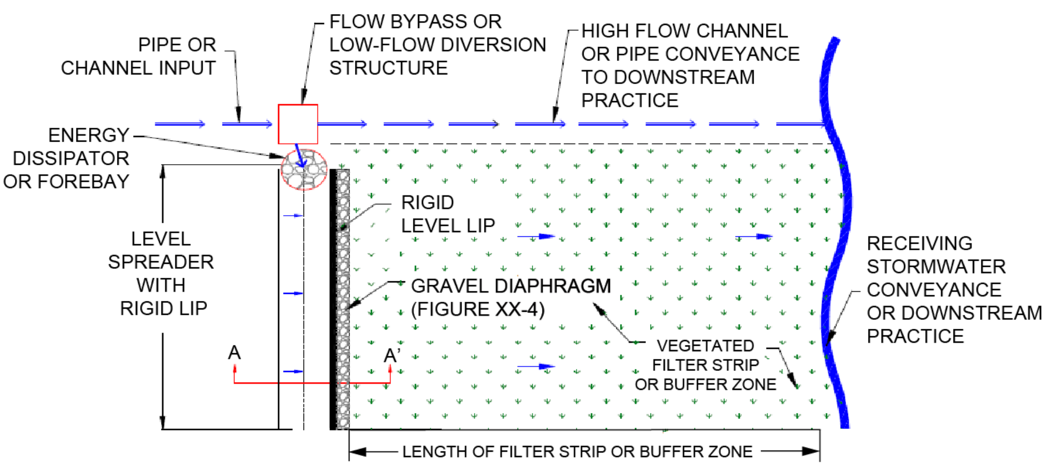

Source: Modified from VA DCR, 2013

Figure 4-11~~4-13~~. Plan View – Disconnection of Concentrated Flow by Rigid Level Lip Spreader

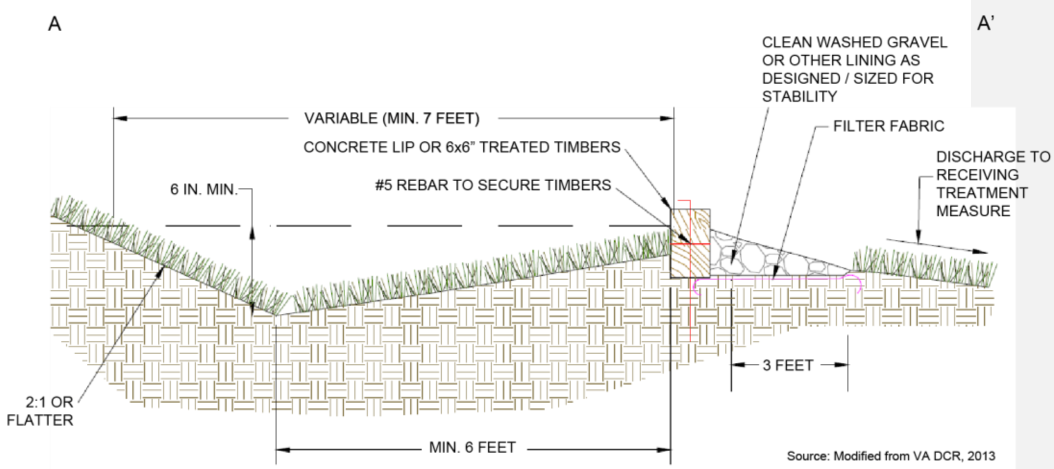

Figure 4-12~~4-14~~. Cross Section – Level Spreader with Rigid Lip

~~4.2.3.2.~~4.2.3.1. 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 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.~~
- The soils underlying the receiving disconnection area must, at minimum, meet the criteria included in the Post-Construction Soil Depth and Quality standard (~~Section~~Subchapter 0).
- Vegetated ~~B~~buffers ~~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.
- Vegetated ~~B~~buffers ~~zones~~ and filter strips may be adjacent to each other, but there shall be no overlap.
- Vegetated ~~B~~buffers ~~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)
- 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 4-2, 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.

4.2.3.3.4.2.3.2. 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 asensure that runoff will flow in a safe and non-erosive manner during larger storm events.
- Runoff mustshall 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 vegetated buffers zones and filter strips that receive sheet flow (**Error! Reference source not found.**Figure 4-9 and **Error! Reference source not found.**Figure 4-10). Stone diaphragms shall comply with the following requirements:
  - The clean stone diaphragm isshall be 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 stone diaphragm.
  - A layer of filter fabric shouldshall be placed between the stone and the underlying soil trench.
  - If the contributing drainage area is steep (6% slope or greater), then larger stone shall be used in the diaphragm, or an engineered level spreader shall be used in place of the stone diaphragm.
- Engineered Level Spreaders:. An engineered level spreader at the top of the slope is required for vegetated buffers 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. KeyThe required design elements of the engineered level spreaders, as provided in **Error! Reference source not found.**Figure 4-11 and **Error! Reference source not found.**Figure 4-12, include the following are as follows:
  - A high flow bypass shall provide safe passage for storms larger than the design storm of the level spreader (**Error! Reference source not found.**Figure 4-11). 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:

- For filter areas that consist of grasses or thick ground cover, 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;~~shall be provided.
- For filter area that are forested or reforested, 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~~shall be provided.
- Where the ~~conserved open space~~filter area is a mix of grass and forest ~~(~~or re-forested area~~)~~, 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~~shall be 13 feet and the maximum ~~is~~length shall be 130 feet.
- For determining the level spreader length, the peak discharge shall be determined using the computational procedure outlined in Section 2.2.4.2.

- The level spreader lip shall be concrete, wood, stone, pre-fabricated metal, or other durable non-erodible material with a well-anchored and frost-protected footer. Level spreaders ~~must~~shall 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~~ (**Error! Reference source not found.**Figure 4-12)~~.
- 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 t~~To prevent grade drops that re-concentrate the flows, a 3-foot wide section of open-graded coarse aggregate with a 1~~"~~ inch to 2.5~~"~~ inch 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~~shall be able to withstand the force of the flow coming over the lip of the device.

~~4.2.3.4.~~4.2.3.3. Disconnection to Filter Strips and Vegetated Buffers Pre-Treatment

If rooftop runoff is disconnected to a filter strip or vegetated 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 vegetated buffer ~~zone~~ via sheet flow (see previous section).

- If stormwater is routed to a forebay for required pre-treatment, the forebay shall be volumetrically sized for 10% of the computed WQ_v. Otherwise, ~~required~~ pre-treatment designed in accordance with Section 4.1 is required.

Design Guidance:

- If the use of traction 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 traction sand application.

~~4.2.3.5.~~4.2.3.4. 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 1, below),~~, and either as wide as the disconnected surface (for flow entering as sheet flow) or the level spreader (for concentrated flows) ~~must~~shall be available down gradient (downslope) of the impervious cover to effectively disconnect runoff.
- Vegetated ~~B~~buffers ~~zones~~ and filter strips shall be fully vegetated.
- Vegetated ~~B~~buffers ~~zones~~ shall remain ungraded and uncompacted to meet the Post-Construction Soil Depth and Quality standard (~~Section~~Subchapter 0), 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~~Subchapter 0), and be densely vegetated.

Table 4-2. Required Filter Strip and Vegetated 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, Channel Protection Standard, Overbank Flood Protection Standard, and Extreme Flood Protection Standard.

~~4.2.3.6.~~4.2.3.5. Disconnection to Filter Strips and Vegetated Buffers Vegetation and Landscaping

Required Elements:

- A minimum 90% vegetative cover shall be maintained within vegetated buffer ~~zones~~ through natural propagation or targeted planting of native or non-invasive, naturalized species. ~~No g~~Grading or clearing of native vegetation is ~~allowed~~prohibited within vegetated buffers ~~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.
- 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.

~~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.~~

~~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.~~

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. Watershed Hydrology Protection

This ~~standard~~ STP is only applicable ~~only~~ to certain ~~high elevation renewable energy~~ high elevation projects ~~and may be applied when a~~that have the ability to apply a group of practices, that together ~~,~~ 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~~ STP 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~~STP.

The Water Quality Treatment Standard, Groundwater Recharge Standard, and Channel Protection Standard ~~s~~ are completely met for portions of a project where the discharges from which satisfy this ~~standard~~STP. Additional demonstration of compliance with the Overbank Flood Protection Standard and Extreme Flood Protection Standard ~~will~~shall be required, as applicable. The Post-Construction Soil Depth and Quality ~~s~~Standard ~~must~~shall ~~still~~ be met for applicable site areas (~~Section~~ Subchapter 3.0).

Under this ~~standard~~STP, 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.

~~4.2.4.1.~~ Watershed Hydrology Protection Design Summary

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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. Stormwater runoff from road surface shall not comingle with cross drainage prior to treatment, accomplished by "clean" conveyance on up-gradient side of roads and grading plan or equivalent method. Unless otherwise required due to presence of groundwater or other drainage features, distances between drainage structures shall be as specified in Table 4-4 Disconnections, including through use of level spreaders and downslope disconnection areas shall receive equivalent to the calculated for contributing drainage area.
	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

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

Treatment Standard Applicability	
Recharge	Yes
Water Quality	Tier 1
Channel Protection	Hydrologic Condition Method (for disconnected areas)
Q_{P10} and Q_{P100}	Hydrologic Condition Method (for disconnected areas). Partial credit through CN_{Adj}.

Key Elements

Feasibility:

- Impervious cover shall not exceed 5% of the watershed area within the site or when pre-routed post-developed discharge does not exceed 2 cfs for the 1-year 24-hour storm event.
- Contributing watershed shall be ≥90%.
- Stream buffers except for required stream crossings.

Treatment:

- Road ditches in excess of 5% slope shall be stone lined OR have permanent stone check dams.
- Frequent cross-drainage (per Table 4-4) shall be provided under roads for passage of groundwater.
- Interception of groundwater shall be avoided.
- Runoff discharged via a ditch or conveyance structure shall be redistributed via a level spreader and disconnected.
    - Level spreaders shall be constructed per specifications in Section 4.2.4.2
    - Disconnection flow path shall be a minimum of 150 feet
- Non-collected runoff shall be disconnected if immediately conveyed to the disconnection area via sheet flow.
    - Disconnection flow path length based on vegetative cover type and width of road (Table 4-5); minimum flow path length 55 feet.

▪ Disconnections are not allowed natural slopes >30%. ▪ Disconnections, including through use of level spreaders and downslope disconnection areas shall receive T_V equivalent to the calculated WQ_V for contributing drainage area.
Other: ▪ Vegetative cover type of a disconnection must be either forest or meadow that is allowed to regenerate to forest. ▪ Silvicultural activities, including logging, are allowed provided the lands are under a forest management plan approved by the Vermont Agency of Natural Resources.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

4.2.4.2.4.2.4.1. 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 STP forto satisfying the requirements of the Channel Protection Standard. Designers 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 STP forto satisfying the requirements of the Channel Protection Standard.
- Except for necessary and authorized 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 STP 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~~'~~ feet 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~~'~~ feet 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.

~~4.2.4.3.~~4.2.4.2. Watershed Hydrology Protection Conveyance and Treatment

There are two allowable approaches to manag~~ing~~e road runoff: uncollected runoff ~~is~~shall be managed under the "Disconnection Adjacent to Downhill Side of the Road" requirements~~;~~, and collected runoff from ditches ~~is~~shall be managed under "Disconnection via Level Spreader~~.~~" requirements. ~~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~~shall be at 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~~or shall have permanent stone check dams installed ~~per~~in compliance with 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~~shall 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~~shall be provided under roads. Each roadway section aligned across a slope ~~must~~shall 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 4-4. Stormwater runoff from road surface shall not comingle with cross-drainage prior to treatment, accomplished by "clean" conveyance on up-gradient side of roads and grading plan or equivalent method.

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~~shall be passed under the travel way and returned to the natural channel on the downhill side of the travel-way.

Required Elements - Groundwater Interception:

- Interception of the groundwater table shall be avoided, where possible.
- Where medium to coarse textured soils occur with potential for significant flow of shallow sub-surface water, including oxygenated water, the roadway ~~must~~shall 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~~shall be used to convey groundwater and shallow distributed surface drainage 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~~shall 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~~shall 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.

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Required Elements - Redistribution and Disconnection of Stormwater:

- The topography of a disconnection area ~~must~~shall 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~~prohibited.
- Vegetation in the disconnection areas ~~must~~shall be consistent with the required elements of Section 4.2.4.3 (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~~in compliance with the following **"Disconnection via 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~~"~~ inches).
    - 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~~shall be at least ~~one~~1 foot high and ~~two~~2 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~~shall 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.
    - The ~~D~~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

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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~~"~~ inch thick top layer of stump grindings/grubbings; and allowing the surface to re-vegetate naturally. Additionally, fill materials shall consist of well-drained soils or stone.

~~4.2.4.4.~~4.2.4.3. 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. The vegetative cover, including the duff layer, ~~must~~shall remain undisturbed with the exception of necessary maintenance or repair, unless otherwise allowable below pertaining to silvicultural activities.

- Silvicultural activities, including logging, are allowed provided the lands are under a forest management plan approved by the Vermont Agency of Natural Resources~~.~~, and provided the activities are limited to harvesting in dry or winter conditions, with no construction of skidder trails, roads, or landings.

- A forest disconnection area 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.~~

4.2.4.5. A meadow disconnection mustshall have a dense cover of grasses, or a combination of grasses and shrubs or trees in the existing condition. A disconnection using a meadow mustshall 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 perin compliance with the requirements of Table 4-5.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.

4.2.4.6. 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.

4.2.4.7. 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.

4.3. Structural Stormwater Treatment Practices

4.3.1. Bioretention ~~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 bioretention 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 b~~Bioretention facilities are well suited to be used in combination with Simple Disconnection Section 0) and Disconnection to Filter Strips and Vegetated Buffers (Section 1.1.1.1).

~~4.3.1.1.~~ Bioretention and Rain Garden Design Summary

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Criteria	Element	Requirements
Feasibility	Water Table	Bottom of filter media, including gravel stone 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 stone 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 stone sump.
Other	Vegetation and Landscaping	Contributing area must should be stabilized before runoff is directed to facility Detailed landscaping plan required Use of native and salt-tolerant plants recommended

Treatment Standard Applicability	
Recharge	Yes (if unlined)
Water Quality	Tier 1 (unlined)/ Tier 2 (lined)
Channel Protection	Hydrologic Condition Method (unlined)/ Extended Detention Method (lined)
Q_{P10} and Q_{P100}	Limited. CN_{Adj} may provide partial credit
Key Elements	
Feasibility: ▪ Infiltration rate shall be ≥0.2 inches per hour as confirmed by methods in Section 4.3.3.2 if designed to infiltrate. ▪ SHGWT must be below bottom of the practice for water quality treatment. Separation to SHGWT for larger storm events varies based size of practice and volume designed to infiltrate.	
Pre-treatment: ▪ Forebay sized for 25% of the WQ_V or other pre-treatment in Section 4.1.	
Treatment: ▪ Filter bed shall be 24-48 inches deep. If underdrained, filter media shall have a phosphorus index between 10 and 30 mg/kg. ▪ Maximum ponding depth of 12 inches ▪ Volume storage within practice, including pore space and ponding depth, is credited towards WQV. For infiltrating practices, this same treatment volume is applied to CP_V, Q_{P10}, and Q_{P100}. For underdrained practices, HC_V is limited to pore space below underdrain. ▪ Volume, including pre-treatment shall be a minimum of 75% the T_V.	
Other: ▪ Minimum 6-inch underdrain shall be provided if not designed to infiltrate. ▪ Landscaping plan shall be provided.	
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.	

Commented [SE34]: Because Elizabeth said so.

	~~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.~~

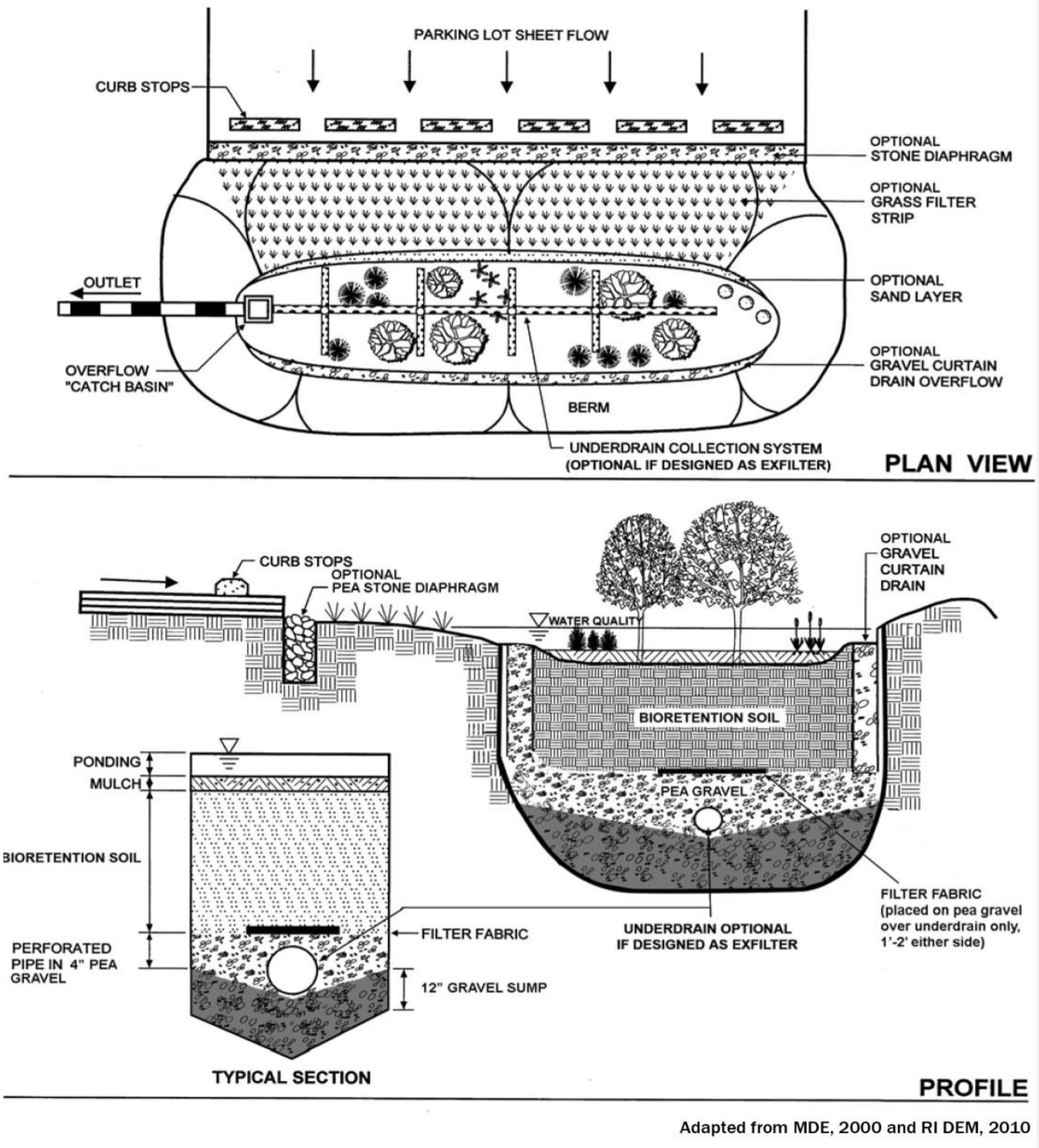
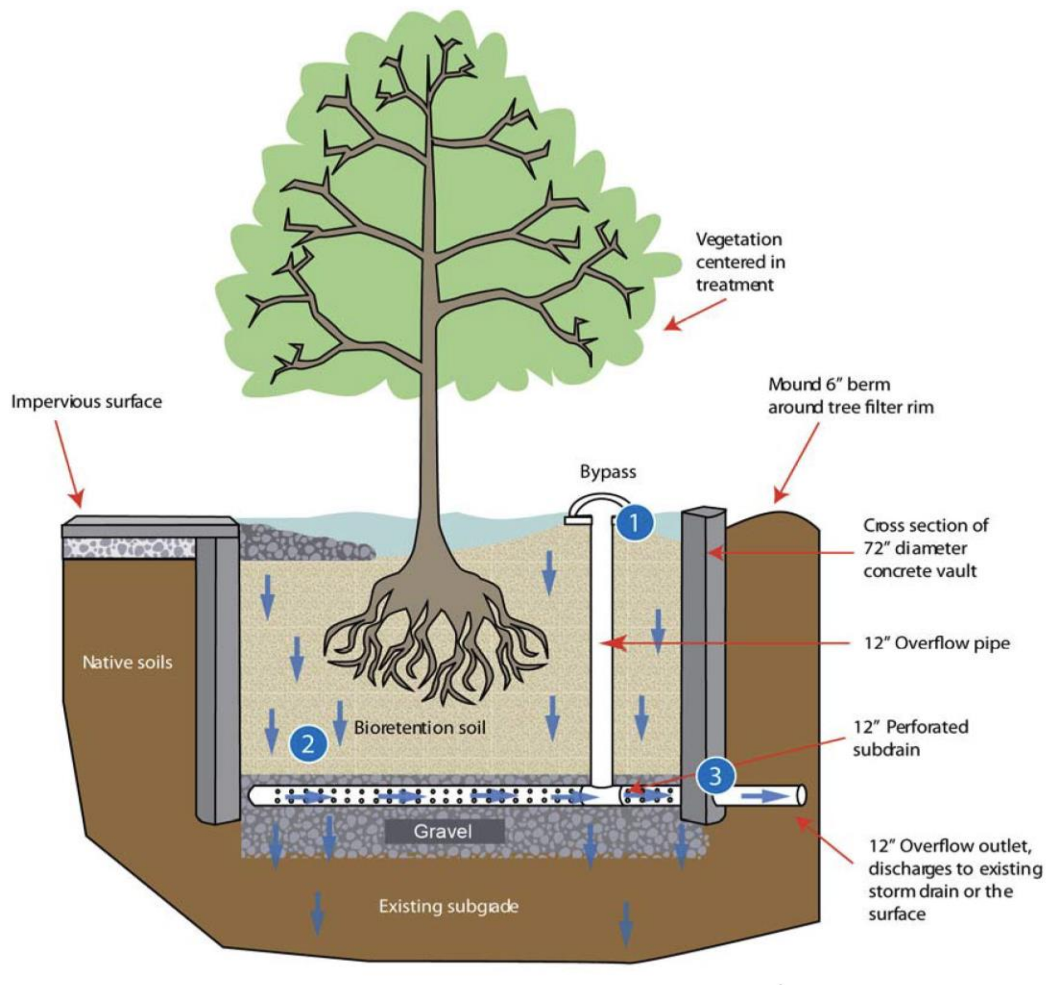


Figure 4-134 15. Bioretention



Source: Adapted from UNH Stormwater Center, 2009

Figure 4-144-16. Tree Filter (A bioretention system adapted for a small contributing drainage area)

~~4.3.1.2.~~4.3.1.1. Bioretention ~~and Rain Garden~~ 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 soil testing requirements for infiltration pursuant to Section 4.3.3.2~~field geotechnical tests (see Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements)~~.
- For bioretention practices designed to infiltrate stormwater, ~~relevant~~applicable feasibility required elements for infiltration trench~~/~~ and basin practices ~~must~~shall also be met (Section 0). The separation to SHGWT requirements identified in Section 4.3.3.1~~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, th~~a~~en there shall be a:
    - Minimum 2 feet of separation to SHGWT from the bottom of the bioretention system when the contributing drainage area (CDA) of 1~~.0~~ acre or less~~,~~ is greater than 50% impervious.
    - Minimum 1 foot of separation to SHGWT from the bottom of the bioretention system when the 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, 24-hour storm event ~~and have a separation from the bottom of the practice to SHGWT of less than four~~4 ~~feet~~ shall provide a groundwater mounding analysis pursuant to Section 4.3.3.1 ~~based on the Hantush Method or equivalent to demonstrate that mounding does not intercept the bottom of the practice (Section 4.3.3and Appendix C1, VSMM, Vol. 2).~~
- ~~No soil-related restrictions (minimum separations to seasonal high groundwater or bedrock) are required for bioretention practices that are under-drained 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.

- 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).

Commented [SE35]: Moved here from intro

~~4.3.1.3.~~4.3.1.2. Bioretention ~~and Rain Garden~~ 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 WQv or Tv 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 WQv or Tv to a stabl~~ilized~~le ~~water course~~ conveyance. Designers ~~must~~shall indicate how on-line practices will safely pass the 10-year storm without re-suspending or flushing previously trapped material.

- To prevent ~~downstream slope~~ erosion, ~~A~~an overflow for the 10-year storm shall be provided to a non-erosive outlet point ~~(i.e., prevent downstream slope erosion)~~.

- The channel immediately below a bioretention system 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 of 3.5 to 5.0 fps.

- Stormwater from bioretention system outlets shall be conveyed to discharge location in non-erosive manner.

- Underdrained bioretention practices shall be equipped with a minimum 6~~"~~ inch perforated pipe underdrain (8~~"~~ inches is preferred) in a 1-foot stone layer. Synthetic filter fabrics shall not be used to completely separate the filter media from the underdrain bedding material. A 3-inch stone 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.~~4.3.1.3. Bioretention ~~and Rain Garden~~ 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 a forebay for required pre-treatment, the forebay shall be volumetrically sized for 25% of the computed WQ_v. Otherwise, required pre-treatment shall be 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 stone 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.~~4.3.1.4. Bioretention ~~and Rain Garden~~ 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 as 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,~~Rip-rap or concrete walls, or ~~soil wraps~~approved equivalent 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~~shall 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~~a 24-48 inch-deep planting soil bed (depending on the 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)~~

Commented [ME36]: For guidance.

- ~~A~~The designer shall identify on the plan sheet that a soil phosphorus test using the Mehlich-3 ~~(or equivalent)~~ method, or equivalent, 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. The plan shall also identify that the~~A~~ record of the phosphorus test shall be maintained with design ~~and/~~or permit records for subsequent ~~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~~shall be 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 (ft²)
  T_V = Treatment volume (ft³)
  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, $Q_{P~~p~~10}$, and Q_{P100} shall be based on the treatment volume provided.

- For bioretention practices used primarily for filtering (e.g., underdrained), credit towards CP_V, Q_{P10}, and Q_{P100} ~~is~~shall be given ~~towards CP_V and Q_P~~ only for the void space in the stone 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.~~4.3.1.5. Bioretention ~~and Rain Garden~~ Vegetation and Landscaping

Required Elements:

- The entire contributing area ~~must~~shall be stabilized before runoff ~~can~~may 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~~A landscaping plan that provides soil stabilization and nutrient uptake ~~must~~shall be provided for bioretention areas ~~(see Appendix A, VSMM, Vol. 2)~~.

Commented [ME37]: For guidance.

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.

4.3.1.7. 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).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

4.3.2. Dry 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 stone 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.

Dry Swale Design Summary

Treatment Standard Applicability	
Recharge	Yes (if unlined)
Water Quality	Tier 1 (unlined)/ Tier 3 (lined)
Channel Protection	Hydrologic Condition Method (unlined)/ Extended Detention Method (lined)
Q_{P10} and Q_{P100}	Limited. CN_{Adj} may provide partial credit
Key Elements	
Feasibility: ▪ Maximum longitudinal slope of 2% without check dams. Slopes up to 6% allowed with check dams. ▪ Maximum side slopes of 2:1. ▪ Infiltration rate shall be ≥0.2 inches per hour as confirmed by methods in Section 4.3.3.2 if designed to infiltrate. ▪ SHGWT must be below bottom of the practice for water quality treatment. Separation to SHGWT for larger storm events varies based size of practice and volume designed to infiltrate.	
Pre-treatment: ▪ Forebay sized for 10% of the WQ_V or other pre-treatment as described in Section 4.1	
Treatment: ▪ Swale is underlain with a sand or filter media mix. If underdrained, filter media shall have a phosphorus index between 10 and 30 mg/kg.	

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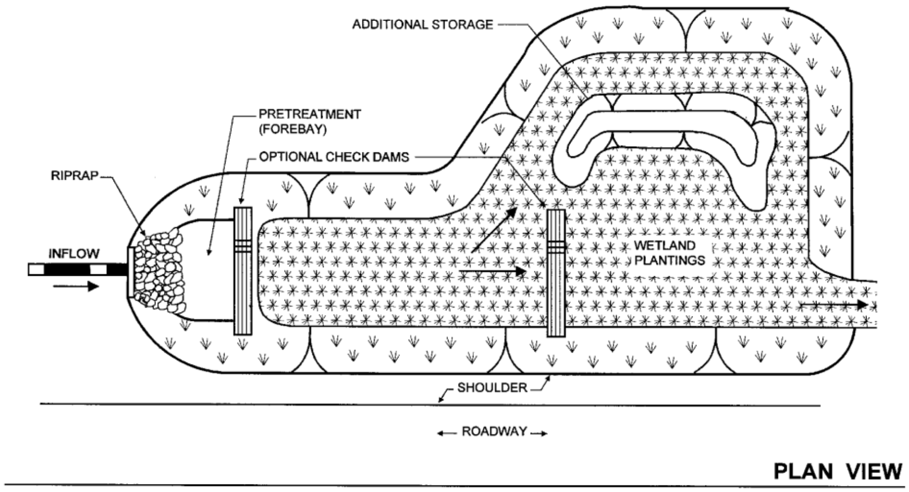
▪ Volume storage within practice, including pore space and ponding depth, is credited towards WQV. For infiltrating practices, this same treatment volume is applied to CP_V, Q_{P10}, and Q_{P100}. For underdrained practices, HC_V is limited to pore space below underdrain. ▪ Volume, including pre-treatment shall be a minimum of 100% the T_V. ▪ Maximum dewatering time of 48 hours
Other: ▪ Minimum 6-inch underdrain shall be provided if not designed to infiltrate.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

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 stone 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 stone 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. 2required
	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 stone 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.



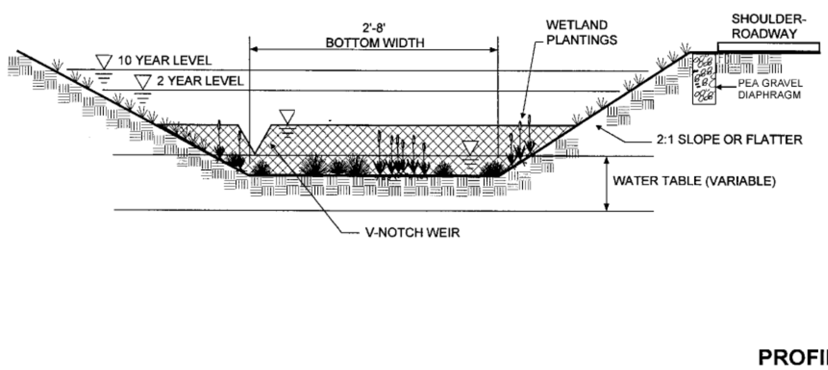


Figure 4-1723. Wet Swale

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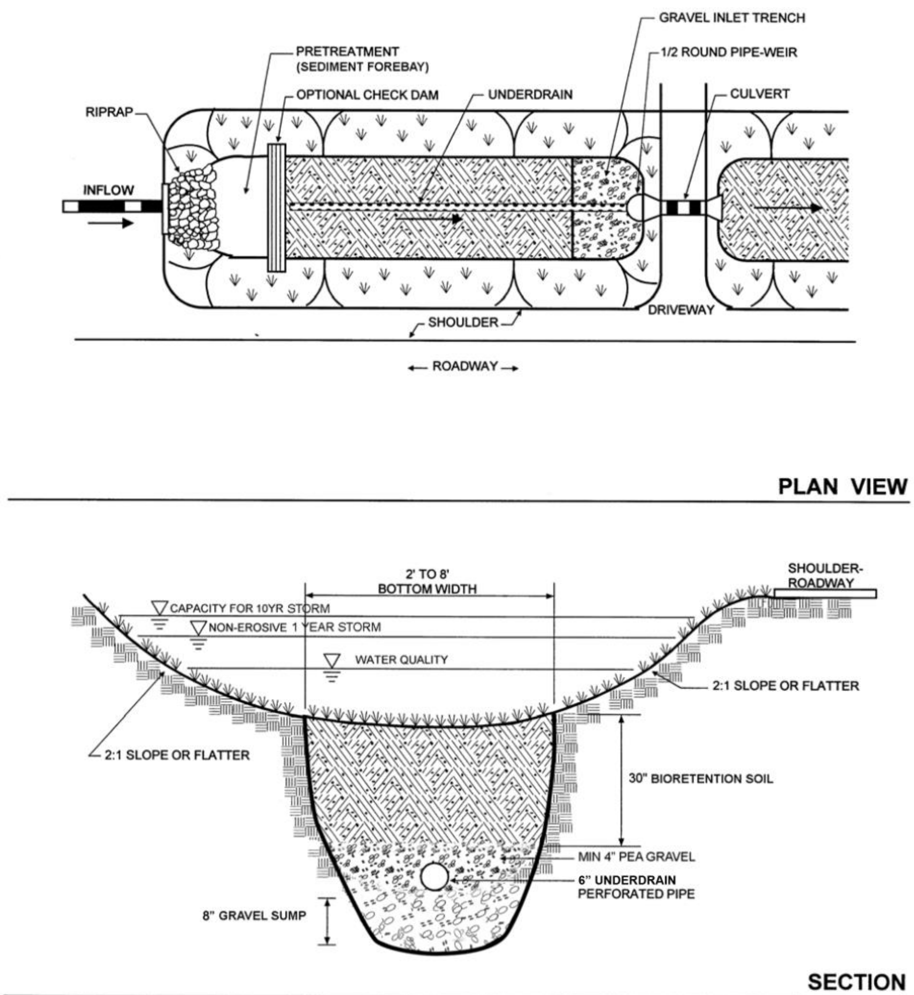

Adapted from MDE, 2000 and RI DEM, 2010

Figure 4-15~~4-18~~. Example of a Dry Swale with Underdrain and ~~Gravel~~ Sstone Sump

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4.3.2.1. Dry Swale Feasibility

Required Elements:

- ~~Open channels~~Dry swales constructed without check dams shall have a maximum longitudinal slope of 5%. 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 (SHGWT).

- 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 soil testing requirements for infiltration pursuant to~~in~~ Section 4.3.3.2~~field geotechnical tests.~~

- 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 the contributing drainage area to the practice is less than or equal to 1~~.0~~ acre, th~~a~~en there shall be a:
  - ~~-~~Minimum of 2 feet separation to SHGWT from the bottom of the dry swale system when the contributing drainage area (CDA) of 1~~.0~~ acre or less~~,~~ is greater than 50% impervious.
  - Minimum of 1 foot separation to SHGWT from the bottom of the dry swale system when the contributing drainage area (CDA) of 1~~.0~~ acre or less~~,~~ is less than or equal to 50% impervious.

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.

4.3.2.2. Dry Swale Conveyance

Required Elements:

- 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.
- Under-drained dry swales shall be equipped with a minimum 6~~"~~ inch perforated pipe underdrain (8~~"~~ inch is preferred) in a 1-foot stone layer. Synthetic filter fabrics shall not be used to completely separate the filter media from the underdrain bedding material. A 3-inch stone 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~~shall be non-erosive~~(~~, in other words 3.5-5 ft/s~~ Appendix C7, VSMM, Vol. 2)~~.

Commented [ME40]: For guidance.

- The swale shall have the capacity to convey the 10-year 24-hour storm event, at a minimum,~~larger storms (minimum 10-year 24-hour storm event)~~ safely with 6~~"~~ inches of freeboard.
- The channel immediately below a dry swale 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. stilling basin or outlet protection shall be used to reduce flow velocities from the principal spillway to non-erosive velocities of 3.5 to 5.0 fps.

Commented [ME41]: For guidance.

- Stormwater from dry swale outlets shall be conveyed to discharge location in non-erosive manner.
- ~~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~~Dry swales shall have a trapezoidal or parabolic cross section with side slopes less than or equal to 2H:1V.
- The longitudinal channel slope shall be less than or equal to 5.0%. If the site slope is greater than 5%, 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. The ~~D~~design requirements for check dams are as follows:

Commented [ME42]: For guidance.

  - ~~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~~shall be designed to facilitate easy mowing~~ (gravel check dams are discouraged)~~.
  - Check dams ~~must~~shall be firmly anchored into the side-slopes to prevent outflanking~~; check dams must also be~~ and 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~~shall be provided at the downstream toe of the check dam, if necessary, 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~~shall not extend above the elevation of the toe of the upstream check dam.
- Check dams composed of wood, concrete, or similar construction, shall have a weep hole or similar drainage feature so the check dam can dewater after a storm event.~~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.

4.3.2.3. Dry 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 a forebay for required pre-treatment, the forebay shall be volumetrically sized for 10% of the computed WQv. Otherwise, required pre-treatment shall be 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~~ stone 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.~~

4.3.2.4. Dry Swale Treatment

Required Elements:

- A dry swale storage volume of at least 75% of the design T_V~~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~~CP_v and Q_p.~~ for infiltrating dry swales, credit toward WQ_V, CP_V, Q_{P10} and Q_{P100} shall be based on the treatment volume provided. For underdrained and unlined practices, HC_V~~HC_v~~ credit is limited to pore space in the ~~gravel~~ stone 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~~A~~ 24-48~~"~~inch~~-~~deep ~~bioretention soil bed~~filter bed, a surface vegetation or mulch layer, and no more than a 12~~"~~ inch deep average surface ponding depth. Soil media shall either consist of a medium sand (meeting ASTM C- 33 concrete sand) or meet the specifications outlined for bioretention areas (Section 4.3.1 and Appendix B8, VSMM, Vol. 2).
- The designer shall identify on the plan sheet that a~~A~~ soil phosphorus test using the Mehlich-3 ~~(or equivalent)~~ method, or equivalent, is required for dry swale facilities using a bioretention soil mix 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 plan shall also identify that the record of the phosphorus test shall be maintained with design or permit records for subsequent design certification requirements.
- 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):~~Bioretention soil mix: 1.0 ft/day for sandy loam soils
    - Sand: 3.5 ft/day
      (Note: the above values are conservative to account for clogging associated with accumulated sediment)
- 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~~2 and ~~eight~~8 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~~WQv~~).
- 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~~WQv~~ is provided as with a 24" deep soil bed.

4.3.2.5. Dry Swale Vegetation and Landscaping

Required Elements:

- The entire contributing area ~~must~~shall be stabilized before runoff ~~can~~may 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 that provides soil stabilization and nutrient uptake ~~must~~shall 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~~may take the place of the landscaping plan.

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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).~~

~~4.3.2.6. 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.

4.3.2.7. 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.

4.3.2.8. 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.

~~4.3.4.~~4.3.3. Infiltration Trenches and Basins

Stormwater infiltration practices capture and store stormwater runoff, for the express purpose of allowing it to infiltrate into the soil. Structural infiltration practices can be used to meet the Groundwater Recharge Standard and Water Quality Treatment Standard, and when designed to accommodate larger volumes can be used to meet the Channel Protection Standard, and larger flood control standards. Infiltration STPs 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 and underground storage chambers~~)~~, that are properly sited and constructed in accordance with this ~~m~~Manual will not be required to obtain a separate permit under the Underground Injection Control Rules (see http://drinkingwater.vt.gov/wastewateruic.htm). Designers should review the infiltration feasibility requirements for structural infiltration systems related to set backs from groundwater source protection and wastewater disposal systems, and consult with the Agency's Drinking Water and Groundwater Protection Division in advance of designing a structural infiltration STP.

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

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~~4.3.4.1.~~ Infiltration Trench and Basin Design Summary

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Criteria	Element	Requirements
Feasibility	Soils	Infiltration rate of 0.2 in/hr or greater
	Slope	Natural site slope <15% None
	Water Table	Vertical separation by at least three feet from the bottom of the STP to 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.
	Groundwater Source Protection	100 feet set back from source in bedrock or confined unconsolidated aquifers. 50 feet set back from source in unconsolidated soils or unconfined unconsolidated aquifers. No structural infiltration STP sited within Zone 1 or Zone 2 of a public community groundwater source protection area. No structural infiltration STP sited within 200 feet of non-transient non-community groundwater source.
	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 24-hour storm event, or 100-year 24-hour storm if applicable
	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 infiltrate through bottom of practice
	Dewatering Time	Maximum dewatering time for designed 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 drainage area must be stabilized before stormwaer runoff is directed to facility

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	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

Treatment Standard Applicability	
Recharge	Yes
Water Quality	Tier 1
Channel Protection	Hydrologic Condition Method
Q_{P10} and Q_{P100}	Hydrologic Condition Method. Partial credit through CN_{Adj}.
Key Elements	
Feasibility: ▪ Infiltration rate shall be ≥0.2 inches per hour as confirmed by methods in Section 4.3.3.2. ▪ Separation to SHGWT of at least 3 feet from the bottom of the infiltration basin, trench, or chambers. Drywells shall have a separation of at least 1 foot from the SHGWT. ▪ Setbacks required for groundwater source protection and wastewater disposal systems.	
Pre-treatment: ▪ Forebay: ○ For infiltration rates ≤ 2 inches per hour sized for 25% of the WQ_V. ○ For infiltration rates >2 inches per hour, sized for 50% of the WQ_V. ▪ Other pre-treatment practice as described in Section 4.1	
Treatment: ▪ System shall be designed to infiltrate the T_V. Design T_V may be subtracted from the Re_V and WQ_V. The T_V may also be credited towards the CP_V, Q_{P10}, and Q_{P100} through the Hydrologic Condition Method. ▪ Observation wells shall be installed at least every 50 feet of practice length for infiltration trenches, dry wells, and subsurface infiltration systems, or as required by the manufacturer. ▪ Direct access shall be provided for maintenance.	
Other: ▪ Landscaping plan shall be provided.	
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.	

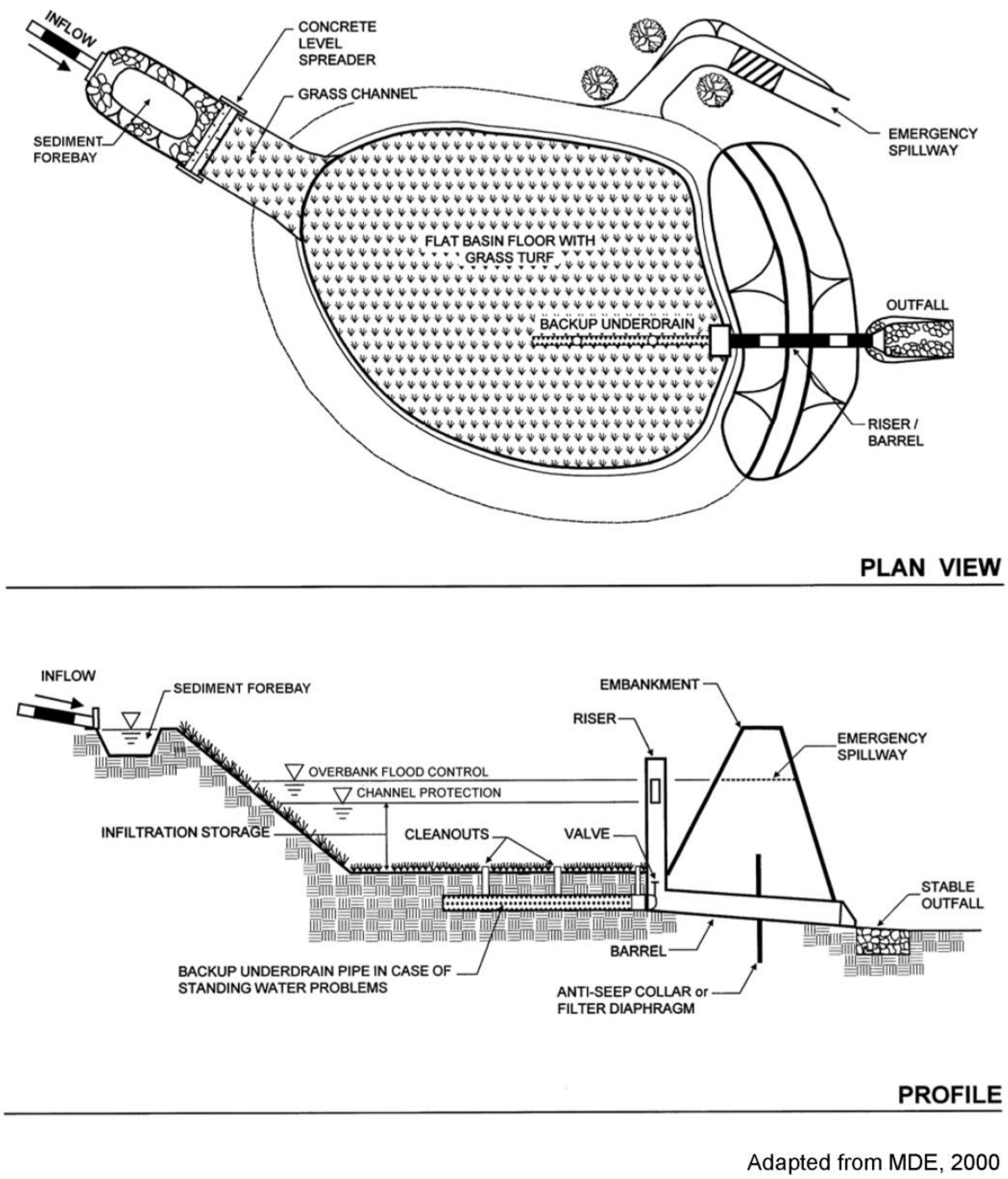

Figure 4-164-19. Example of Infiltration Basin

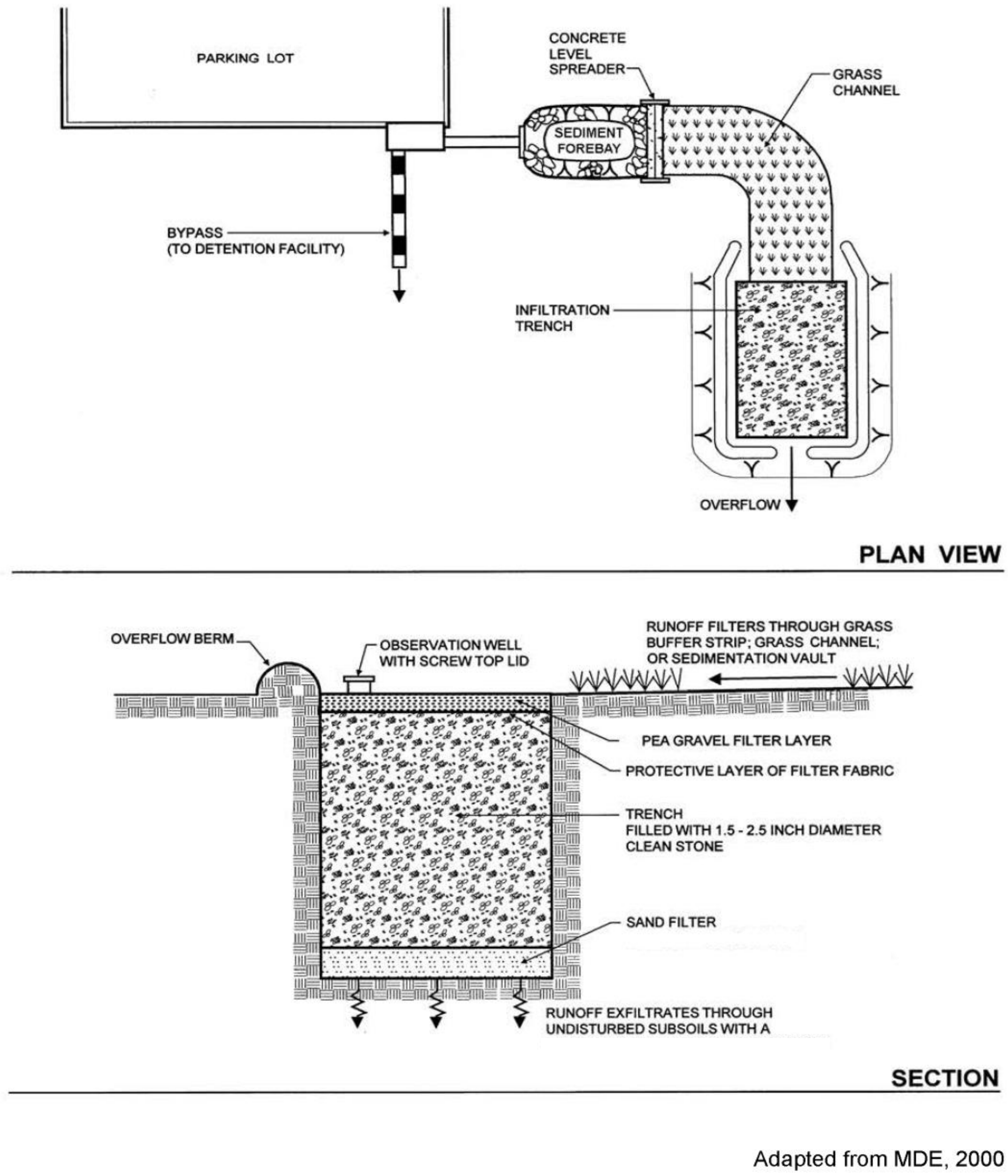

Figure 4-17~~4-20~~. Example of Infiltration Trench

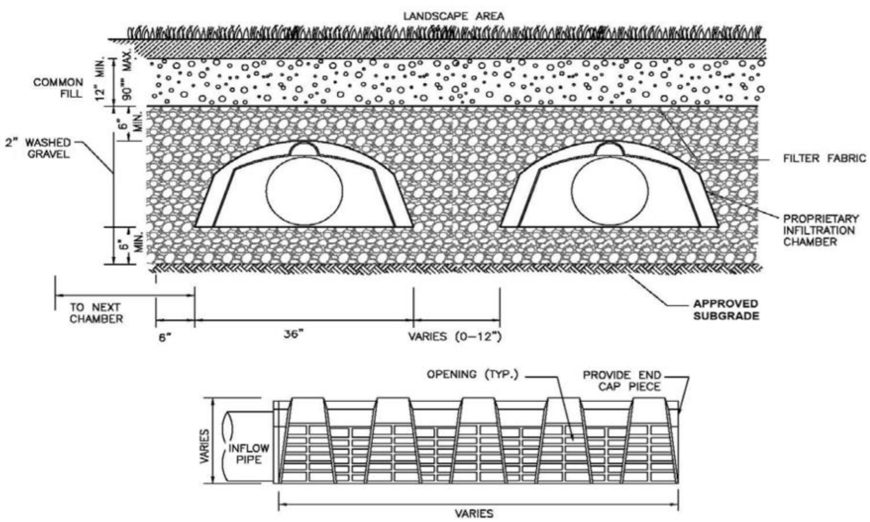

Figure 4-18~~4-21~~. Example of Underground Infiltration Chambers (Source: RI DEM, 2010)

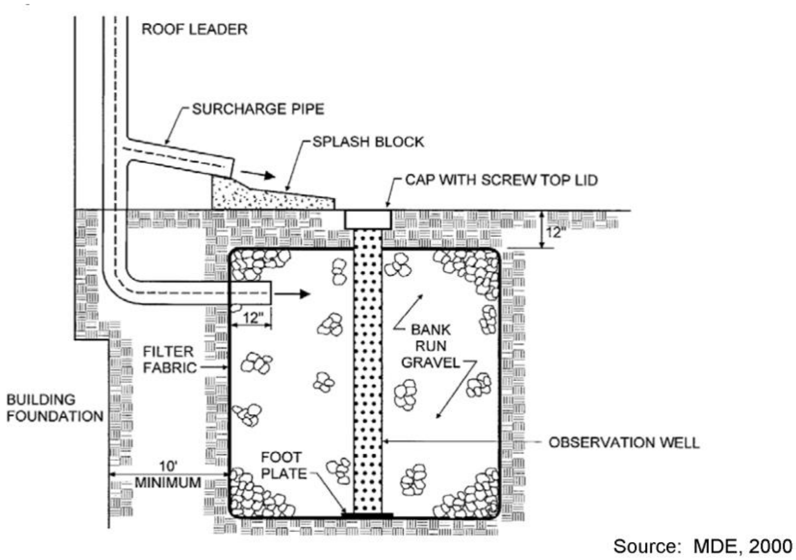

Figure 4-19~~4-22~~. Dry Well

~~4.3.4.2.~~4.3.3.1. Infiltration Feasibility

Required Elements:

- Underlying soils shall have an infiltration rate (f_c) of at least 0.2 inches per hour, as ~~confirmed~~ documented by ~~field geotechnical tests~~soil testing requirements for infiltration pursuant to Section 4.3.3.2 ~~(see Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements)~~.~~Infiltration practices cannot~~shall not ~~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~~3 feet vertically from the seasonal~~ly~~ high groundwater table (SHGWT) or bedrock layer, as documented by on-site soil testing. For ~~D~~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 practices that are designed to infiltrate more than the 1-year, 24-hour storm event ~~or greater~~ and that have a separation from the bottom of the practice to ~~seasonal high groundwater table (~~SHGWT~~)~~ of less than ~~four~~4 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).

- Infiltration basins shall have vegetated side slopes of 2:1 or flatter.

- The following set back requirements shall be observed for g~~G~~roundwater source protection:
    - 100 feet set back from source in bedrock or confined unconsolidated aquifers.
    - 150 feet set back from source in unconsolidated soils or unconfined unconsolidated aquifers.
    - No structural infiltration STP sited within Zone 1 or Zone 2 of a public community groundwater source protection area.
    - No structural infiltration STP sited within 200 feet of non-transient non-community groundwater source.~~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).~~
    - Designers shall refer to the Vermont Wastewater and Potable Water Supply Rules (or their replacement) for all applicable restrictions.

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- 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 shallshould 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 roadtraction sand used in winter maintenance can cause clogging and failure of the practices. Infiltration practices shall not be used for snow storage, as traction 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.

4.3.3.2. Soil Testing Requirements for Infiltration Practices

4.3.3.2.1. Introduction

- For structural infiltration-based practices including infiltration trenches and infiltration basins, permeable pavements, dry wells, and bioretention and dry swales designed to infiltrate, a minimum field infiltration rate (f_c) of 0.2 inches per hour shall be required. Areas yielding a lower infiltration rate preclude the design of these practices as infiltration systems.

- Soil testing shall be conducted by a qualified professional. This professional must either be a registered professional engineer or licensed Site Designer in the State of Vermont, or a qualified soil scientist, geologist, or hydrogeologist.

4.3.3.2.2. Infiltration Feasibility Analysis

A feasibility analysis shall be completed to determine whether full-scale infiltration testing is necessary, and is meant to screen unsuitable sites and reduce testing costs.

The infiltration feasibility analysis shall be representative of all variable site conditions present and the location evaluated for infiltrating, and be based on one or more of the following:

- NRCS Soil Survey mapping.

- Test pit(s) or soil boring(s).
- Previous written geotechnical reporting on the site location, as prepared by a qualified geotechnical consultant

If the results of the initial feasibility analysis indicate an infiltration rate of less than 0.2 inches per hour is probable, or the presence of a HSG D soil in the applicable areas of investigation, then no further analysis is necessary. If the results of initial feasibility testing indicate that an infiltration rate of greater than or equal to 0.2 inches per hour is probable and infiltration is otherwise considered feasible by any other requirement in this Manual, then the designer shall proceed with the soil characterization and infiltration testing requirements Sections 4.3.3.2.3 through 4.3.3.2.5.

4.3.3.2.3. Soil Characterization and Infiltration Testing

- The number of test pits and infiltration tests shall be:
    - For infiltration practices, 1 infiltration test and 1 test pit per 2,500 square feet of proposed practice area, or
    - For linear infiltration practices, 1 infiltration test and 1 test pit per 100 feet of proposed practice length.
- The location of the test pit or boring shall correspond to the facility location;

4.3.3.2.4. Test Pit Requirements

- Designer shall excavate a test pit or dig a standard soil boring to a depth of at least 1 foot below the required separation depth to the SHGWT of the proposed facility.
- The designer's soil descriptions shall include USDA or Unified Soil Classification System textures for all soil horizons. Soil profile descriptions shall be provided consistent with the Vermont Wastewater System and Potable Water Supply Rules, §1-902(b)(2) and Appendix 2-A, or their replacement.
- The designer shall verify that the depth to groundwater table and the depth to bedrock meet the separation distance required of the proposed practice.

4.3.3.2.5. Infiltration Testing Requirements

Field infiltration test methods to assess saturated hydraulic conductivity shall simulate the "field-saturated" condition (see ASTM D5126-90 *Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone*). Infiltration tests shall be conducted at the depth of the bottom of the proposed infiltrating practice. Design infiltration rates shall be determined by using a factor of safety of 2 from the field-derived value. Percolation tests shall not be used in place of testing for saturated hydraulic conductivity, as they overestimate saturated hydraulic conductivity values. One or more of the following methods shall be used:

- Guelph permeameter - ASTM D5126-90 Method
- Falling head permeameter – ASTM D5126-90 Method
- Double ring permeameter or infiltrometer - ASTM D3385-09, D5093-02, D5126-90 Methods
- Amoozemeter or Amoozegar permeameter – Amoozegar 1992
- Borehole Infiltration Test as described below:

- Install casing (solid 6-inch diameter) to 24 inches below proposed practice bottom.
- Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a 2-inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with clean water to a depth of 24 inches and pre-soak for 24 hours.
- 24 hours later, refill casing with another 24 inches of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure, filling the casing each time 3 additional times, for a total of 4 observations. Upon the tester's discretion, the final field rate may either be the average of the 4 observations, or the value of the last observation. All observations shall be reported. The final rate shall be reported in inches per hour.
- This test may be completed in a soil boring or in an open excavation.
- Upon completion of the testing, the casings shall be immediately pulled, and the test pit back-filled.

- Equivalent method approved by the Agency.

4.3.4.3.4.3.3.3. 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 ((of 3.5-5.0 ft/s, see Appendix D7, VSMM, Vol. 2) for the 1-year storm event, an overflow channel to a stableilized watercourse conveyance 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 1.1.1.1).

Commented [ME49]: For guidance.

- For infiltration basins and trenchespractices, adequate stormwater outfall protections shall be provided for the overflow associated with larger storm events, the 1-year, 10-year, and 100-year design storm events, as applicable (the design shall provide for non-erosive velocities on the down-slope).
- Stormwater from infiltration system overflow shall be conveyed to discharge location in non-erosive manner.
- 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 mustshall be designed as an off-line practice, except when used to also meet CP_V, Q_{P10}, and Q_{P100}.

Design Guidance:

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

~~4.3.4.4.~~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 WQv.~~
- 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 pre-treatment chambers flowing over vegetated channels shall be non-erosive ~~(~~, in other words 3.5 to 5.0 fps~~)~~, during the 1-year design storm (Appendix C7, VSMM, Vol. 2).
- Infiltration basins or trenches shall have robust pre-treatment methods to ensure the long-term integrity of the infiltration rate. This ~~must~~shall 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 separated at least ~~three~~3 feet vertically from the SHGWT if located over permeable soils.
  - Deep sump catch basin, AND one of the following:
    - Upper sand layer (6~~"~~ inches minimum with filter fabric at the sand/gravel interface); or
    - Washed stone (1/8~~"~~ inch to 3/8~~"~~ inch)
  - Proprietary device
- Provide a fixed vertical sediment marker to measure depth of accumulated sediment.

~~4.3.4.5.~~4.3.3.5. Infiltration Treatment

Required Elements:

- Infiltration practices shall be designed to exfiltrate the entire T_V and sized using TR-20 or approved equivalent method.~~through the floor of each practice (sides are not considered in sizing) in soil horizons (not through bedrock).~~

Commented [ME50]: For guidance.

- An observation well shall be installed in every infiltration trench, ~~- and~~ dry well, and subsurface infiltration system 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. Observation wells shall be installed every 50 feet or as otherwise required by manufacturers specifications.~~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.~~

Design Guidance:

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

$$A_p = \frac{T_v}{nd_t + f_c T/12}$$

Where:

A_p = practice surface area (ft^2)
T_V ~~T_v~~ = design treatment volume (e.g., WQ_V, CP_V ~~CP_v~~, or Q_P ~~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:

$$A_b = \frac{2T_v - A_t d_b}{d_b - (P/6)\,\sout{P/6} + (f_c T/6)\,\sout{f_c T/6}}$$

Where:

A_b = surface area at the bottom of the basin (ft^2)
T_V ~~T_v~~ = design treatment volume (e.g., WQ_V, CP_V ~~CP_v~~, Q_P ~~Q_p~~)(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~~T_v~~	=	design treatment volume (e.g., WQ_v, CP_v~~CP_v~~, or Q_p~~$_p$~~) (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 C~~p~~P_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~~ stone 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.

~~4.3.4.6.~~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~~ Contributing drainage areas shall be stabilized~~over the contributing pervious drainage areas~~ before runoff can be routed ~~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 to stabilize soils and provide nutrient uptake.

Design Guidance:

~~4.3.4.7.~~ The selection of upland landscaping materials should include ~~salt-tolerant~~native plants and grasses where appropriate.~~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.~~

~~4.3.4.8. 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.~~

4.3.4.9. 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.

~~4.3.5.~~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.

4.3.5.1. Filter System Design Summary

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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.

Treatment Standard Applicability	
Recharge	Yes (if unlined)
Water Quality	Tier 1 (unlined)/ Tier 3 (lined)
Channel Protection	Hydrologic Condition Method (unlined)/ Extended Detention Method (lined)
Q_{P10} and Q_{P100}	Limited. CN_{Adj} may provide partial credit
Key Elements	
Feasibility: ▪ Infiltration rate shall be ≥0.2 inches per hour as confirmed by methods in Section 4.3.3.2 if designed to infiltrate.	

▪ SHGWT must be below bottom of the practice for water quality treatment. Separation to SHGWT for larger storm events varies based size of practice and volume designed to infiltrate.
Pre-treatment: ▪ Forebay sized for 25% of the WQ_V or other pre-treatment as described in Section 4.1
Treatment: ▪ Filter media is ≥18 inches of medium sand for filter beds. Perimeter filters shall have ≥ 12 inches of sand. ▪ Filter bed is designed according to Darcy's Law. Storage volume (including pre-treatment) shall be at least 75% of T_V. ▪ T_V is credited towards WQ_V. For infiltrating practices, this same treatment volume is applied to Re_V, CP_V, Q_{P10}, and Q_{P100}. For underdrained practices, HC_V is limited to pore space below underdrain. ▪ Maximum dewatering time of 48 hours.
Other: ▪ Minimum 6-inch underdrain shall be provided if not designed to infiltrate.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

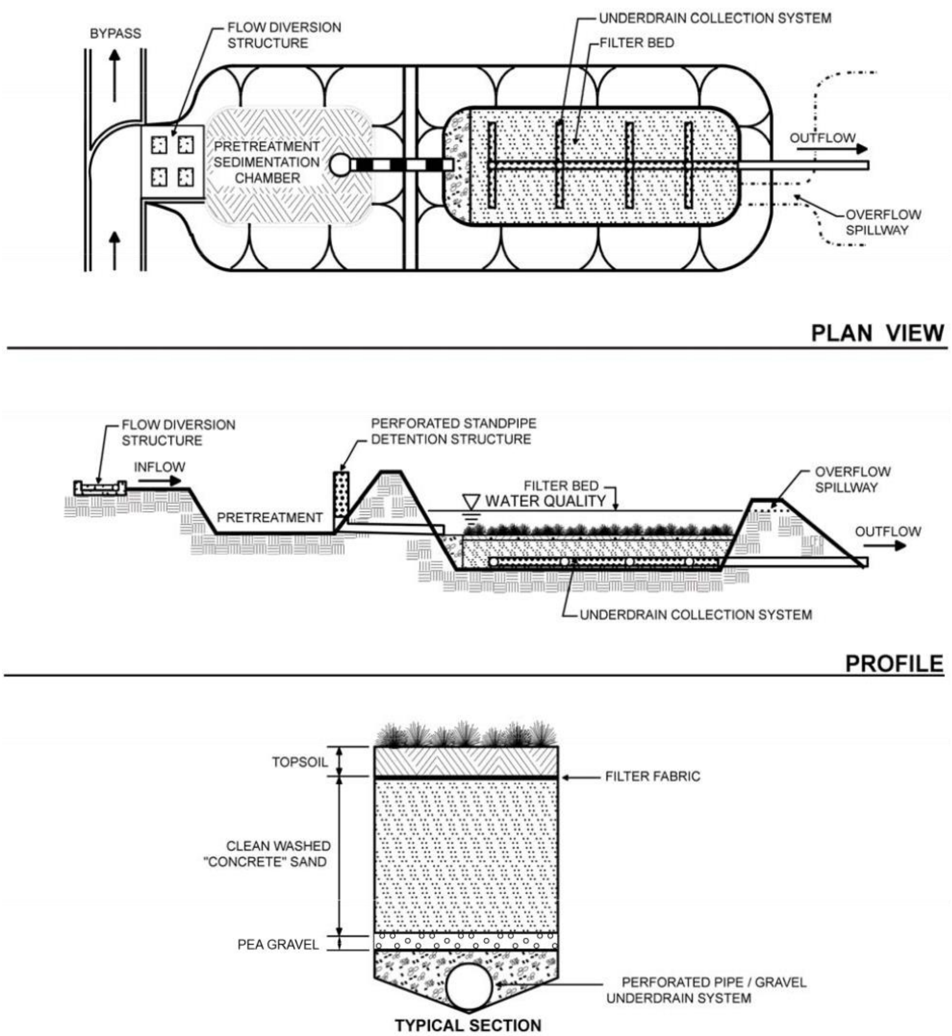

Figure 4-20~~4-23~~. Surface Sand Filter

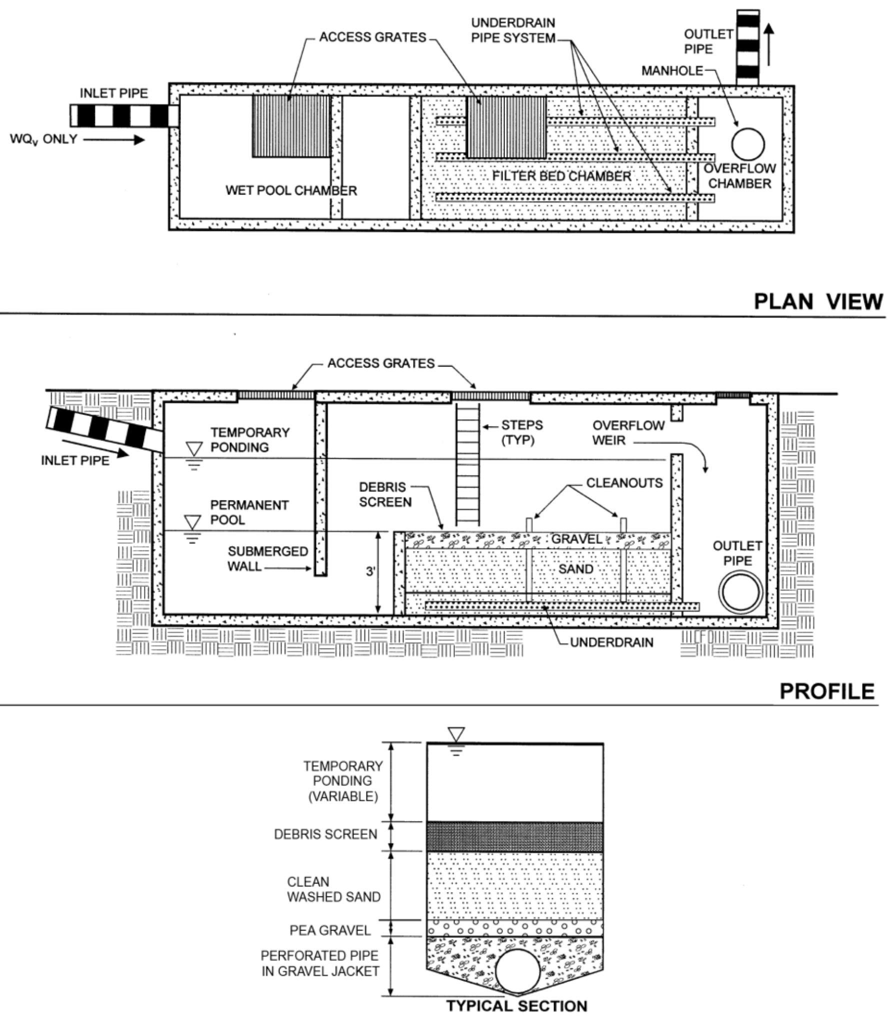

Figure 4-21~~4-24~~. Underground Sand Filter

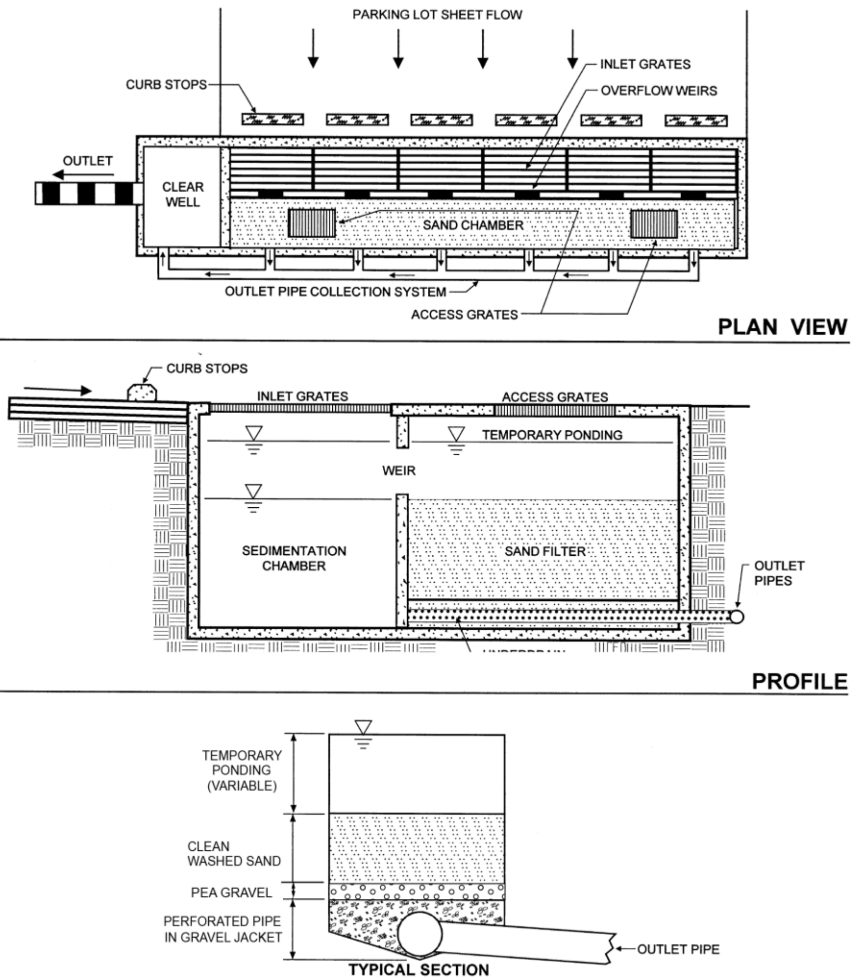

Figure 4-224~~-25~~. Perimeter Sand Filter

~~4.3.5.2.~~4.3.4.1. 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 0.2 inches per hour, as confirmed by soil testing requirements for infiltration pursuant to~~in~~ Section 4.3.3.2~~see Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements)~~.

Commented [ME51]: For guidance.

- For filtering practices designed to infiltrate stormwater, ~~relevant~~applicable feasibility required elements for infiltration trench~~/~~ and basin practices ~~must~~shall also be met (Section 4.3.3.1~~4.3.3~~). The separation to SHGWT requirements identified in Section 4.3.3.1~~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, th~~a~~en there shall be a:
  - Minimum of 2 feet separation to SHGWT from the bottom of the filtering system when the contributing drainage area (CDA) of 1~~.0~~ acre or less~~,~~ is greater than 50% impervious.
  - Minimum of 1 foot separation to SHGWT from the bottom of the filtering system when the 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 traction ~~road~~ sand for de-icing), will require more aggressive sedimentation pretreatment techniques.

~~4.3.5.3.~~4.3.4.2. 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 stable conveyance~~stabilized water course~~. Designers ~~must~~shall indicate how on-line filtering practices will safely pass the 10-year storm without re-suspending or flushing previously trapped material.

- To prevent ~~downstream slope~~ erosion, ~~A~~an overflow for the 10-year storm shall be provided to a non-erosive outlet point ~~(i.e., prevent downstream slope erosion)~~.
- Stormwater from filtering system outlets shall be conveyed to discharge location in non-erosive manner.
- Stormwater filters shall be equipped with a minimum 6~~"~~ inch perforated pipe underdrain (8~~"~~ inch is preferred) in a 1-foot stone layer. Synthetic filter fabrics shall not be used to completely separate the filter media from the underdrain bedding material. A 3-inch stone 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.

~~4.3.5.4.~~4.3.4.3. 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.,~~, for example via a closed pipe system or grass channel~~)~~, and provided the runoff is not commingled with other runoff.

Required Elements:

- If stormwater is routed to a forebay for required pre-treatment, the forebay shall be volumetrically sized for 25% of the computed WQ_v. Otherwise, required pre-treatment shall be 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

~~4.3.5.5.~~4.3.4.4. 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 as within the filter media – is required ~~in order~~ to capture the volume from high-intensity storms prior to filtration and to avoid premature bypass.
- Filter media shall consist of a medium sand (~~meeting~~ ASTM C- 33 concrete sand) or approved equivalent.

- The filter bed shall have a minimum depth of 18" inches. The perimeter filter shall have a minimum filter bed depth of 12" inches.
- The filter area for sand filters shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) shouldshall 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 isshall be 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.

4.3.5.6.4.3.4.5. Filtering Vegetation and Landscaping

Required Elements:

- The entire contributing area mustshall 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:

4.3.5.7. 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.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 gravelstone 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 uniform stone (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.

4.3.5.8. 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.

4.3.5.9. 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.~~

~~4.3.6.~~4.3.5. 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-inch 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.

Treatment Wetland 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 WQv. 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. No treatment credit applied toward Recharge Standard or Hydrologic Condition Method.
	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. No treatment credit applied toward Recharge Standard or Hydrologic Condition Method.
	Geometry (length to width ratio)	Minimum flowpath of 11:1
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

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		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.

Treatment Standard Applicability	
Recharge	No
Water Quality	Tier 3
Channel Protection	Extended Detention Method
Q_{P10} and Q_{P100}	Yes
Key Elements	

Pre-treatment:

- Forebay sized for 10% of the WQ_V or other pre-treatment as described in Section 4.1.

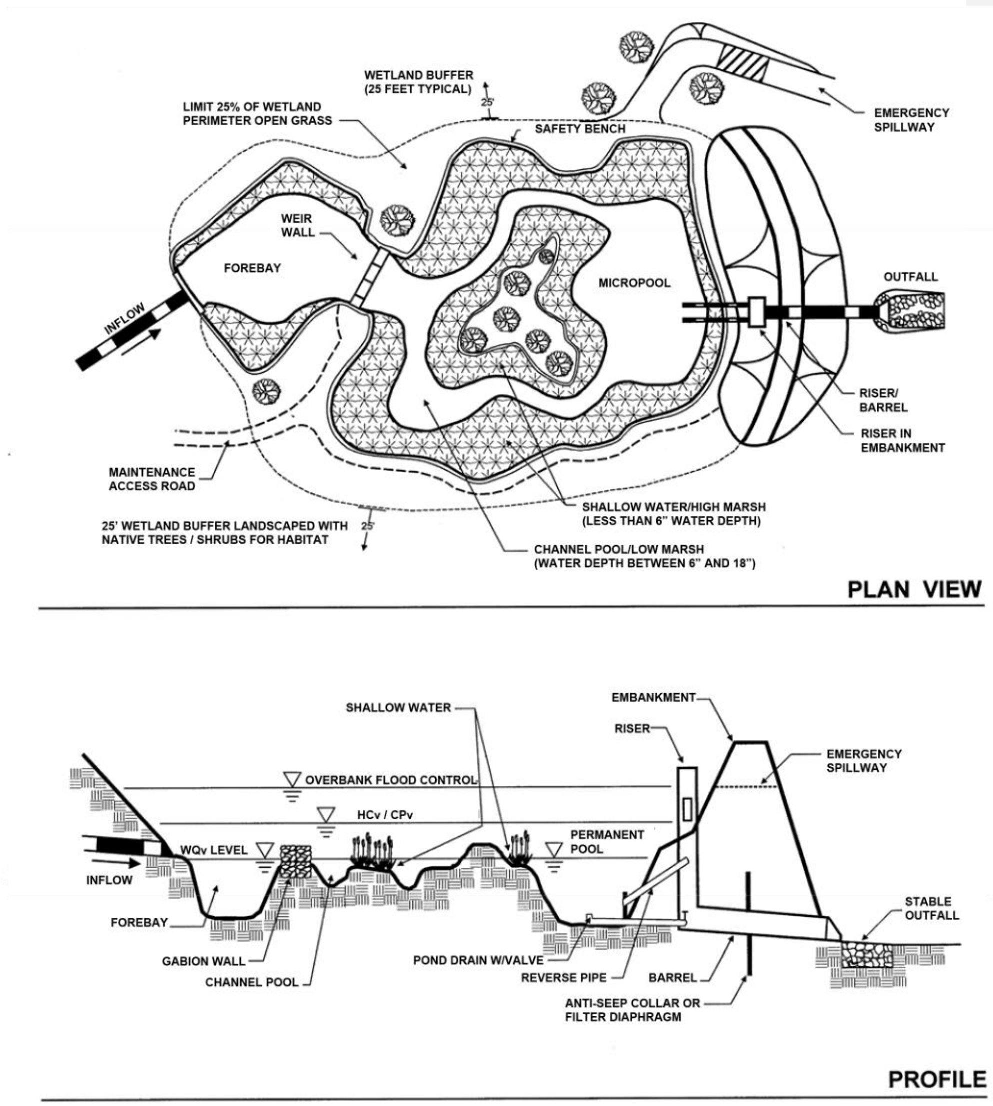
Treatment:

- Shallow Surface Treatment Wetlands
  - Minimum 35% of the WQ_V shall be less than 6 inches deep. A minimum of 65% of the WQ_V shall be less than 18 inches deep.
  - At least 25% of the WQ_V shall be provided in deep water zones greater than 4 feet deep
  - Minimum length to width ratio of 2:1.
- Gravel Wetlands
  - WQ_V is stored in a combination of gravel storage and extended detention. Extended storage shall not exceed 50% of the WQ_V.
  - Minimum length to width ration of 1:1. Minimum flow path within the gravel substrate is 15 feet.

Other:

- Shallow surface treatment wetlands discharging to cold water fisheries shall be designed to discharge storms up to and including the CP_V through a gravel trench outlet.
- A liner is required if underlying soils have an infiltration rate >0.05 inches per hour.
- 10-foot safety bench around deep pool areas (4 feet or deeper) extending outward from normal water surface, unless side slopes are 4:1 or shallower.
- 5-foot aquatic bench required extending ≥5 feet inward from normal water surface.

Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.



Adapted from MDE, 2000 and RIDEM, 2010

Figure 4-234-32. Shallow Surface Treatment Wetland

~~4.3.6.1.~~4.3.5.1. Treatment 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 DepartmentAgency.~~

- Shallow surface treatment wetlands ~~discharges~~ discharging directly to cold-water fishery streams shall be designed to discharge up to and including the CP_v through an underdrained stone trench outlet~~(~~. ~~g~~Gravel wetlands are not subject to the stone trench outlet requirement~~)~~. Additional storage for Q~~p~~$_{P10}$ and Q~~p~~$_{P100}$ 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 Department 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.

~~4.3.6.2.~~4.3.5.2. Treatment 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~~shall be stabilized to ensure that non-erosive conditions exist for at least the 1-year design ~~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 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 WQ_V.

- 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 ~~(~~of 3.5 to 5.0 fps, see Appendix C7, VSMM, Vol. 2).

Commented [ME53]: For guidance.

- Stormwater from treatment wetland outlets shall be conveyed to discharge location in non-erosive manner.
- A subsurface water level ~~must~~shall be maintained in the gravel 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~~)~~, then a liner is required. The acceptable liner 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 stone trench ~~(**Error! Reference source not found.**Figure 4-25)~~ shall be designed to meet the following requirements:
  - The trench ~~S~~shall be at least ~~four~~4 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~~cubic feet of extended detention storage volume, have a depth of at least 3 feet, and maintain 2 feet of stone cover over a 6-inch diameter perforated pipe outlet ~~(Rigid Sch. 40 PVC or SDR35)~~;
  - ~~Shall utilize g~~Geotextile fabric shall be placed between the stone trench and adjacent soil; and
  - ~~Shall utilize c~~Clean, uniformly-sized stone ~~size~~ shall be used.

Commented [ME54]: For guidance.

~~4.3.6.3.~~4.3.5.3. 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 WQ_V. Otherwise, required pre-treatment shall be designed in accordance with Section 4.1. Forebay storage volume shall count~~s~~ toward the total WQ_V 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 ~~(~~, in other words 3.5 to 5.0 fps~~)~~, during the 1-year design storm (Appendix C7, VSMM, Vol. 2).

Commented [ME55]: For guidance.

Design Guidance:

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

~~4.3.6.4.~~4.3.5.4. Treatment Wetland Treatment

Required Elements:

- ~~For s~~S**hallow 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 WQ_v shall be provided in a sediment forebay if used for pre-treatment. At least 25% of the WQ_v shall be provided in "deep water zones" with a depth equal to or greater than 4 feet. The remaining WQ_v shall be provided ~~in some~~through a combination of shallow permanent pool ~~(~~with 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 WQ_v and shall drain over 24 hours.
  - ~~For s~~Shallow surface treatment wetlands~~:~~ shall have a length to width ratio of 2:1 (L:W).
- ~~For g~~G**ravel wetlands**~~:~~.
  - At least 10% of the WQ_v shall be provided in a sediment forebay if used for pre-treatment. The remaining WQ_v shall be provided ~~in some~~through a 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 WQ_v and shall drain over 24 hours.
  - ~~For a g~~Gravel wetland~~:~~s shall have a length to width ratio of 1:1 (L:W) or greater ~~is~~as needed for each treatment cell, with a minimum flow path (L) within the gravel substrate of 15 feet.
- Shallow surface wetlands and gravel wetlands do not achieve runoff reduction and therefore do not receive a treatment volume credit toward the Groundwater Recharge Standard or the Hydrologic Condition Method of the Channel Protection Standard. The practice may be used to meet the Water Quality Treatment Standard, the Overbank Flood Control Standard, and the Extreme Flood Control Standard.

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 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.

~~4.3.6.5.~~4.3.5.5. 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 4-24):

    - Except when side slopes are 4:1 (H:V~~h:v~~) or flatter, ~~provide~~ a safety bench shall be provided that ~~generally~~ extends 10~~5~~ feet~~.~~ outward ~~(a 10 ft. minimum bench is allowable on sites with extreme space limitations at the discretion of the approving DepartmentAgency)~~ from the normal water edge to the toe of the treatment wetland side slope. ~~A 10 foot minimum bench may be allowed on sites with extreme space limitations on a case-by-case basis at the discretion of the Agency.~~ The maximum slope of the safety bench shall be 6%; and

    - ~~Incorporate a~~An aquatic bench shall be incorporated that ~~generally~~ extends at least~~up~~ 5 ~~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.

    -

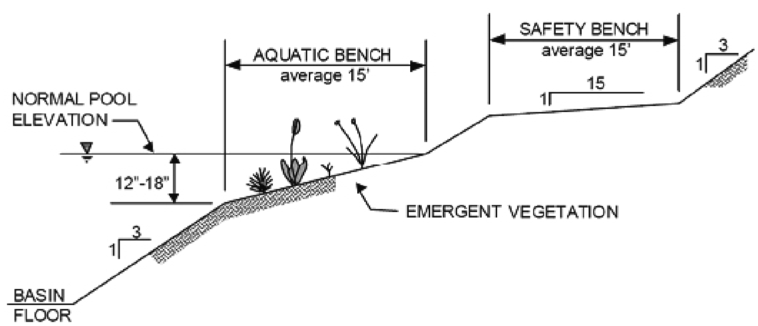


Figure 4-24~~4-35~~. Typical Shallow Treatment Wetland Bench Geometry (ARC, 2001 and RIDEM, 2010)

- 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.

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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.~~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.
- 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 stone 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 gravelstone.
- 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.

~~4.3.7.~~4.3.6. Wet Ponds

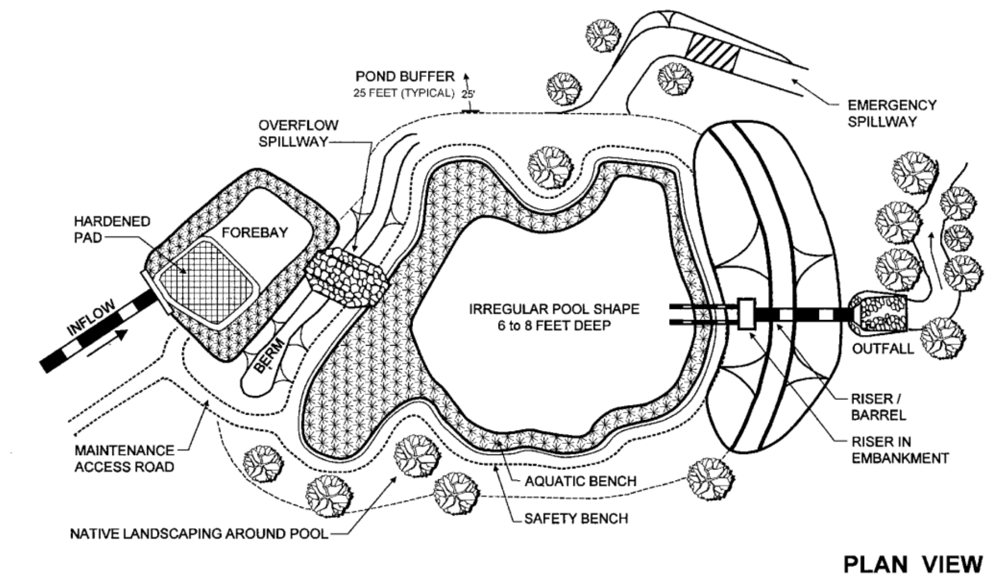
Wet ponds consist of a permanent pool of standing water that promotes a stable environment for gravitational settling, biological uptake, and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension 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_{P10}, and Q_{P100} requirements.

Wet Pond Design Summary

Treatment Standard Applicability	
Recharge	No
Water Quality	Tier 3
Channel Protection	Extended Detention Method
Q_{P10} and Q_{P100}	Yes
Key Elements	
Pre-treatment: ▪ Forebay sized for 10% of the WQ_V or other pre-treatment as described in Section 4.1.	
Treatment: ▪ At least 25% of the WQ_V shall be in deep water zones. ▪ Extended storage shall not exceed 50% of the WQ_V. ▪ Minimum length to width ration of 3:1.	
Other: ▪ Wet ponds discharging to cold water fisheries shall be designed to discharge storms up to and including the CP_V through a gravel trench outlet. ▪ 10-foot safety bench around deep pool areas (4 feet or deeper) extending outward from normal water surface, unless side slopes are 4:1 or shallower. ▪ 5-foot aquatic bench required extending ≥5 feet inward from normal water surface.	
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.	

~~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~~ stone ~~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 a forebay for required pre-treatment, forebay volumetrically sized for 10% of the computed WQv. Otherwise, required pre-treatment designed in accordance with Section 4.1.~~
~~Pre-Treatment~~	~~Permanent pool~~	~~Minimum of 50% of WQv is stored in permanent pool. 50% of the WQv can be as extended detention above the permanent pool.~~
~~Treatment~~	~~Extended Detention Volumes~~	~~Extended Detention (ED) storage volume shall not exceed 50% of the WQv~~
	~~Permanent pool depth zones~~	~~25% of the WQv in deepwater zones. The remaining 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.~~
	~~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.~~



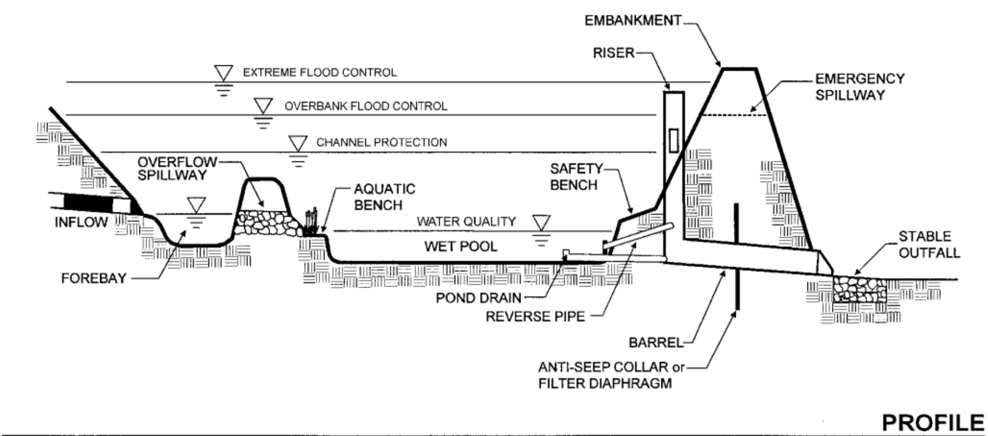


Figure 4-254-30. Wet Pond

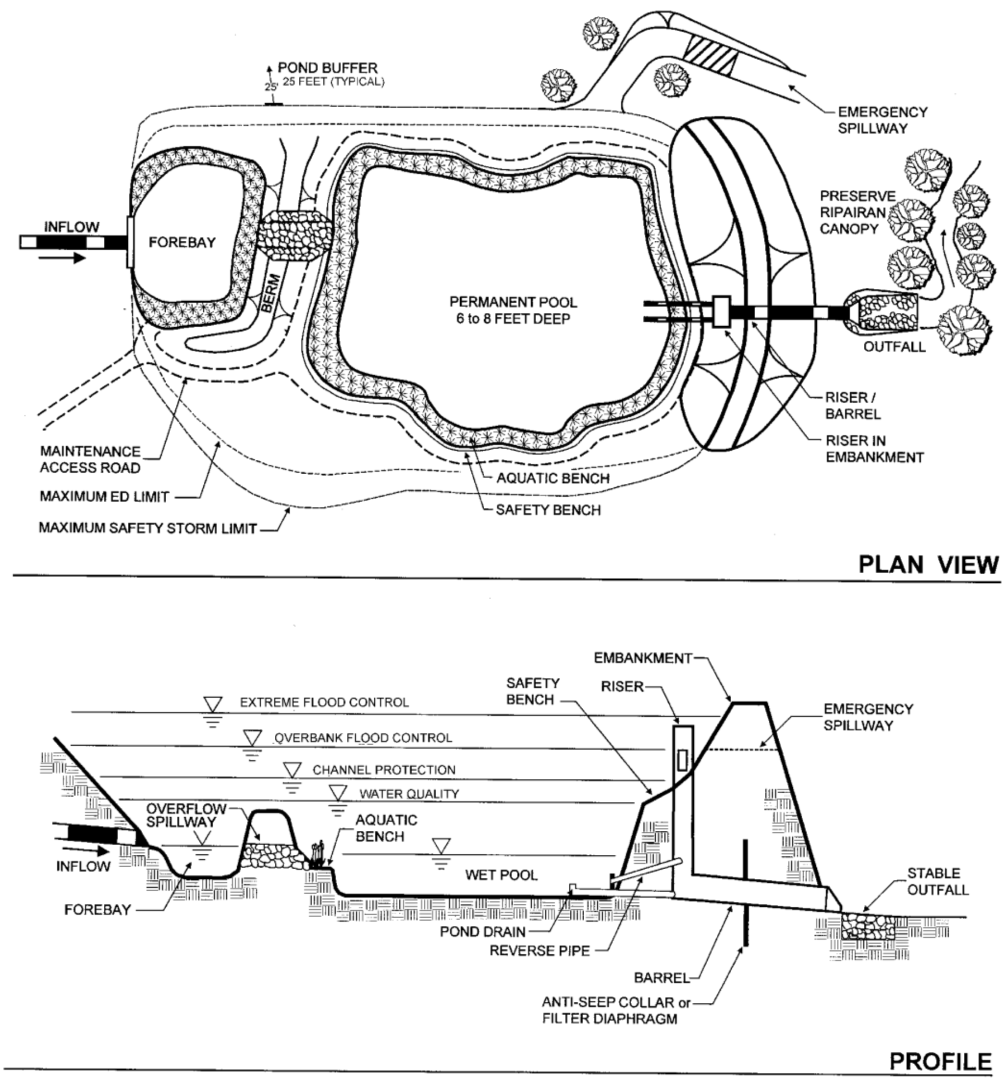


Figure 4-264-31. Wet Extended Detention Pond

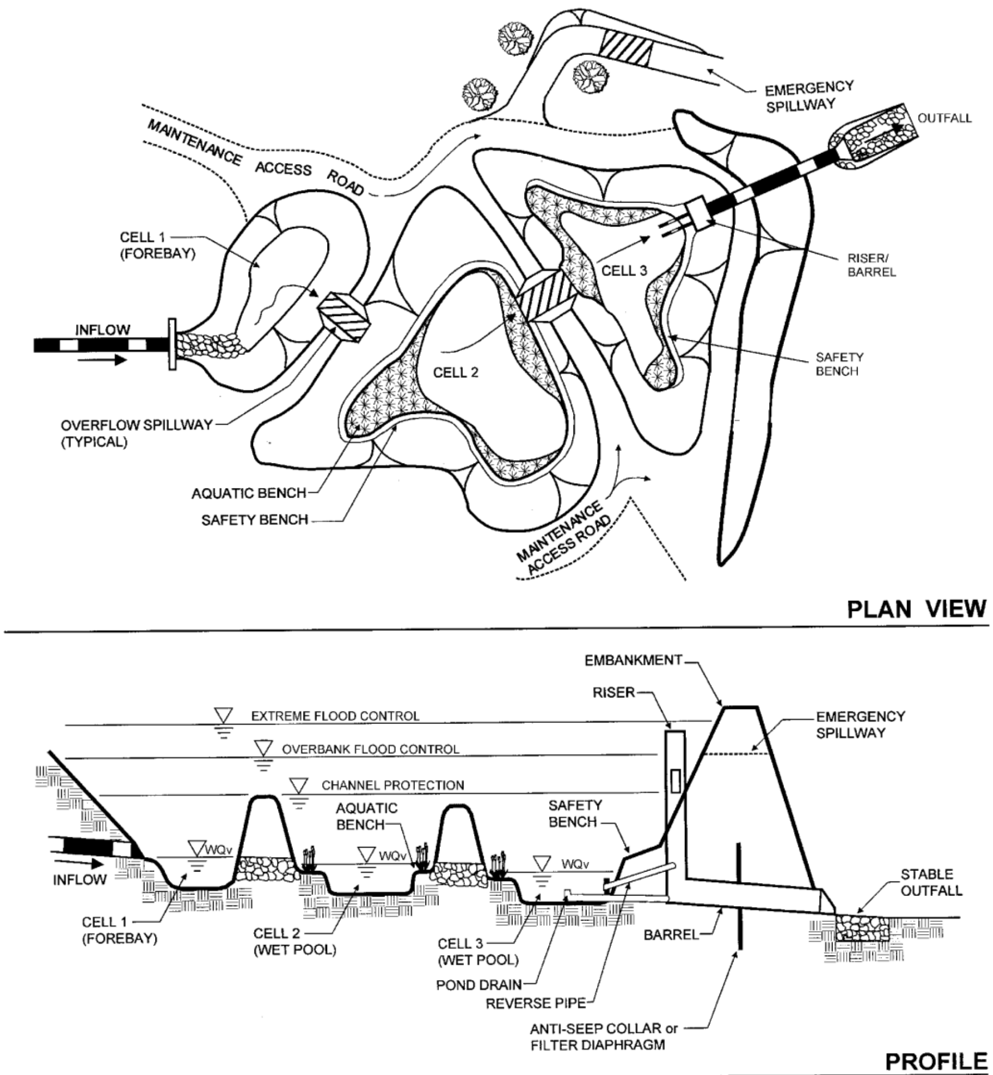


Figure 4-274-32. Multiple Pond System

~~4.3.7.1.~~4.3.6.1. 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 DepartmentAgency.~~

- ~~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~~shall 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.

~~4.3.7.2.~~4.3.6.2. 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 under-drained stone trench outlet~~ (**Error! Reference source not found.**Figure 4-25)~~ that meets the following requirements:
  - The trench shall be excavated in a pond bench having a minimum width of 8 feet. The trench ~~must~~shall be ~~four~~4 feet wide, located at least ~~two~~2 feet laterally from the permanent pool on the pond side of the bench~~(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~~shall 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 ~~ft³~~cubic feet of extended detention storage volume, have a depth of at least 3 feet, and maintain 2 feet of stone cover over and 6 inches below a 6-inch diameter perforated pipe outlet ~~(Rigid Sch. 40 PVC or SDR35);~~;
  - ~~Shall utilize g~~Geotextile fabric shall be placed between the sides of the stone trench and adjacent soil; ~~and,~~
  - ~~Shall utilize c~~Clean, uniformly-sized stone shall be used; and
  - The pond outlet or orifice shall be designed to prevent clogging and to allow access to the underdrain outlet for inspection and maintenance.

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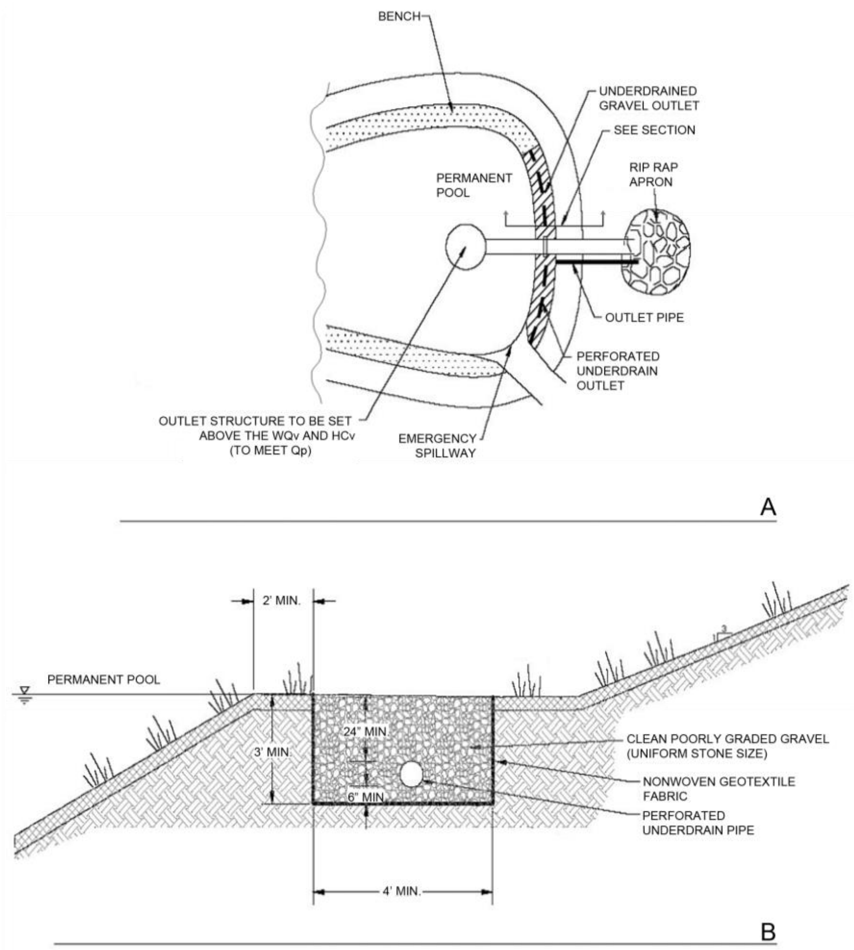

Figure 4-28: (A) Generalized plan view of underdrained stone trench outlet for a shallow treatment wetland or basin and (B) Profile of underdrained stone trench (adapted from Maine DEP 2006 and RI DEM 2010)

- Additional storage for Q_{P10} and Q_{P100} may be discharged through traditional basin outlet structures.
- The design ~~must~~shall specify an outfall that will be stable for the Q_{10} design storm event.
- The channel immediately below a wet pond 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~~,~~ of 3.5 to 5.0 fps (see Appendix C7, VSMM, Vol. 2).

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- Stormwater from wet pond outlets shall be conveyed to discharge location in non-erosive manner.
- The outlet control structure shall be located within the embankment for maintenance access and safety.
- All basins shall have an emergency spillwayoutlet, maintaining at least one1 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. and must be a minimum of 8-feet wide and 1-foot deep, with 2:1 channel side slopes.
- Emergency spillways (those placed above the water elevation of the largest managed storm) are required, if not already provided as part of the conveyance offor the 100-year storm event.
- The principal spillway opening shall not permit access by small children, and eEndwalls above pipe outfalls greater than 3048 inches in diameter shall be fenced with pipe or rebar at 8-inch intervals to prevent a hazard.
- If pond draining is required for any reason, the pond shall be drained in a non-erosive fashion and with consideration of impacts to downstream properties.

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.

~~4.3.7.3.~~4.3.6.3. Wet Pond Pre-Treatment

Required Elements:

- Each wet pond shall have a sediment forebay ~~volumentrically~~ sized to contain ~~for~~ at least 10% of the WQv. Otherwise, pre-treatment shall be provided 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:

If winter road sanding is prevalent in the contributing drainage area, increase the forebay size to 25% of the WQv ~~WQv~~ to accommodate additional sediment loading.

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

~~4.3.7.4.~~4.3.6.4. Wet Pond Treatment

Required Elements:

- At least 25% of the WQv shall be provided in "deep water zones" with a depth equal to or greater than ~~four~~4 feet, but not more than ~~eight~~8 feet. As required above, at least 10% of the WQv shall be provided in a sediment forebay or other pretreatment practice. The remaining 65% of the WQv shall be provided in some combination of shallow permanent pool ~~(~~with 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 WQv.
- 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~~shall 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.

4.3.7.5.4.3.6.5. Wet Pond Vegetation and Landscaping

Required Elements:

- The perimeter of all deep pool areas (of four4 feet or greater in depth) shall be surrounded by two2 benches as follows:
  - Except when side slopes are 4:1 (Hh:Vv) or flatter, provide a safety bench shall be provided that generally extends 105 feet 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. A 10-foot minimum bench may be allowed on sites with extreme space limitations on a case-by-case basis at the discretion of the Agency. The maximum slope of the safety bench shall be 6%; and
  - Incorporate aAn aquatic bench shall be incorporated that generally extends at leastup 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 10 foot minimum bench may be allowed on sites with extreme space limitations on a case-by-case basis at the discretion of the Agency.
- 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 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 shall include: delineation of pondscaping zones,; selection of corresponding plant species,; 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 two2 inches in diameter shall not be planted or allowed to grow on a dam , or 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.

4.3.7.6. 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.

4.3.7.7. 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 stone 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 WQv release pipe and the pond drain should be sized one pipe size greater than the calculated design diameter.
- Both the WQv 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.

4.3.7.8. 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 AgencyDepartment, as temperature stratification and high chloride concentrations can occur at the pond bottom and result in negative downstream effects.
- If pond draining is required for any reason, the pond shall be drained in a non-erosive fashion and with consideration of impacts to downstream properties.
- For discharges in cold-water fisheries, the gravel stone 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 gravelstone. When clogging occurs, at least the top 8 inches of gravel stone 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.

Design Guidance

- 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.

~~4.3.8.~~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 (CSO~~s~~) 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 storage and detention capabilities, and do not offer widespread application in Vermont, they are not examined further in this ~~m~~Manual as an applicable green stormwater infrastructure practice. They still, however, may be proposed for storage as part of an overall stormwater management plan.

A typical green roof includes vegetation planted in a substrate over a drainage layer and a root barrier membrane. There are two main types: (1) intensive ~~(~~, which are planted with woody vegetation with a deeper planting soil and walkways~~, designed for performance and public access)~~, and (2) extensive ~~(~~, which are 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.

Green Roof 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

Treatment Standard Applicability	
Recharge	No
Water Quality	No
Channel Protection	Hydrologic Condition Method
Q_{P10} and Q_{P100}	Limited. CN_{Adj} may provide partial credit

Key Elements

Feasibility:

- Only applicable to rooftop areas.
- Maximum Slope of roof shall be 20%.

Pre-treatment:

- Not required for direct precipitation.

Treatment: ▪ T_V credit equal to the volume of runoff stored in the void space of the planting medium above the drain layer and without bypass to the overflow system. T_V can be applied to CP_V, Q_{P10}, and Q_{P100}.
Other: ▪ Landscaping plan shall be provided. ▪ Roof drain shall include at least 2 outlets, or an outlet and an overflow. ▪ System shall safely convey 100-year storm away from the building.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

Figure 4-29~~4-33~~. Example of extensive green roof, Philadelphia, PA (Source: UNHSC)

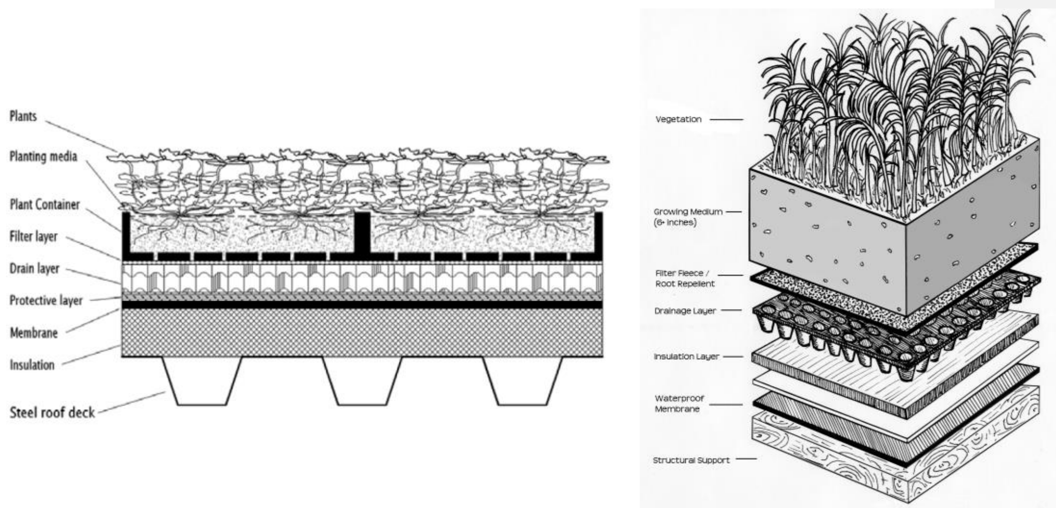

Figure 4-30~~4-34~~. Extensive (L) and Intensive (R) Green Roof – Typical Sections (Source: Wark and Wark, 2003)

~~4.3.8.1.~~4.3.7.1. 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.

~~4.3.8.2.~~4.3.7.2. Green Roof Conveyance

Required Elements:

- Roof drain designs ~~should~~shall include at least ~~two~~2 outlets or an outlet and an overflow. Outlets ~~must~~shall 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~~STP without causing erosion. If an overland path is used, a stabilized channel shall be provided for erosive velocities ~~(~~of 3.5 to 5.0 ft/s, see Appendix C7, VSMM, Vol. 2~~)~~ 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.

Commented [ME59]: For guidance.

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).

~~4.3.8.3.~~4.3.7.3. 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.

~~4.3.8.4.~~4.3.7.4. Green Roof Treatment

Required Elements:

- Green roofs shall ~~be~~ receive T_v credit equal to the volume of runoff stored in 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~~ The treatment volume shall be calculated as follows:

$$T_v = A_g \times n \times d_t$$

Where:

T_v~~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 above drain layer (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~~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.

4.3.8.5.4.3.7.5. 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 to achievinge 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.

4.3.8.6. 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.

4.3.8.7. 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.

4.3.8.8. 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.

~~Intensive Green Roof Systems:~~

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

4.3.9. Permeable Pavement ~~and Reinforced Turf~~

Permeable pavement~~s~~ includes 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 GlossarySubchapter 7.0)~~ Pursuant to Subchapter 2.0, 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~~under a ~~S~~stormwater ~~P~~permit or ~~A~~authorization to ~~D~~discharge. ~~However, the following section of this manual may nonetheless be useful for permeable pavement system design and maintenance, asrequirements concerning permeable pavement and reinforced turf are necessary because a 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~~ A permeable pavement system ~~can~~may be ~~used~~ designed as an STP to treat runoff from other jurisdictional rooftop 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 is routed in such a way as to not accumulate additional sediment and 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 runoff 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~~/~~ and 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.

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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 tTo 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, and 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. They must be Ccombined with other practices to handle runoff from large storm events, when required.

Permeable Pavement and Reinforced Turf Design Summary

Treatment Standard Applicability	
Recharge	Yes (if unlined)
Water Quality	Tier 1 (unlined)/ Tier 3 (lined)
Channel Protection	Hydrologic Condition Method (unlined)/ Extended Detention Method (lined)
Q_{P10} and Q_{P100}	Hydrologic Condition Method. Partial credit through CN_{Adj}.
Key Elements	
Feasibility: ▪ Permeable pavements shall only be used to treat direct precipitation and properly conveyed roof runoff. ▪ Infiltration rate shall be ≥0.2 inches per hour as confirmed by methods in Section 4.3.3.2 if designed to infiltrate. ▪ Separation to SHGWT of at least 3 feet from the bottom of the practice. ▪ Practice shall be located on slopes less than 5%. ▪ Permeable pavements shall not be sanded in winter.	
Pre-treatment: ▪ Not required for direct precipitation and properly conveyed roof runoff.	
Treatment: ▪ Permeable pavement systems designed to store and infiltrate the 1-year design storm are jurisdictionally pervious.	

- Permeable pavements used for infiltration of rooftop runoff shall be designed to exfiltrate the entire T_V through the floor of each practice. T_V can be credited towards Re_V, WQ_V, HC_V, Q_{P10}, and Q_{P100}.
- Reservoir course minimum depth shall be 6 inches, but generally 12 to 24 inches.

Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

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 ft² 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, HC_v, Q_{P10}, and Q_{P100}.
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 4-31~~4-35~~. Porous Asphalt in a Low-Density Residential Area in Pelham, NH (Source: UNHSC

Figure 4-32~~4-36~~. Pervious concrete roads in Sultan, WA (Source: Washington Aggregates and Concrete Association)

Figure 4-33~~4-37~~. Reinforced Turf - Westfarm Mall, Harford, CT (source: HW file photo)

4.3.9.1. Permeable Pavement Feasibility

Required Elements:

- A permeable pavement system shall only be designed as a STP to treat runoff from rooftops, where the rooftop runoff is not expected to have elevated sediment and solids concentrations, and the rooftop runoff is routed in such a way as to not accumulate sediment and solids.

- ~~A permeable pavement system designed as a STP to treat runoff from rooftops shall provide storage in excess of that required to qualify as a pervious surface, such that additional capacity exists for crediting toward rooftop runoff treatment requirements.~~

- The bottom of infiltrating permeable pavement practices ~~must~~ shall be located in the soil profile, if the practice is being used to meet the ~~water quality standard~~WQTS. 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 ~~confirmed~~documented by soil testing requirements for infiltration pursuant to~~in~~ Section 4.3.3.2. ~~as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical testsinfiltration testing (Section 4.3.3) (Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements)~~.

- ~~The bottom of an infiltrating permeable pavement practice canshall not be located in fill. An exception willmay 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~~shall 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~~shall be sited on slopes less than 5%. The bottom of the reservoir course shall be designed to be close to 0% slope as possible ~~(i.e.~~, and no greater than ~~<~~ 0.5%~~)~~ slope~~;~~. ~~terrace t~~The bottom layers shall be terraced, as necessary, to maintain th~~is~~e 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~~SHGWT or ~~ledge~~ bedrock (when treating WQv), as documented pursuant to ~~by on-site soil testing.~~soil testing requirements for infiltration ~~pursuant to~~ Section 4.3.3.2.

- 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).

- Use of heavy trucks or equipment on permeable pavements should be avoided to prevent compaction of the permeable surface.

- 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.).

4.3.9.2. Permeable Pavement Conveyance

Required Elements:

- Rooftop runoff shall be routed to permeable pavement in such a way as to not accumulate sediment and solids. ~~In rare instances where runoff is directed onto the permeable pavement surface, an Erosion Prevention and Sediment Control (EPSC) Plan should~~shall ~~be provided to address any run-on and specify at a minimum:~~

- Runoff from disturbed area shall not be directed to permeable pavement.~~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.

4.3.9.3. 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.

4.3.9.4. Permeable Pavement Treatment

Required Elements:

A permeable pavement system designed as a STP to treat runoff from rooftops shall provide storage in excess of that required to qualify as a pervious surface, such that additional capacity exists for crediting toward rooftop runoff treatment requirements.

- 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 (or 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). The Bbase material mustshall be washed and clean, uniformly sized material (poorly graded), and 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 (that consists of 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, HC_V, Q_{P10}, and Q_{P100} 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 stone fill; the accepted porosity of gravel (if used) 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)

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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, HC_V,, Q_{P10}, and Q_{P100} treatment requirements.

- Solid blocks with open-cell joints < 15% of the surface shall be designed to provide one inch of surface storage above the permeable pavement system to meet the recharge and water quality treatment requirements.
- For pPermeable pavement paving practices used for detention only (e.g., systems with an underdrain), no T_V credit isshall be given toward WQ_V or HC_V and impermeable CNs shall be used in hydraulic and hydrologic models when calculating CP_V and, Q_{P10}, and Q_{P100}.
- For permeable pavement paving practices with a stone sump beneath an underdrain system, T_V credit isshall be 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.

4.3.9.5. 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 mustshall be fully stabilized and, consisting of turf (i.e., and absent bare soil). Trees that have the potential to shed leaf litter shouldshall not be planted immediately adjacent to pervious pavements (and mature tree drip lines should not overhang permeable pavement surface).

4.3.9.6. 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.

4.3.9.7. 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.

4.3.9.8. 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.

4.3.10. 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 ~~(~~of gutters~~/~~, downspouts~~/~~, and 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.~~, such as a 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).

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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.

Rainwater Harvesting Design Summary

Treatment Standard Applicability	
Recharge	Yes (if water is reused for irrigation)
Water Quality	Tier 1
Channel Protection	Hydrologic Condition Method
Q_{P10} and Q_{P100}	Hydrologic Condition Method. Partial credit through CN_{Adj}.

Key Elements
Feasibility: ▪ Limited to roof runoff. ▪ Storage shall be designed to capture 0.2 inches of runoff from contributing rooftop.
Pre-treatment: ▪ Inflow shall be filtered of leaf litter and other debris. ▪ Mosquito screening (1 mm mesh size) shall be installed at openings.
Treatment: ▪ Water budget analysis shall be provided that identifies how water will be used. ▪ T_V is the storage volume of the system. T_V can be credited towards HC_V, Q_{P10}, and Q_{P100}.
Other: ▪ System shall be designed prevent ponding or soil saturation within 10 feet of building foundations, and underground cisterns shall be sited at least 10 feet from building foundations.
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.

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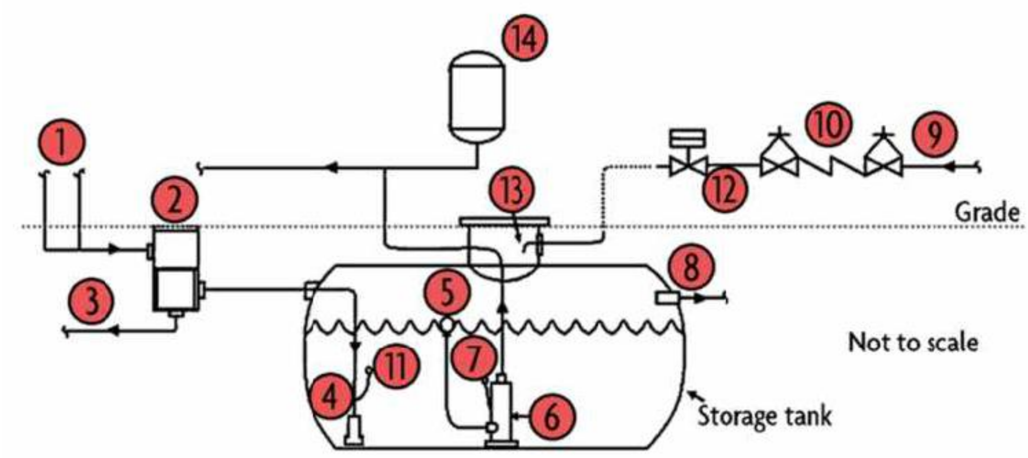
Criteria	Element	Requirements
Feasibility	Runoff source	Rooftop runoff only
	Contributing drainage area	Storage must be sufficient capture at least 0.2" from the contributing drainage area
	Application area/Reuse requirement	Area must be sufficient to handle an application rate of 1"/week
Conveyance	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 4-34~~4-20~~. 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

4.3.10.1. 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~~shall be identified that is sufficient to reuse the stormwater volume stored within a week at an application rate of 1~~"~~inch ~~/~~ per week over the irrigation period from May through September.
- For underground storage tanks, the bottom of the tank ~~must~~shall be above groundwater level, and the top of the tank ~~must~~shall 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.

4.3.10.2. 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 ~~/~~ per hour for credit.
- Overflow runoff ~~must~~shall 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.

4.3.10.3. 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~~are 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 0).

4.3.10.4. Rainwater Harvesting Treatment

Required Elements:

- A water budget analysis ~~must~~shall 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~~/~~ and 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.

4.3.10.5. Rainwater Harvesting Landscaping and Vegetation

Required Elements:

- Stormwater shall not be diverted to the rainwater harvesting system until the overflow conveyance and/~~or~~ application areas ha~~s~~ve 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.

~~4.3.10.6.~~ 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.~~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.

4.3.10.7. 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.

4.3.10.8. 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.

4.4. 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 ~~water quality treatment standard (~~WQTS~~)~~. ~~Demonstration of~~Compliance with the ~~g~~Groundwater ~~r~~Recharge, ~~c~~Channel ~~p~~Protection, ~~o~~Overbank ~~f~~Flood ~~p~~Protection, and ~~e~~Extreme ~~f~~Flood ~~c~~Control standards can be demonstrated through hydrologic modeling. Proposals for use of alternative treatment systems ~~will~~shall 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 to Vermont's climate; or through a new design-alternative systems proposed for use in Vermont.

Alternative STPs shall achieve a minimum of 50% TP and 80% TSS removal.

Following review of performance standards provided under either method, the Agency will assign the alternative STP to one of the three tiers of practices acceptable for meeting the WQTS as defined in Section 2.2.4.1. If the Secretary has provided prior approval of an Alternative STP, designers shall not be required to evaluate the ability to use the approved Alternative STP in their Water Quality Practice Selection conducted pursuant to Section 2.2.4.1. ~~Justification will not be required for not using an alternative STP before consideration of STPs in a lower tier.~~

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 ~~water quality treatment standard~~WQTS described in Section 2.2.4, 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)

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- 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

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- 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

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- Other protocol or program as approved by the Agency.

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~~may not be sufficient in all cases. The Agency reserves the right to evaluate ~~any~~ applications on a case-by-case basis 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 ~~water quality treatment standard~~WQTS described in Section 2.2.4, 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~~shall be provided. This certification ~~must~~shall 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 verify the performance of the STP shall be submitted and approved by the Agency prior to the commencement of the study. Minimum elements of the study plan ~~must~~shall include:

- Storm events ~~must~~shall be sampled under a varying and representative range of precipitation intensities and antecedent conditions;
- Methods for calculating removal efficiencies of TSS and TP ~~must~~shall be included;
- Influent and effluent concentrations ~~must~~shall be provided;
- Concentrations reports in the study ~~must~~shall be flow-weighted;
- The study ~~must~~shall be conducted in the field, as opposed to a testing laboratory;
- The practice ~~must~~shall have been in the ground for at least ~~one~~1 year at the time of monitoring; and,
- The study must be completed within ~~three~~3 years of construction of the STP.

Study plan design may consult testing protocols provided by the programs listed in Section 4.4.1.

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 ~~C~~Subchapter. 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 APPLICABILITYDETENTION AND CONVEYANCE PRACTICES

As previously described, there is a suite of stormwater management treatment practices STPs 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 STPs described in theis Mmanual in order to achieve the required level of water quality treatmentmeet the remaining applicable treatment standards. Limited applicability practices include:

- Dry Detention Ponds
- Underground Storage Vaults
- Wet Swales and Conveyance Swales
- 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 cChannel pProtection (CP_v), and oOverbank (Q), and eExtreme Fflood ($Q_{P100}$$Qp_{100}$) Ccontrol only. They are not suitable for meeting the Water Quality Treatment Standard water quality or recharge or the Groundwater Recharge Standardcriteria as stand-alone stormwater treatment practicesSTPs.

Required Elements:

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- Dry detention ponds shall be constructed with side slopes no steeper than 2:1, unless site constraints require use of retaining walls or similar structural support.
- 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 24-hour storm (CP_v) event 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.

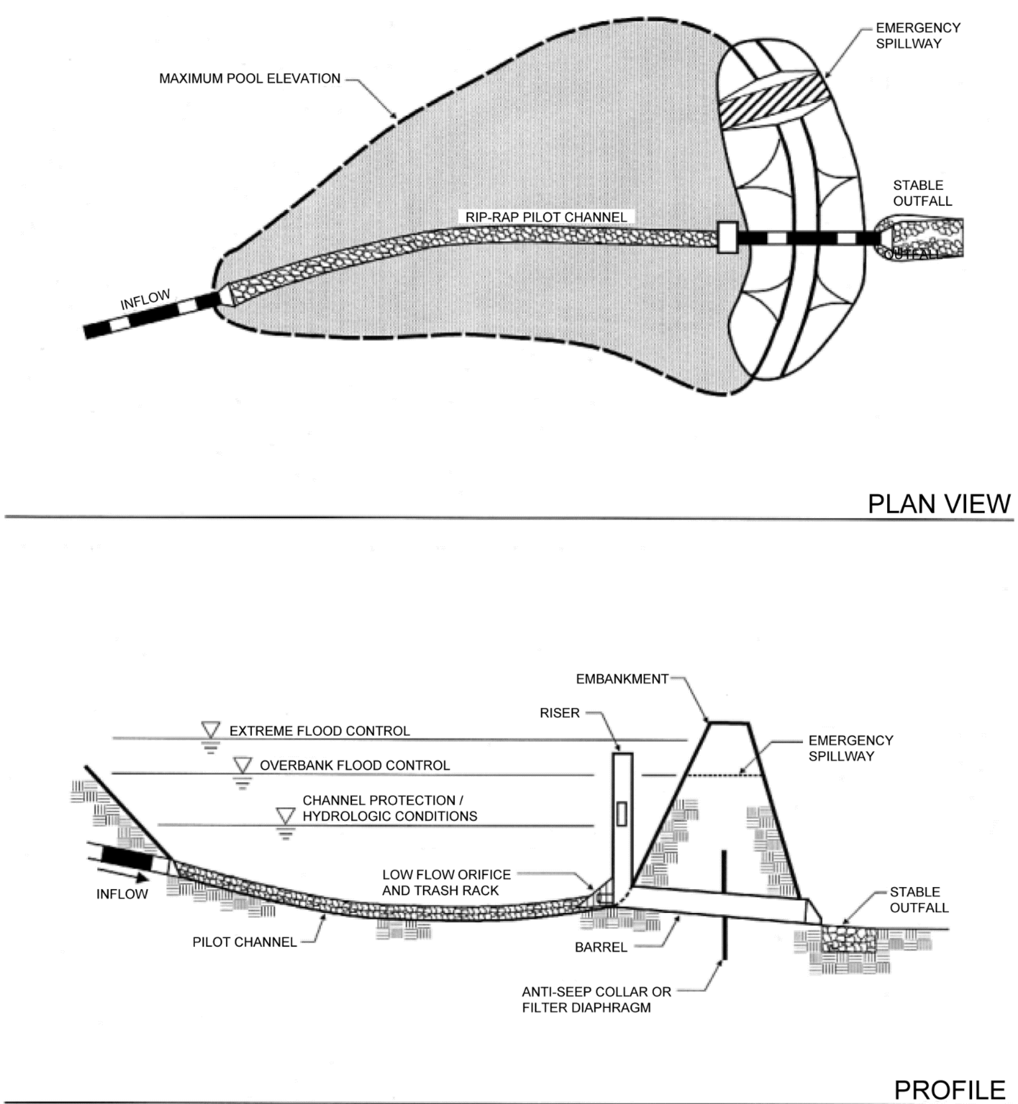

Figure 5-1~~5-1~~. Dry Detention Pond

5.2. ~~Underground~~ Storage Vaults

~~Underground s~~Storage vaults are designed to provide stormwater runoff volume control only; ~~c~~Channel P~~p~~rotection (~~CPv),~~ and O~~o~~verbank ~~(Qp10),~~ and E~~e~~xtreme F~~f~~lood ~~(Qp100)~~ C~~c~~ontrol~~ only~~. They are not suitable for meeting the Water Quality Treatment Standardwater quality or recharge criteriaGroundwater Recharge Standard as stand-alone stormwater treatment practicesSTPs.

Required Elements:

- 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. An observation well or equivalent access for inspection shall be installed in every storage vault system 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. Observation wells shall be installed every 50 feet or as otherwise required by manufacturers specifications.

Design Guidance:

- The inlet and outlet of the vault shall should 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.

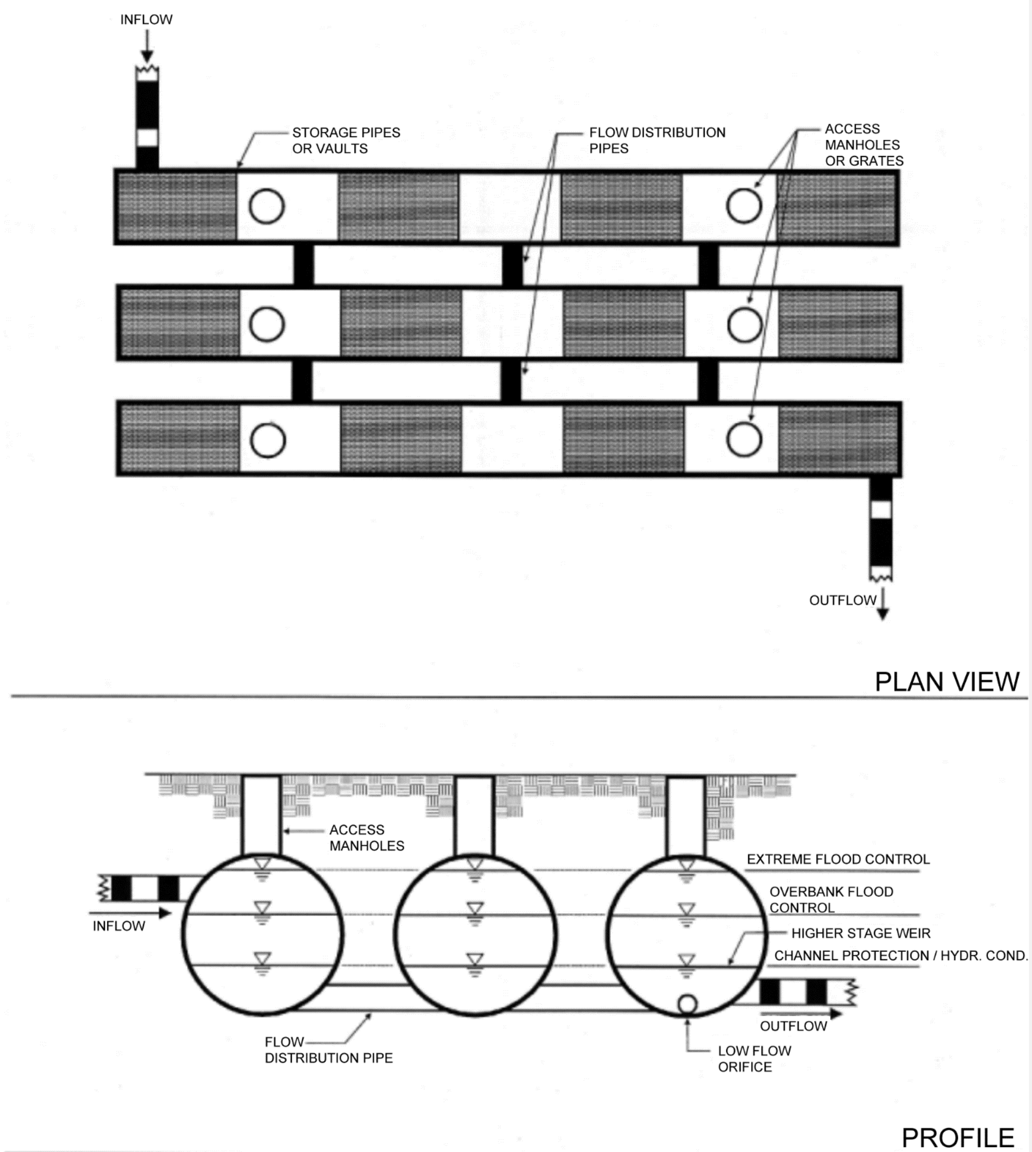

Figure 5-2~~5-2~~. Underground Storage Vault

5.3. Conveyance Swales

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Conveyance swales are not suitable for meeting the Water Quality Treatment Standard or Groundwater Recharge Standard as stand-alone STPs, but may be allowed for conveyance or to provide Channel Protection, and Overbank and Extreme Flood Control, when designed with storage capacity and stormwater volume control.

Required Elements:

Conveyance swales shall have a trapezoidal or parabolic cross section with side slopes less than or equal to 2H:1V.

- The bottom width of the conveyance swale shall be between 2and 8 feet wide.
- The peak velocity for the 1-year storm within the conveyance swale must be non-erosive, in other words 3.5-5.0 ft/s.
- Conveyance swales constructed on slopes of greater than 5%, shall be stone-lined or shall have equivalent stabilization such as through use of rolled erosion control product and vegetation, designed and installed per manufacturers specifications.
- The conveyance swale shall have the capacity to convey the 10-year 24-hour storm event, at a minimum, safely with 6 inches of freeboard.
- Conveyance swales used for CP_v are not required to conform to the outlet requirements in Section 4.3.6.

6.0 PUBLIC ~~HIGHWAY~~TRANSPORTATION PROJECTS

T~~he objective of t~~his Subchapter ~~is to~~ provides ~~guidance on how to comply with the VSMM~~ site design and ~~stormwater treatment practice~~STP sizing criteria ~~(Chapter 2.0), and apply~~as well as acceptable ~~stormwater treatment practices (~~STPs~~), when developing stormwater management strategies~~ for public ~~highway~~transportation projects, as ~~well as other public linear transportation projects such as trails, multi-use paths, and sidewalks.~~defined in this Manual. A variety of physical constraints associated with projects located within existing public ~~highway~~ rights-of-way often limit the options for stormwater management improvements. Therefore, this Subchapter deals with the unique constraints of existing ~~highways~~public transportation projects; and the STPs that can be readily and reasonably applied to ~~highway~~ reconstruction and improvement projects, including redevelopment.

The information in this Subchapter of the ~~m~~Manual is intended to provide flexibility in the design of STPs for ~~highway~~public transportation projects while maximizing water quality protection. All requirements detailed in other chapters of this ~~m~~Manual shall be adhered to for these types of projects, unless otherwise stated in this Subchapter. This Subchapter of the ~~m~~Manual ~~is not intended to~~does not apply to ~~parcel-basednon-linear transportation-focused~~transportation-related projects, such as maintenance garages, park & ride facilities, and airports, which are generally located outside of linear rights-of-way.

6.1. Applicability of the Stormwater Treatment Standards to ~~Highway~~Public Transportation Projects

As with other development projects in Vermont, if the Stormwater Management Rules apply to a ~~highway~~public transportation project, then the project must meet certain performance standards. These stormwater treatment standards are listed in Table 2-1, and explained in ~~Section~~Subchapter 2.0. Owners and operators of public ~~highways~~transportation projects undertake several general types of roadway projects, including routine maintenance, redevelopment, and new construction. Table 6-1 summarizes how the stormwater treatment standards apply to each of the project types, and each type of project is further discussed below.

Table 6-1. Summary of Stormwater Treatment Standards for ~~Highway~~Public Transportation Projects

Type and Size of ~~Highway~~Public Transportation Project	**Applicable Stormwater Treatment Standards[1]**	**Treatment Standard Details**
Routine Maintenance (Examples include tree and brush trimming; line painting; bridge painting; guard rail replacement; ditch cleaning; patching; crack sealing; surface treatment; slope repair; bridge repair; sign and/or signal replacement; pavement resurfacing, reclamation)	Post-construction Stormwater Treatment Standards do not apply	
Redevelopment - Major Maintenance ~~Highway~~ Public Transportation ~~r~~Reconstruction sites with no net increase in impervious surface (Examples include pavement removal to subgrade with replacement)	Post-construction Stormwater Treatment Standards apply as established in Section 6.1.2	The project ~~will~~shall be fully evaluated by discharge point for opportunities that exist within the highway right-of-way to install STPs to improve water quality and reduce runoff from project impervious areas.
Redevelopment with Expansion ~~Highway~~Public Transportation ~~r~~Reconstruction sites with a net increase in impervious area (Examples include correcting substandard intersections; road profile improvements; roadway or shoulder widening, and generally include projects with a combination of redevelopment and expansion)	Expanded impervious area (or equivalent area) must meet the Water Quality Treatment Standard. Redeveloped portions of project are evaluated under Section 6.1.2. Sites with net expansion and ≥1 acre of expansion discharging to any one receiving water must also meet CP_V, Q_{P10}, and Q_{P100} if the standards apply	The treatment standard for the “Water Quality Volume” (WQ_V) is 100% of the WQ_V for net expanded impervious surfaces.
New Construction (Examples include new highway in undeveloped right-of-way)	Projects must meet all applicable Stormwater Treatment Standards	The treatment standard for the “Water Quality Volume” (WQ_V) is 100% of the WQ_V for new impervious surfaces. Channel Protection, Q_{P10}, and, Q_{P100} standards apply, pursuant to existing thresholds and exemptions

[1] **The Post-Construction Soil Depth and Quality Standard applies to all jurisdictional projects.**

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6.1.1. Routine Maintenance

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Routine maintenance consists of activities that are completed to maintain and preserve the condition of the ~~highway~~public transportation system at a satisfactory level of service. Examples of pavement-related routine maintenance activities include cleaning of roadside ditches and structures, maintenance of pavement markings, crack filling and sealing, pothole patching, cold planing, resurfacing, paving a gravel road, reclaiming, or grading treatments used to maintain pavement, bridges, and unpaved roads.

Such activities rarely involve site disturbance, do not change the imperviousness of roadways or other surfaces in the right-of-way, and are not subject to post-construction Stormwater Treatment Standards.

6.1.2. Redevelopment - Major Maintenance

Major maintenance projects involve restoring an existing roadway to its original condition and often include the replacement of pavement to subgrade. There is no net increase in total impervious area and very limited conversion of pervious areas into impervious areas. These projects do not substantively change the existing rate, volume, or quality of stormwater runoff from existing site conditions, and are usually bound by existing highway right-of-way limits. These types of projects, however, may present opportunities for improving runoff quality, control, and reduction through improvements.

When opportunities exist within the highway right-of-way, the designer willshall consider the use of STPs or other practices to improve pre-existing stormwater runoff conditions. Where existing swales, vegetated shoulders, and median areas within existing highway rights-of-way can be retrofitted without adversely affecting safety or the integrity of the highwaypublic transportation project, STPs and other measures willshall be designed to disconnect, capture and infiltrate, and/or evapotranspire the runoff from impervious areas to the extent practicable.

Each drainage area shall be evaluated for the ability to:

- Retrofit existing swales and median areas with acceptable non-structural or structural STPs and other acceptable methods to increase residence time, slow velocities, and encourage infiltration/evapotranspiration. Opportunities to evaluate include but are not limited to the following:
    - Retrofit portions of existing medians or swales along the project length with structural STPs for infiltration and/or filtering, including dry swales, unlined filtering systems, or VTrans Micropool Filter systems. Practice sizing may vary and may be limited by existing highway right-of-way (but this does not exclude practices that treat 100% of WQ_V or meet the gGroundwater rRecharge, cChannel pProtection, oOverbank fFlooding, and eExtreme fFlooding sStandards where full capture and/or treatment is possible).
    - Restore the profile and function of existing swales, and install adequate erosion protection (including but not limited to improved vegetative cover, check dams (Sections 4.1.1.2 and 6.5.3), and stone lining) in existing roadside channels along the project length. Design for retrofits of conveyance swales should also be in accordance with Sections 5.7.4 to 5.7.7 of the VTrans Hydraulics Manual, 2015 (or most recent edition), or with the Vermont Better Roads Manual, 2009 (or most recent edition) as applicable. If swales are being used as pre-treatment for a downstream practice, the design requirements for pre-treatment swales (Section 4.1.1) should also be considered.
    - Turn out existing swales wherever possible to avoid direct outlet into surface waters. Provide adequate outlet protection at the end of the turnout through the use of structural (rock) or vegetative filtering areas.
    - Retrofit micro-bioretention cells between roadway and sidewalk where right-of-way width allows and sidewalks are present.
    - Eliminate or reduce existing concentrated flows and promote distributed flow over vegetation, particularly during smaller storms.

- Repair and stabilize rill and gully erosion within the highway right-of-way.
- Install headwalls and wing-walls where there is erosion or undermining of existing culverts.
- Retrofit existing pipe and culvert outlets with splash pads, plunge pools, level spreaders, or energy dissipators. Splash pads and energy dissipators should be designed in accordance with the VTrans Hydraulics Manual, 2015 (or most recent edition). Plunge pools should be designed using the guidance in Section 6.5.2. Level spreaders should be designed in accordance with Section 4.2.3.2.
- Remove curbing (treated timber, asphalt, granite, concrete) and shoulder built-up berms in areas where distributed flow of runoff from the roadway can be maintained (Figure 6-3Figure 6-4), and disconnect runoff through the use of Filter Strips and Vegetated Buffers (Section 4.2.3). Disconnection lengths may vary and may be limited by existing highway right-of-way (but this does not exclude longer lengths where full dispersion is possible).

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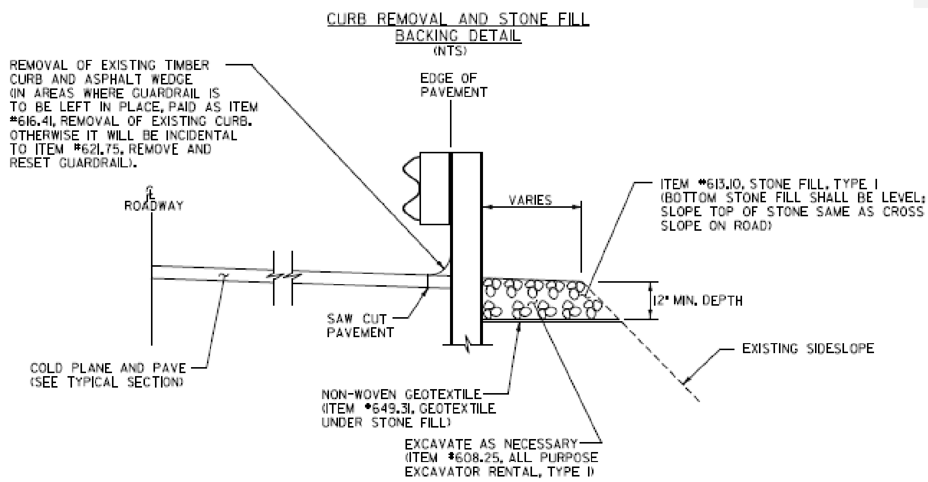


Figure 6-3. Curb Removal Detail Example

- Meet the Post-Construction Soil Depth and Quality Standard for applicable disturbed areas (Section 6.3).
- Preserve trees and revegetate to establish dense and vigorous vegetative cover as appropriate. Native plant species shouldshall be specified over non-native species, where possible; though non-invasive cultivars are also acceptable where they provide comparable functions.
- Restore areas used for off-site activities including temporary staging areas, haul roads, and material supply and disposal sites in accordance with Standard Specification 105.28. These areas will be restored to the Post-Construction Soil Depth and Quality Standard where applicable. Preserve permeable (HSG A and B) soils during site construction and restoration activities (e.g., do not place clay waste material on top of permeable native material).

6.1.3. Redevelopment with Expansion

This sSection covers highway reconstruction projects that involve renovation of an existing highwaypublic transportation project along the existing alignment with net increaseexpansions of existing impervious surfaces, and do not generally change the direction of runoff.

The Water Quality Treatment StandardWQTS willshall apply to the expanded portions of highwaypublic transportation reconstruction projects (or equivalent areas). The treatment standard is 100% of the WQv for the net increase in impervious area (shall be provided pursuant to Section 2.2.4. In cases where the net increase in impervious surface exceeds 1one acre discharging to any one receiving water, the gGroundwater rRecharge, cChannel pProtection, oOverbank fFlooding, and eExtreme fFlooding sStandards may also apply, pursuant to existing thresholds and exemptions. The "same receiving water" shall be determined by the Agency during pre-application review, required under Section 2.1.2 of this Rule, on a case-by-case basis.

If capture and treatment of the required WQv is not practical through acceptable STPs, a designer may propose alternatives that would achieve an equivalent pollutant reduction, in consideration of and with preference for practices that can comparably meet the highest water quality treatment goals (Tier 1 through Tier 3 STPs), where possible, as established in SectionSubchapter 2.0 2.0 of the manual. For example, a site may use a combination of STPs and strategies to treat net expanded impervious surface area with STPs either not included in this mManual, or those with a lesser pollutant removal efficiency than stipulated in CSubchapter 4.0. In such cases, it will be the responsibility of the designer to document expected pollutant removal, consistent with the requirements outlined in Section 2.4 of this manual. Designers should refer to Alternative Design STPs (Section 4.4) in this manual for documentation requirements.In such cases, the designer shall document, pursuant to the Section 4.4 documentation requirements, the site constraints or limitations and expected pollutant removal for any proposed alternative STP. This approach will not allow for higher performing practices, including those identified as Tier 1 through Tier 3 Practices, or approved equivalent to be use to "offset" treatment not provided elsewhere on site. The Department reserves the right to not allow this approach where treatment and/or control is deemed inequivalent and/or presents greater risk to water quality, in consideration of impervious surface proximity to water resources, existing site condition, or other factors.Proposed alternatives shall be subject to Agency approval. If the Agency determines that a proposed alternative will not provide equivalent pollutant reduction or presents greater risks to water quality, in consideration of impervious surface proximity to water resources, existing site conditions, or other factors, the Agency shall deny the proposed alternative.

If capture and treatment of the WQv within the drainage area flowing to the same discharge point and receiving water is not practical, a designer may propose to use site balancing as further described in Section 6.2.

6.1.4. New Construction

On projects that involve new roadsimpervious surface on undeveloped rights-of-way, the entire project willshall be subject to of the full suite of stormwater treatment standards, as applicable in Subchapter 2.0. While these projects have unique constraints associated with the nature of roadwaypublic transportation projects, there is greater opportunity for site planning for new highwayspublic transportation projects than for existing highwaysones.

6.2. Site Balancing for Stormwater Discharges Associated with Redevelopment -– HighwayPublic Transportation Reconstruction Projects

~~Due to the wide variety of existing physical site constraints present in highway reconstruction projects, control and/or treatment of stormwater runoff from the complete extent of proposed expanded or redeveloped impervious surfaces is not always practicable. The concept of site balancing may be utilized in Redevelopment Highway Reconstruction projects for treating runoff from existing untreated highway impervious surfaces when it is demonstrated that control and/or treatment of runoff from expanded or redeveloped impervious surfaces is not reasonably feasible, or has marginal benefit due to site constraints.~~

~~"Site balancing" means that where an area of redeveloped/reconstructed or expanded impervious surface is not reasonably feasible to treat, other untreated impervious surfaces may be controlled/treated on an equivalent basis (Section 2.1.2).~~

~~Methods of accomplishing "equivalent treatment" include~~

- ~~Providing additional control and/or treatment beyond what is required for existing impervious surfaces to be redeveloped, that are not otherwise required to provide stormwater treatment under an operational stormwater discharge permit.~~
- ~~Controlling and/or treating impervious surfaces that are not otherwise required to provide stormwater treatment under an operational state stormwater discharge permit.~~

~~The requirements for treatment and/or control on these impervious surfaces are equal to or greater than the treatment and/or control requirements on the expanded or redeveloped impervious surfaces for which treatment is not reasonably feasible.~~

~~Prior to applying this concept to a highway project, the designer shall discuss the application of site balancing with the Agency's Stormwater Program, in the specific context of the project under development, prior to stormwater permit application submittal. The designer must demonstrate that treatment and/or control of the impervious areas in question is not reasonably feasible or has marginal benefit due to physical, topographical, or environmental constraints. Examples of infeasibility may include, but are not limited to, instances where control and/or treatment for the expanded or redeveloped impervious surfaces would require the permittee to acquire new land, pump the stormwater in question, remove existing impervious surface or other infrastructure, construct stormwater treatment and/or control systems in wetlands or other surface waters or riparian buffer zones, or result in other negative impacts on waters. Examples of marginal benefit include instances where control and/or treatment for expanded or redeveloped impervious surfaces within the project limits would provide less volume reduction or water quality benefit than control and/or treatment of other existing impervious surfaces discharging to the same point, or to another point within the same watershed. The designer will clearly specify in the application that site balancing is being proposed, along with providing the necessary explanation and justification for its use. Stormwater Program review and approval for use of site balancing due to site constraints will occur as part of the stormwater discharge permit application process. The Agency reserves the right to not allow site balancing where treatment and/or control is deemed inequivalent and/or presents a greater risk to water quality, in consideration of impervious surface proximity to water resources, existing site condition, or other factors.~~

The concept of site balancing can be applied to highway projects with the overall goal of treating and/or controlling runoff as close to the point of collection or potential discharge as possible, in keeping with site planning and design strategies in Section 2.1. Any area to be used as compensation shall discharge to the same receiving water, or the same watershed, as the area to be balanced. The 'same receiving water' or 'same watershed' shall be determined by the Stormwater Program during pre-application review on a case by case basis.Redevelopment - Highway CPublic Transportation Reconstruction Projects shall comply with the Site Balancing requirements under Section 2.1.32.1.2, except for the Section 2.1.2. (I)(f)(2) site balancing requirement.

A tiered approach will be applied for site balancing on highway projectsIn lieu of the Section 2.1.32.1.2(I)(f)(2) site balancing requirement, Redevelopment-Highway CPublic Transportation Reconstruction Projects shall comply with the following:

1. First, site balancing willshall be attempted within the drainage area flowing to the same discharge point and receiving water.
2. If site balancing within the same discharge point's drainage area is not reasonably feasible, then site balancing willshall be attempted within the same receiving water within project limits, or to the nearest possible discharge point to the same receiving water where the impervious surface area to be used as compensation is under the ownership and/or control of the permitteeapplicant.
3. If site balancing to the same receiving water upstream of the discharge point within project limits is not reasonably feasible, then site balancing willshall be attempted within the same watershed as the highway reconstruction project's discharge point, where the impervious surface area to be used as compensation is under the ownership and/or control of the permitteeapplicant.
4. If site balancing within the same watershed as the highway reconstruction project's discharge point is not reasonably feasible, then site balancing willshall be attempted toprovided the same watershed below the discharge point, where the impervious surface area to be used as compensation is under the ownership and/or control of the permitteeapplicant.
5.

6.3. Post-Construction Soil Depth and Quality Requirements for ~~Highway~~Public Transportation Projects

~~With increased focus on the role of healthy soils in the mitigation of stormwater quality and quantity impacts, establishment of soil quality standards have become an important component of the VSMM. Topsoil is a biologically active system of minerals, organic matter, air, water, and microorganisms that can take thousands of years to develop. Topsoil nourishes and provides structural support for plant roots and absorbs and cleans water.~~ As discussed in greater detail in Subchapter 3.0, naturally occurring, undisturbed soil and vegetation provide important stormwater functions. This ~~s~~Section focuses on soil quality requirements and the use of amendments, particularly compost, for roadside projects.

Much of the roadside environment is reduced to subsoil at the surface following a typical roadway construction project. Subsoil has little or no organic matter, few pore spaces, and few microorganisms, all of which are important for absorbing and cleaning water. While the mineral component of soil provides structural support for roads and bridges, most types of native vegetation cannot grow in this environment. The resulting community of native and exotic, invasive plants can require costly maintenance and time consuming management. The job of reconstructing a functioning soil community without establishing healthy soil during project execution is difficult and costly, and might not be achievable.

It is necessary to have healthy soil to revegetate a site. Revegetation is necessary to provide slope stabilization, erosion control, biofiltration and infiltration for water quality, screening, local climate modification, and habitat, and may also be required to meet permit or environmental requirements. As a result, healthy topsoil is an important component of a development project.

Plant life and water absorption capability require similar soil conditions: loose, friable soil with the right balance of organic matter, microorganisms, and minerals. In contrast, roadway construction requires highly compacted soils with low organic matter content for stability. The Vermont Agency of Transportation (~~VAOT~~VTrans) requires that soils for road foundations ~~are~~be compacted to 95% density—however, most plants require that soils have a density of less than 80-85%, and compacted soils similarly have poor water infiltration and stormwater management capability. This density complication poses a challenge in all phases of roadside stormwater and vegetation management.

6.3.1. Requirements for ~~Highway~~Public Transportation Projects

The requirements of ~~Section~~Subchapter 3.0 ~~generally~~ apply to ~~highway~~public transportation redevelopment and new construction projects. Sections 201, 651, and 755 of the ~~VAOT~~VTrans 2011 *Standard Specifications for Construction* (or most recent edition) (Standard Specifications) contain many similarities to the requirements of ~~Section~~Subchapter 3.0. ~~In order to ensure that highway projects comply with the requirements of Section 3.0, the designer shall specify Sections 201, 651, and 755 of the VAOT *Standard Specifications for Construction* with modifications to account for differences between the manual requirements and the VAOT specifications.~~

Differences between ~~Section~~Subchapter 3.0 ~~of this manual~~ and Sections 201, 651, and 755 of the ~~VAOT~~VTrans ~~2011~~ Standard Specifications ~~*for Construction*~~ are described below, along with required modifications to these specifications to ensure that ~~highway~~public transportation projects comply with ~~Section~~Subchapter 3.0.

SECTION 201 - CLEARING

- There is no requirement or provision for preserving or stockpiling topsoil in Sections 201.2 Clearing, 201.3 Grubbing, or 201.6 Disposal of the Standard Specifications. ~~Section 3.3, Treatment: Soil Retention states "Retain native topsoil where practical. In any areas requiring grading, remove/stockpile existing topsoil on site to be reapplied on site where feasible." This is not feasible for many highway projects due to space limits within ROW, but staging areas are commonly used. If it is not feasible to stockpile topsoil within the highway right-of-way or project limits, topsoil should be stockpiled in a nearby staging area if feasible~~ Subchapter 3.0 requires that in areas requiring grading, topsoil be removed, stockpiled on site, and reapplied to other portions of the site where feasible. For purposes of this subsection, "on site" shall include ~~linear~~ public transportation project staging areas.

  Specification Modification - Retain native topsoil where practical. In any areas requiring grading, remove~~/~~ and stockpile existing topsoil ~~on site~~within the ~~highway~~ right-of-way or project limits to be reapplied ~~on~~to the site where feasible. If it is not feasible to stockpile topsoil within the ~~highway~~ right-of-way or project limits, topsoil ~~should~~shall be stockpiled in a nearby staging area if feasible.

SECTION 651 – TURF ESTABLISHMENT

- Section 651.05 Preparation of Area of the Standard Specifications requires areas unsuitable for vegetation to be covered with 50 mm (2 inches) of topsoil. Section 651.06 Topsoil of the Standard Specifications requires topsoil be spread to depth of 50 mm (2 inches) or to depth shown on Plans. ~~Section 3.3 Treatment: Soil Quality~~Subchapter 3.0 requires a minimum topsoil depth of 4~~"~~ inches~~,~~ or to match the native NRCS soil series description depth.

  Specification Modification - Required depth of topsoil shall be increased to 4~~"~~ inches to meet the Post-Construction Soil Depth and Quality Requirements.

- Section 651.05 Preparation of Area of the Standard Specifications requires that soils shall be loosened to depth of approx~~.~~imately 50 mm (2 inches). There is no "or to depth shown on Plans" language. ~~Section 3.3 Treatment: Soil Quality~~Subchapter 3.0 requires subsoils be scarified at least 4 inches with some incorporation of upper material.

  Specification Modification - Increase required soil loosening depth to 4~~"~~ inches minimum. Add "or to depth shown on Plans" and require a minimum 4-inch scarification depth for jurisdictional projects.

- Sections 651.05 and 651.06 of the Standard Specifications both provide for 2 inches of topsoil cover, but the method used to establish compliance with ~~Section 3.3~~Subchapter 3.0 soil quality requirements (amend existing site topsoil or subsoil; stockpile and replace, import topsoil) for different parts of the site will need to be clearly identified on Plans. Site-~~-~~specific ~~P~~plan requirements are included in Section 3.4, Vegetation and Landscaping.

  Specification Modification - To demonstrate compliance with Section 3.4 Vegetation and Landscaping requirements, designers ~~will need to~~shall specify construction details on acceptable methods~~,~~ as well as instructions for contractor verification and the verification sampling scheme.

SECTION 755 – LANDSCAPING MATERIALS

Section 755.05 Compost of the Standard Specifications requires compost to comply with EPA requirements for compost (Table 755.05A), while ~~Section 3.3 Treatment: Soil Quality states~~Subchapter 3.0

requires that compost used to meet "pre-approved" amendment rates must meet the definition of "compost" in the Vermont Solid Waste Management Rules §6-1102. A few of the compost specificationsrequirements differ between Section 755.05 and this mManual's Section 3.3:

- Section 755.05 of the Standard Specifications requires an organic matter content of 30-60%, and has no requirement for carbon to nitrogen ratio. Section 3.3 Treatment: Soil Quality statesSubchapter 3.0 requires that the compost must have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.

  Specification Modification - Adjust organic matter content range to correspond with this mManual. Add C:N requirement to Standard Specifications, or to bid specifications for applicable projects.

- Section 755.05 of the Standard Specifications requires that the compost meet U.S. EPA Part 503 exceptional quality concentration limits for trace elements/heavy metals. Section 3.3 Treatment: Soil QualitySubchapter 3.0 requires compost to meet contaminant standards of the Vermont Solid Waste Management Rules §6-1104(g)(6-7), §6-1105(e)(8-9), and §6-1106(e)(87-9). Thesese Vermont Solid Waste Management Rules in a few cases contain contaminant standards that are stricter than those from EPA (all in mg/kg): Arsenic (41 EPA, 15 VT), Cadmium (39 EPA, 21 VT), Mercury (17 EPA, 10 VT).

  Specification Modification - If compost is specified to be purchased from operations licensed under the VTermont Solid Waste Management Rules, it should be compliant with both EPA and VTermont requirements.

6.4. Additional Acceptable STPs for ~~Highway~~Public Transportation Projects

The following STPs may be considered for meeting ~~Post-Construction~~the Stormwater Treatment Standards during the design and implementation of ~~highway~~public transportation projects. Any STP contained in ~~Section~~Subchapter 4.0 ~~4.0 can~~may also be used to treat and manage stormwater from ~~highway~~public transportation projects in accordance with ~~Section~~Subchapter 2.0.

6.4.1. Infiltration Berm

An infiltration berm is a mound of compacted earth with sloping sides that is usually located along (i.e., parallel to) a contour in a moderately sloping area. Berms create shallow depressions that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater. They function similar to infiltration trenches. Berms are ideal in areas where runoff is free to discharge over slopes. ~~The~~A berm can be installed parallel to the road and intercept runoff prior to being discharged into adjacent areas or bodies of water. Berms can be constructed on disturbed slopes and revegetated as part of the construction process. Infiltration berms may also be constructed in combination with a subsurface infiltration trench at the base of the berm to increase retention capacity. Where infiltration is not feasible, filter media and an underdrain may be provided below the depression storage, allowing the practice to function as a filter.

Infiltration Berm Design Summary

Treatment Standard Applicability	
Recharge	Yes (if designed to infiltrate)
Water Quality	Tier 1 (infiltrating)/ Tier 2 (filter)
Channel Protection	Hydrologic Condition Method (unlined)/ Extended Detention Method (lined)
Q_{P10} and Q_{P100}	Hydrologic Condition Method (unlined). Partial credit through CN_{Adj}.
Key Elements	
Feasibility: ▪ Infiltration rate shall be ≥0.2 inches per hour as confirmed by methods in Section 4.3.3.2 if designed to infiltrate. ▪ Separation to SHGWT of at least 3 feet from the bottom of the practice if designed to infiltrate. Otherwise SHGWT should be below the bottom of the practice.	
Pre-treatment: ▪ Forebay: ○ For infiltration rates ≤ 2 inches per hour sized for 25% of the WQ_V. ○ For infiltration rates >2 inches per hour, sized for 50% of the WQ_V. ▪ Other pre-treatment practice as described in Section 4.1	
Treatment: ▪ For practice designed to infiltrate, the practice shall infiltrate the T_V. Design T_V may be subtracted from the Re_V and WQ_V. The T_V may also be credited towards the CP_V, Q_{P10}, and Q_{P100} through the Hydrologic Condition Method. ▪ For practice designed as a filter, the filter bed is designed according to Darcy's Law. Storage volume (including pre-treatment) shall be at least 75% of T_V. ▪ When infiltration berms are located on public transportation project slopes or toe of slopes, the slopes shall be evaluated for stability by a geotechnical engineer.	
Other: ▪ Longitudinal slope of practice ≤ 5%.	
Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.	

~~6.4.1.1.~~ Infiltration Berm Feasibility

~~6.4.1.2.~~6.4.1.1.

Required Elements:

- For practices designed to infiltrate, underlying soils shall have an infiltration rate (f_c) of at least 0.2 inches per hour, as confirmed by soil testing requirements for infiltration pursuant to ~~in~~ Section

4.3.3.2 ~~by field geotechnical tests~~ (see Appendix C1, VSMM, Vol. 2, Technical Guidance, Infiltration-Based Practice Testing Requirements).

Commented [ME69]: For guidance.

- For practices designed to infiltrate, relevant feasibility required elements for infiltration trench and ~~/~~basin practices ~~must~~shall ~~also~~ be met pursuant to ~~(~~Section 0~~)~~.

Design Guidance:

- Berms are ideal for mitigating runoff from relatively small impervious areas with limited adjacent open space (e.g. roadways). Conversely, berms are often incapable of controlling runoff from very large, highly impervious sites. Due to their relatively limited volume capacity, the length and/or number of berms required to retain large quantities of runoff can make them impractical as the lone BMP. In these situations, berms are more appropriately used as pre-treatment.
- Systems of parallel berms have been used to intercept stormwater from roadways or sloping terrain.
- Berms can sometimes be threaded carefully contour on wooded hillsides, minimally disturbing existing vegetation and yet still gaining stormwater management credit from the existing woodland used.

~~6.4.1.3.~~6.4.1.2. Infiltration Berm Pre-Treatment

Required Elements:

- If the berm functions as an ~~I~~infiltration ~~P~~practice, required elements pursuant to Section 4.3.3.4~~4.3.3elements and design guidance from Section 4.3.3.3~~ shall apply.
- If the berm functions as a ~~F~~filtering ~~P~~practice, required elements pursuant to ~~and design guidance from~~ Section 4.3.4.3 shall apply.

Design Guidance:

- If pre-treatment cannot be obtained, the infiltration berm itself may function as a pre-treatment practice. If an infiltration berm is functioning as pre-treatment, at least one additional berm should be placed down-slope to ensure that both settling of coarse sediment and filtering and/or infiltration can occur within the berm series.

~~6.4.1.4.~~6.4.1.3. Infiltration Berm Conveyance

Required Elements:

- Conveyance for berms that function as infiltration practices shall be sized ~~per~~pursuant to the required elements pursuant to~~in~~ Section 4.3.3.2.
- Conveyance for berms that function as filtering practices shall be sized ~~per~~pursuant to the required elements pursuant to~~in~~ Section 4.3.4.2.

~~6.4.1.5.~~6.4.1.4. Infiltration Berm Treatment

Required Elements:

- Infiltration ~~B~~berms ~~can~~may be used toward meeting ~~w~~Water ~~q~~Quality, ~~r~~Recharge, ~~c~~Channel ~~p~~Protection, ~~o~~Overbank ~~f~~Flood, and ~~e~~Extreme ~~f~~Flood requirements. Sizing criteria are dependent on berm function, location, and storage volume requirements.
- Berms that function as infiltration practices shall be sized ~~per~~pursuant to the required elements in Section 4.3.3.5. For infiltrating berms, the treatment volume (T_V) stored behind the berm and infiltrated ~~is~~shall be credited towards WQ_V, CP_V, Q_{P10}, and Q_{P100}. Infiltration berms that infiltrate are Tier 1 practices.
- Berms that function as Filtering Practices shall be sized ~~per~~pursuant to the required elements in Section 4.3.4.4. ~~For berms that are not designed to infiltrate.~~ Infiltration berms that function as filters are Tier 2 practices.
- When infiltration berms are located on ~~highway~~public transportation project slopes or toe of slopes, the slopes shall be evaluated for stability by a geotechnical engineer.

Design Guidance:

- Low berm height (less than or equal to 24 inches) is recommended to encourage maximum infiltration and to prevent excessive ponding behind the berm. Greater heights may be used where berms are being used to divert flow or to create "meandering" or lengthened flow pathways. In these cases, stormwater is designed to flow adjacent to (parallel to), rather than over the crest of the berm. Generally, more berms of smaller size are preferable to fewer berms of large size.
- Berm length is dependent on functional need and site size. Berms installed along the contours should be level and located across the slope. Maximum length will depend on width of the slope.
- Infiltration Berms should be constructed along (parallel to) contours at a constant elevation.
- **Soil.** A berm may consist entirely of high quality topsoil. To reduce cost, only the top foot needs to consist of Topsoil, with well-drained soil making up the remainder of the berm. The use of gravel is not recommended in the layers directly underneath the topsoil because of the tendency of the soil to wash through the gravel. In some cases, the use of clay may be required due to its cohesive qualities (especially where the berm height is high or relatively steeply sloped). However, well-compacted soil usually is sufficient provided that the angle of repose (see below) is not exceeded for the soil medium used.
- A more sustainable alternative to importing berm soil from off-site is to balance berm cut and fill material as much as possible, provided on-site soil is deemed suitable as per the Specifications below. Ideally, the concave segment (infiltration area) of the berm is excavated to a maximum depth of 12 inches and then used to construct the convex segment (crest of berm).
- The Angle of Repose of Soil is the angle at which the soil will rest and not be subject to slope failure. The angle of repose of any soil will vary with the texture, water content, compaction, and vegetative cover. Typical angles of repose are given below:
  - Non-compacted clay: 5-20%
  - Dry Sand: 33%

- Loam: 35-40%
- Compacted clay: 50-80%

- **Side Slopes**. The angle of repose for the soil use in the berm should determine the maximum slope of the berm with additional consideration to aesthetic, drainage, and maintenance needs. If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to avoid "scalping" by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 ratio. Other herbaceous plants, which do not require mowing, can tolerate slopes of 3:1. Berm side slope should not exceed a 2:1 ratio
- **Infiltration Design.** Infiltration berms located along slopes should be composed of low berms (less than 12 inches high) and should be vegetated. Subsurface soils should be uncompacted to encourage infiltration behind the berms.
- **Infiltration Trench Option.** Infiltration trenches are not recommended in existing woodland areas as excavation and installation of subsurface trenches could damage tree root systems. See Section 4.3.3– Infiltration Trenches and Basins, for information on infiltration trench design.
- **Aesthetics.** To the extent possible, berms should reflect the surrounding landscape. Berms should be graded so that the top of the berm is smoothly convex and the toes of the berms are smoothly concave. Natural, asymmetrical berms are usually more effective and attractive than symmetrical berms. The crest of the berm should be located near one end of the berm rather than in the middle.

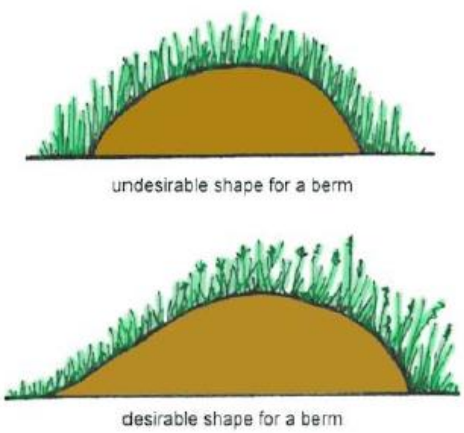


Figure 6-4. Infiltration Berm Shape

~~6.4.1.6.~~6.4.1.5. Infiltration Berm Vegetation and Landscaping

Required Elements:

- Berms that function as ~~I~~infiltration ~~P~~practices shall be vegetated and landscaped ~~per~~pursuant to the required elements in Section 4.3.3.6.

- Berms that function as ~~F~~filtering ~~P~~practices shall be vegetated and landscaped ~~per~~pursuant to the required elements in Section 4.3.4.5.

Design Guidance:

- **Plant Materials.** It is important to consider the function and form of the berm when selecting plant materials. If using trees, plant them in a pattern that appears natural and accentuates the berm's form. Consider tree species appropriate to the proposed habitat. If turf will be combined with woody and herbaceous plants, the turf should be placed to allow for easy maneuverability while mowing. Low maintenance plantings, such as trees and meadow plants rather than turf and formal landscaping, are encouraged.

6.4.2. Media Filter Drain

The media filter drain (MFD) is a linear flow-through stormwater runoff treatment device that can be sited along ~~highway~~public transportation project side slopes (conventional design) and medians (dual media filter drains), borrow ditches, or other linear depressions. Cut-slope applications may also be considered. The MFD is well-suited where the available right-of-way is limited, distributed flow from the ~~highway~~public transportation project surface is feasible, and lateral gradients are generally less than 25% (4H:1V). The MFD ~~can~~may also be applied in an end-of-pipe application, where surface runoff is collected and conveyed to a location where flows can be re-dispersed to the MFD.

The MFD removes suspended solids, phosphorus, and metals from ~~highway~~stormwater runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration. Stormwater runoff is conveyed to the MFD via distributed flow or is re-dispersed to a vegetation-free gravel zone to ensure sheet flow and provide some pollutant trapping. Next, a grass strip provides pretreatment, further enhancing filtration and extending the life of the system. The runoff is then filtered through a bed of porous, alkalinity-generating granular medium—the media filter drain mix. Then treated water drains away from the MFD mix bed into a downstream conveyance system.

MFDs are suitable for providing water quality treatment, runoff reduction (for exfiltrating filters), and limited peak flow attenuation if designed properly. If large storm peak flow attenuation is required, MFDs need to be coupled with upstream or downstream detention practices.

Media Filter Drain Design Summary

Treatment Standard Applicability	
Recharge	Yes (if designed to infiltrate)
Water Quality	Tier 1 (infiltrating)/ Tier 2 (filter)
Channel Protection	Hydrologic Condition Method (unlined)/ Extended Detention Method (lined)
Q_{P10} and Q_{P100}	Hydrologic Condition Method (unlined). Partial credit through CN_{Adj}.
Key Elements	
Feasibility: ▪ Infiltration rate shall be ≥0.2 inches per hour as confirmed by methods in Section 4.3.3.2 if designed to infiltrate. ▪ Separation to SHGWT of at least 3 feet from the bottom of the practice if designed to infiltrate. Otherwise SHGWT should be below the bottom of the practice. ▪ Shall be located on slopes ≤25%.	
Pre-treatment: ▪ Pre-treatment includes a gravel no-vegetation zone 1 to 3 feet wide and a grass strip ≥ 3 feet wide.	

Treatment:
▪ For practice designed to infiltrate, the practice shall infiltrate the T_V. Design T_V may be subtracted from the Re_V and WQ_V. The T_V may also be credited towards the CP_V, Q_{P10}, and Q_{P100} through the Hydrologic Condition Method.
▪ For practice designed as a filter, the filter bed shall be sized to filter the T_V.
▪ Contributing drainage area slope ≤ 9.4%.
▪ Media filter drain bed:
  ○ Drain mix shall be composed of mineral aggregate, perlite, dolomite lime, and gypsum in proportions listed on Table 6-2.
  ○ Width is based on infiltration rate and length of drain, but not less than 2 feet.
  ○ Depth ≥ 12 inches.
▪ 4-inch grassed topsoil blanket over media filter drain.
▪ Underdrain shall be provided if underlying soils do not allow water to infiltrate.	

Information contained in this table is for quick reference and is not inclusive of all requirements. All required elements in this section shall be met in order for the STP to be in conformance with this Manual.	

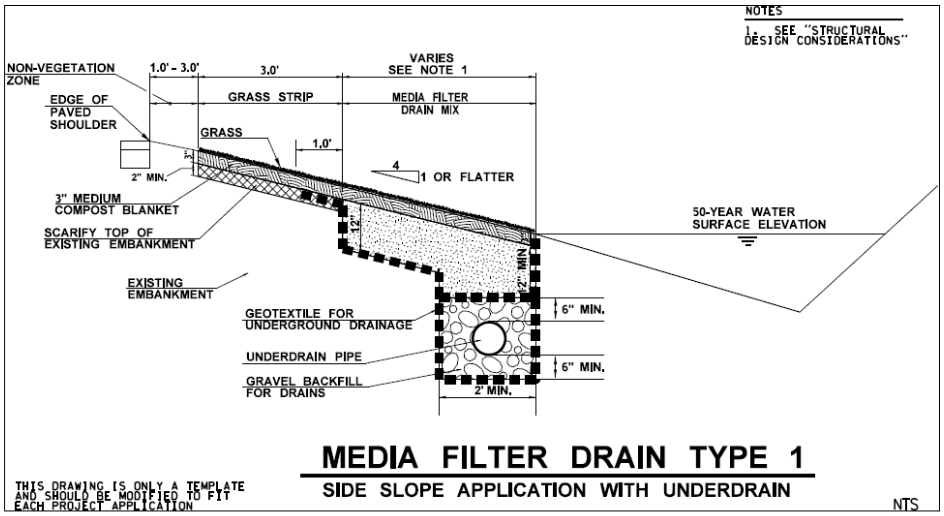


Figure 6-5. Media Filter Drain, Type 1

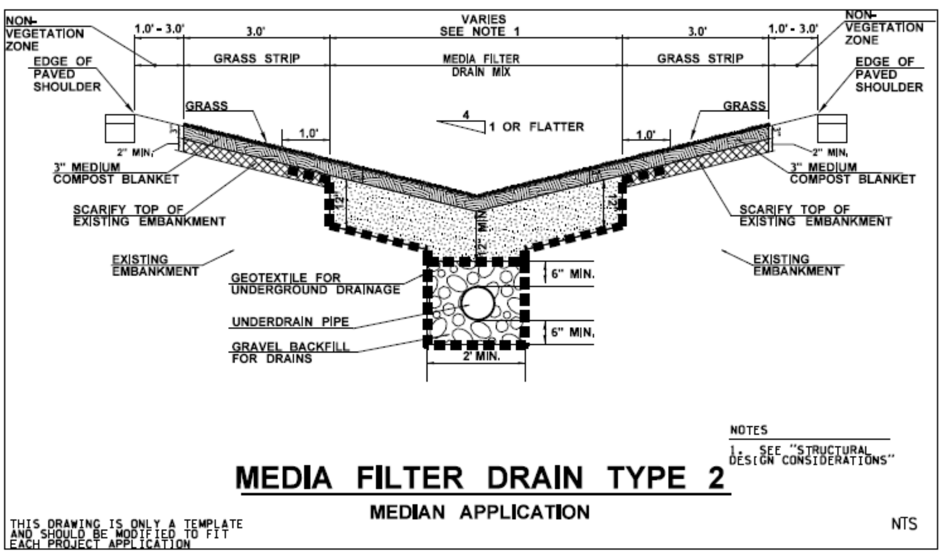


Figure 6-6. Media Filter Drain, Type 2

6.4.2.1. Media Filter Drain Feasibility

Required Elements:

- For use as an infiltration practice, underlying soils shall have an infiltration rate (f_c) of at least 0.2 inches per hour, as confirmed by soil testing requirements for infiltration pursuant to ~~in~~ Section 4.3.3.2~~field geotechnical tests~~.
- **Shallow groundwater.** Determine seasonal high groundwater table levels at the project site to ensure the MFD mix bed and the underdrain~~(~~, if applicable~~)~~, will not become saturated by shallow groundwater. The hydraulic and runoff treatment performance of the MFD may be compromised due to backwater effects and lack of sufficient hydraulic gradient due to shallow groundwater or pooling at the discharge location. Vertical separation from the bottom of the MFD and seasonal high groundwater or bedrock shall be the same as for infiltration practices (Section 4.3.3.1) if designed to infiltrate, or as for filtering practices (Section 4.3.4.1) if lined ~~and/~~or underdrained.
- MFDs shall only be ~~considered~~used where the site can be reasonably designed to locate a MFD on lateral slopes less than or equal to 25%.

Design Guidance:

- **Unstable slopes.** In areas where slope stability may be problematic, consult a geotechnical engineer.
- **Narrow roadway shoulders.** In areas where there is a narrow roadway shoulder (width less than 10 feet), consider placing the MFD farther down the embankment slope. This will reduce the amount of rutting from vehicles leaving the roadway shoulder in the MFD and decrease overall maintenance repairs.

6.4.2.2. Media Filter Drain Conveyance

Required Elements:

- Water shall be conveyed to the MFD via sheet flow. Concentrated flows shall be re-dispersed prior to entering the MFD.
- Lateral MFD side slopes adjacent to the roadway pavement shall be equal to or less than 4H:1V. As side slopes approach 3H:1V, without design modifications, sloughing may become a problem due to friction limitations between the separation geotextile and underlying soils.
- Longitudinal MFD slopes shall be no steeper than 5%.
- The longest flow path from the contributing area delivering distributed flow to the MFD shall not exceed 150 feet.

6.4.2.3. Media Filter Drain Pre-Treatment

Required Elements:

- **No-Vegetation Zone.** The no-vegetation zone (vegetation-free zone) is a shallow gravel zone located directly adjacent to the ~~highway~~public transportation project pavement~~.~~. The no-vegetation zone functions as a level spreader to promote distributed flow and a deposition area for coarse sediments. The no-vegetation zone ~~must~~shall be between 1 foot and 3 feet wide. Depth ~~will~~shall be a function of how the roadway section is built from subgrade to finish grade; the resultant cross section will typically be triangular to trapezoidal. Within these bounds, the width varies depending on VTrans or municipal maintenance spraying practices if applicable.

- **Grass Strip.** The grass strip functions as additional pre-treatment and runoff velocity reduction for distributed flow from the adjacent ~~highway~~public transportation project surface. Pre-treatment is achieved through filtering and limited infiltration. The width of the grass strip ~~is~~shall be dependent on the availability of space within the ~~highway~~public transportation side slope~~. The minimum grass strip width is~~, but shall be 3 feet~~.~~ wide at a minimum. At a minimum, the existing embankment ~~will~~shall be scarified 2 inches and covered with 4~~"~~ inches of topsoil meeting the Post-Construction Soil Depth and Quality Treatment Standard (Section 6.3) and seeded. Consider adding aggregate to the soil mix to help minimize rutting problems from errant vehicles. The soil mix ~~should~~shall ensure grass growth for the design life of the MFD.

Design Guidance:

- To ensure sediment accumulation does not restrict distributed flow, edge of pavement installations should include a 1-inch drop between the pavement surface and no-vegetation zone.
- Grass strips wider than 3 feet are recommended if additional space is available within the right of way.

6.4.2.4. Media Filter Drain Treatment

Required Elements:

- **Credit toward Treatment Standards.**
  - For MFDs that are not designed to infiltrate, the treatment volume stored above and within the filter media ~~is~~shall be credited towards WQ_V. MFDs that function as filters are Tier 2 practices.
  - For MFDs that function as infiltration practices, the treatment volume (T_V) stored behind above and within the filter media and infiltrated ~~is~~shall be credited towards WQ_V, CP_V, Q_{P10}, and Q_{P100}. MFDs that function as infiltration practices are Tier 1 practices. ~~MFDs function as filters are Tier 2 practices.~~
  - Where T_V credit for infiltration from the bottom of the filter bed to native soil is desired, the sizing equation from the Media Filter Drain Mix Bed Sizing Procedure below should be combined with the sizing equation for infiltration trenches (Section 4.3.3.5).
- **Components**
  - **Media Filter Drain Mix Bed.** The MFD mix is a mixture of crushed rock (sized by screening), dolomite, gypsum, and perlite. The crushed rock provides the support matrix of the medium; the dolomite and gypsum add alkalinity and ion exchange capacity to promote the precipitation and exchange of heavy metals; and the perlite improves moisture retention to promote the formation of biomass within the MFD mix. The combination of physical filtering, precipitation, ion exchange, and biofiltration enhances the water treatment capacity of the mix. The permeability rate used to size the MFD shall be 10 inches per hour.
  - **4-Inch Medium Topsoil Blanket and Grass.** Place a 4-inch medium topsoil blanket with grass over the media filter drain bed area to reduce noxious weeds and unwanted vegetation. Topsoil shall meet required elements of the Post-Construction Soil Depth and Quality Treatment Standard (~~Section 3.3~~Subchapter 3.0 and Section 6.3).

- **Conveyance System below Media Filter Drain Mix.** The gravel underdrain trench provides hydraulic conveyance when treated runoff needs to be conveyed to a desired location such as a downstream flow control facility or stormwater outfall. In Group C and D soils, an underdrain pipe helps ensure free flow of the treated runoff through the MFD mix bed. In some Group A and B soils, an underdrain pipe may not be necessary if most water percolates into subsoil from the underdrain trench. ~~Evaluate t~~The need for underdrain pipe shall be evaluated in all cases. The gravel underdrain trench ~~can~~may be eliminated if flows can be conveyed laterally to an adjacent ditch or onto a fill slope that is properly vegetated to protect against erosion. ~~Keep t~~The MFD mix shall be kept free draining up to the 50-year storm event water surface elevation represented in the downstream ditch.

Materials.

- The MFD mix ~~consists~~shall include of the amendments listed in Table 6-2. Mixing and transportation ~~must~~shall occur in a manner that ensures the materials are thoroughly mixed prior to placement and that separation does not occur during transportation or construction operations.

Table 6-2. Media Filter Drain Mix

<table>
<tr><th>Amendment</th><th>Quantity</th></tr>
<tr><td>Mineral Aggregate:
Shall meet all requirements in VTrans Standard Specification 704.11 – Aggregate for Bituminous Surface Treatment with exception that the fracture requirement in 704.11(c) shall be at least two fractured faces.
Shall meet grading requirements for Stone Grits as shown in Table 704.11A.</td><td>3 cubic yards</td></tr>
<tr><td>Perlite:
Horticultural Grade shall be in pelletized o~~f~~r granular form.
Shall meet the following requirements for quality and grading:
<table>
<tr><th colspan="3">Quality Requirements</th></tr>
<tr><th>Property</th><th>Test Method[1]</th><th>Requirement</th></tr>
<tr><td>pH (of water slurry)</td><td>PI 202</td><td>6.5-8.0</td></tr>
<tr><td>Bulk Density (lb/ft³)</td><td>PI 200</td><td>2 -10</td></tr>
</table>
[1]PI, abbreviation for the Perlite Institute
<table>
<tr><th colspan="2">Gradation Requirements</th></tr>
<tr><th>Sieve Size</th><th>Percent Passing</th></tr>
<tr><td>No. 4</td><td>99-100</td></tr>
<tr><td>No. 18</td><td>30 max</td></tr>
<tr><td>No. 30</td><td>10 max</td></tr>
</table>
All percentages by weight</td><td>1 cubic yard per 3 cubic yards of mineral aggregate</td></tr>
<tr><td>Dolomite Lime: $CaMg(CO_3)_2$ (calcium magnesium carbonate)
Agricultural grade shall be in a pelletized or granular form meeting requirements of ASTM C 602 Class Designation E</td><td>40 pounds per cubic yard of perlite</td></tr>
<tr><td>Gypsum: $CaSO_4 \bullet 2H_2O$ (hydrated calcium sulfate)
Agricultural grade shall be in a pelletized o~~f~~r granular form and shall meet the following grading requirements:
<table>
<tr><th>Sieve Size</th><th>Percent Passing</th></tr>
<tr><td>¼”</td><td>99-100</td></tr>
<tr><td>No. 20</td><td>20 max</td></tr>
</table>
All percentages by weight</td><td>12 pounds per cubic yard of perlite</td></tr>
</table>

- These materials ~~should~~shall be used in accordance with the following VTrans Standard Specifications:
  - Drainage Aggregate – Section 704.16

- Underdrain Pipe – Sections 710.03 or 710.06
- Geotextile for Underdrain Trench Lining – Section 720.01

- **Design Method**

Length (perpendicular to direction of flow).

- The length of the MFD shall be the same as the length of the contributing pavement.

Cross-Section.

- The surface of the MFD should have a lateral slope less than 4H:1V (<25%). On steeper terrain, it may be possible to construct terraces to create a 4H:1V slope, or other engineering may be employed to ensure slope stability up to 3H:1V.

- The resultant slope from the contributing drainage area should be less than or equal to 9.4%, calculated using the following equation:

$$S_{CFS} \leq (G^2 + e^2)^{0.5}$$

Where:

S_{CFS} = resultant slope of the lateral and longitudinal slopes (%)

e = lateral slope (superelevation) (%)

G = longitudinal slope (grade) (%)

Media Filter Drain Mix Bed Sizing Procedure.

- The width of the MFD mix bed ~~is~~shall be determined by the amount of contributing pavement routed to the embankment.

- The surface area of the MFD mix bed ~~needs to~~shall be sufficiently large to fully infiltrate and filter the runoff treatment design flow rate using the long-term filtration rate of the MFD mix.

- For design purposes, ~~incorporate~~ a 50% safety factor shall be incorporated into the long-term MFD mix filtration rate to accommodate variations in slope, resulting in a design filtration rate of 10 inches per hour.

- The MFD mix bed shall have a bottom width of at least 2 feet in contact with the conveyance system below the MFD mix.

- The MFD mix bed shall be a minimum of 12 inches deep, including the section on top of the underdrain trench.

- For runoff treatment, ~~base~~ the sizing of the MFD mix bed shall be based on the requirement that the runoff treatment flow rate from the pavement area, $Q_{Highway}$, cannot exceed the long-term infiltration capacity of the MFD, $Q_{Infiltration}$.

- $Q_{Highway}$ is the water quality volume ~~P~~peak ~~F~~flow rate as determined using ~~TR-55,~~ TR-20 or an approved equivalent. Water Quality Peak Flow Curve Number calculations apply when determining $Q_{Highway}$ (see Section 2.2.4.2).

- ~~Base t~~The long-term infiltration capacity of the MFD shall be based on the following equation:

$$\frac{LTIR\ x\ L\ x\ W}{C\ x\ SF} = Q_{Infiltration}$$

Where:

$LTIR =$ long − term infiltration rate of the media filter drain mix (use 10 inches per hour for design)

L = length of media filter drain (parallel to roadway) (ft.)

W = width of the media filter drain mix bed (ft.)

C = conversion factor of 43200 ((in./hr.)/(ft./sec.))

SF = safety factor (equal to 1.0, unless unusually heavy sediment loading is expected)

- Assuming that the length of the MFD is the same as the length of the contributing pavement, solve for the width of the media filter drain:

$$W \geq \frac{Q_{Highway}\ x\ C\ x\ SF}{LTIR\ x\ L}$$

Underdrain Design

- Underdrain pipe can provide a protective measure to ensure free flow through the MFD mix and is sized similar to storm drains. For MFD underdrain sizing, an additional step is required to determine the flow rate that can reach the underdrain pipe. This is done by comparing the contributing basin flow rate to the infiltration flow rate through the MFD mix and then using the smaller of the two to size the underdrain. The analysis described below considers the flow rate per foot of MFD, which ~~allows you~~provides the flexibility of incrementally increasing the underdrain diameter where long lengths of underdrain are required.
- When underdrain pipe connects to a storm drain system, ~~place~~ the invert of the underdrain pipe shall be placed above the 25-year water surface elevation in the storm drain to prevent backflow into the underdrain system.
- The following describes the ~~procedure~~required process for sizing underdrains.

1. Calculate the flow rate per foot from the contributing basin to the MFD. The design storm event used to determine the flow rate ~~should~~shall be relevant to the purpose of the underdrain. For example, if the MFD will be used to convey treated runoff to a detention practice, size the underdrain for the design storm event to be conveyed to the detention practice.

$$\frac{Q_{highway}}{ft} = \frac{Q_{highway}}{L_{MFD}}$$

Where:

$\frac{Q_{highway}}{ft}$ = contributing flow rate per foot (cfs/ft)

L_{MFD} = length of MFD contributing runoff to the underdrain (ft)

2. Calculate the MFD flow rate of runoff per foot given an infiltration rate of 10 in./hr. through the MFD mix.

$$Q_{\frac{MFD}{ft}} = \frac{f\ x\ W\ x\ 1\ ft}{ft}\ x\ \frac{1\ ft}{12\ in}\ x\ \frac{1\ hr}{3600\ s}$$

Where:

$Q_{\frac{MFD}{ft}}$ = flow rate of runoff through MFD mix layer (cfs/ft)
W = width of underdrain trench (ft); minimum width is 2 ft
f = infiltration rate throug the MFD mix (in/hr) = 10 in/hr

3. Size the underdrain pipe to convey the runoff that can reach the underdrain trench. This is taken to be the smaller of the contributing basin flow rate or the flow rate through the MFD mix layer.

$$Q_{\frac{UD}{ft}} = \text{smaller}\left\{Q_{\frac{highway}{ft}}\ \text{or}\ Q_{\frac{MFD}{ft}}\right\}$$

Where:

$Q_{\frac{UD}{ft}}$ = underdrain design flow rate per foot (cfs/ft)

4. Determine the underdrain design flow rate using the length of the MFD and a factor of safety of 1.2.

$$Q_{UD} = 1.2\ x\ Q_{\frac{UD}{ft}}\ x\ W\ x\ L_{MFD}$$

Where:

Q_{UD} = estimated flow rate to the underdrain (cfs)
W = width of underdrain trench; minimum width is 2 ft
L_{MFD} = length of MFD contributing runoff to the underdrain (ft)

5. Given the underdrain design flow rate, determine the underdrain diameter. Round pipe diameters to the nearest standard pipe size and have a minimum diameter of 6 inches.

$$D = 16\left(\frac{(Q_{UD}\ x\ n)}{s^{0.5}}\right)^{3/8}$$

Where:

D = underdrain pipe diameter (inches)
n = Manning's coefficient
s = slope of pipe (ft/ft)

6.4.2.5. Media Filter Drain Vegetation and Landscaping

Required Elements:

- Landscape the grass strip using the required elements for Pre-Treatment Filter Strips (Section ◍).
- Topsoil shall meet the requirements of Subchapter 3.0 and Section 6.3.

6.5. Runoff Control Measures for ~~Highway~~Public Transportation Project Redevelopment – Major Maintenance Projects

The ~~best management practices~~BMPs below, referred to in this section as measures, are available for use on Redevelopment-Major Maintenance projects. These measures ~~will~~shall be considered for implementation to improve pre-existing stormwater runoff conditions within existing ~~highway~~ rights-of-way or if possible, outside of the right-of-way. Where existing swales, vegetated shoulders, median areas, and discharge points within existing ~~highway~~ rights-of-way or drainage easements can be retrofitted with these measures without adversely affecting safety or the integrity of the ~~highway~~public transportation project, measures ~~will~~shall be designed to disconnect, capture and infiltrate, ~~and/~~or evapotranspire water quality volume from impervious areas, and to reduce or eliminate existing erosion issues, to the extent practicable.

Runoff control measures in this ~~s~~Section may be implemented on any project, but ~~cannot be used to meet~~ ~~pP~~ost-~~cC~~onstruction ~~sS~~tormwater ~~tT~~reatment ~~sS~~tandards if necessary as determined in Table 6-1.~~ ~~AnyA~~all new impervious areas subject to ~~pPost-cConstruction s~~Stormwater ~~t~~Treatment ~~s~~Standards ~~must~~shall be treated with STPs in ~~Section~~Subchapter 4.0 or Section 6.4 and pursuant to the requirements of this Manual.

6.5.1. Modifications to Acceptable STPs

Any STP contained in ~~Sections~~Subchapter 4.0 ~~and~~or Section 6.4 ~~can~~may be used to treat and manage stormwater from Redevelopment-Major Maintenance impervious surfaces. They should be designed to meet sizing requirements if practical. If sizing for the full treatment standard is impractical within the right-of-way ~~and/~~or project limits, these STPs ~~can~~may be sized to fit within project constraints~~,~~ as long as safe conveyance of larger storm flows can be maintained.

6.5.2. Plunge Pools

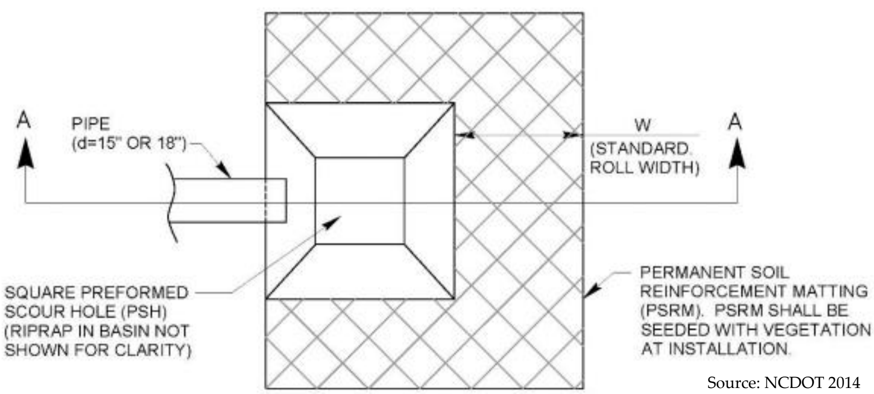
Plunge pools are pre-shaped, stone-lined basins located directly downgrade of a discharge point~~-~~. The man-made structure mimics the natural scour hole that would otherwise form at the conveyance outlet if no energy dissipation were provided. The pool is stabilized with riprap underlain by a gravel layer (or filter fabric in clay and silt soils) to absorb the impact of the discharge, prevent additional erosion and allow suspended particles to settle trapping trash and debris. Once runoff has filled the shallow basin, it overtops the plunge pool and is redistributed as diffuse flow to the surrounding area.

Figure 6-7. Plunge Pools

Plunge pools absorb the impact of high velocities and reduce the potential for downgrade erosion from point discharges by reducing flow velocities. When plunge pools are implemented under small peak flow conditions and installed on level ground, they redistribute concentrated inflow to diffuse outflow to adjacent land. Plunge pools provide a water quality benefit by dispersing flow, which achieves the following:

- Prevents scour at the pipe discharge
- Promotes runoff infiltration
- Reduces soil erosion

Typical examples of a plunge pool layout and profile are shown in Figure 6-8 and Figure 6-9.



Source: NCDOT 2014

Figure 6-8. Example of Plunge Pools (Plan)

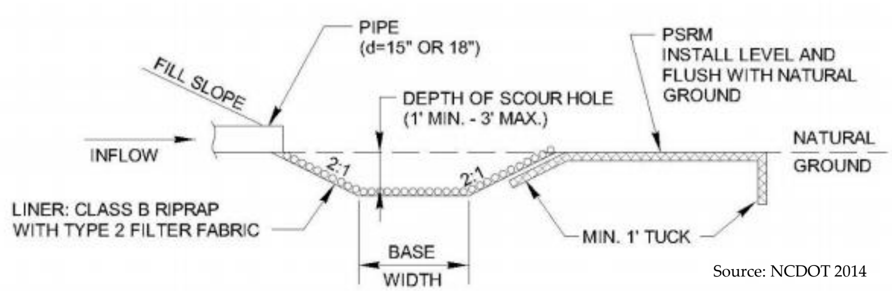
Figure 6-9. Example of Plunge Pools (Profile)

Commented [SE70]: This is guidance

6.5.2.1. Plunge Pool Feasibility

Design Guidance:

- Plunge pools can be used for energy dissipation and diffuse flow in a variety of man-made conveyance systems. For a plunge pool to perform both functions, specific conditions must exist. Most importantly, the ground downgrade must be flat to prevent re-concentration of runoff. To redistribute runoff from channelized flow to diffuse flow, plunge pools should be implemented only for (Q_{10}) peak flows of 10 ft^3/s or less. If diffuse flow is desired and either (1) the Q_{10} peak flow is greater than 10 ft^3/s or (2) the site slope is not relatively flat (<5%), additional requirements apply. Alternatively, the designer could consider the use of a level spreader. If diffuse flow is not desired, then plunge pools need to outlet to a stable channel or other conveyance without causing downstream erosion.



Source: NCDOT 2014

6.5.2.2. Plunge Pool Design

Required Elements:

- To prevent erosion immediately downgrade of the plunge pool, an apron of permanent soil reinforcement matting (PSRM) is required downgrade of the measure.

Required Elements (for pipes ≤ 18" diameter and flows ≤ 9 ft^3/s):

- The downstream area ~~must~~shall be flat (<5%) if diffuse flow is a goal. For slopes greater than 5%, outlet to a stable channel or other stable conveyance shall be provided.
- The maximum allowable discharge for a 15-in. pipe is 6 ft^3/s, based on the Q_{10} discharge.
- The maximum allowable discharge for an 18-in. pipe is 10 ft^3/s, based on the Q_{10} discharge.
- For 15-in. and 18-in. pipes, only Type II Stone Fill (d_{50} = 12 in.), VTrans Standard Specification 706.04(b), ~~can~~shall be used to line the plunge pool. This specification is based on empirical relationships between the area of the discharge pipe and the stone fill d_{50} and unsuccessful

applications of smaller stone fill sizes. A d_{50} of 12 inches allows for a minimum pool depth of approximately 1 foot and a maximum depth of 3 feet. The minimum and maximum stone sizes for Type II Stone Fill are 2 inches to 36 inches, respectively.

- Stone fill thickness and other design requirements of Section 5.3.2 of the VTrans Hydraulics Manual, 2015 apply.
- The base of the plunge pool is square. The width is calculated as follows:
    - Base width = 3 × Discharge pipe size
- Minimum width of the PSRM apron is the standard PSRM roll width.
- PSRM ~~must~~shall be tucked a minimum of 1 foot underneath the filter fabric and natural ground around the perimeter of the plunge pool.
- Side slopes for all four sides of the plunge pool is no greater than 2:1.
- Minimum depth of the plunge pool is 1 foot.
- Maximum depth of the plunge pool is 3 feet.

Required Elements (additional for pipes > 18" diameter and flows > 9 ft^3/s):

- The size of the stone fill ~~will~~shall be selected using the design criteria of Section 5.3.2 of the VTrans Hydraulics Manual, 2015.
- The filter fabric ~~is~~shall be placed between the riprap and soil foundation to prevent soil movement through the openings of riprap.

Design Guidance:

- For plunge pools with swale inlets, the swale should be flared around the plunge pool to match the pool width. Circular plunge pools are typically used only with pipes.

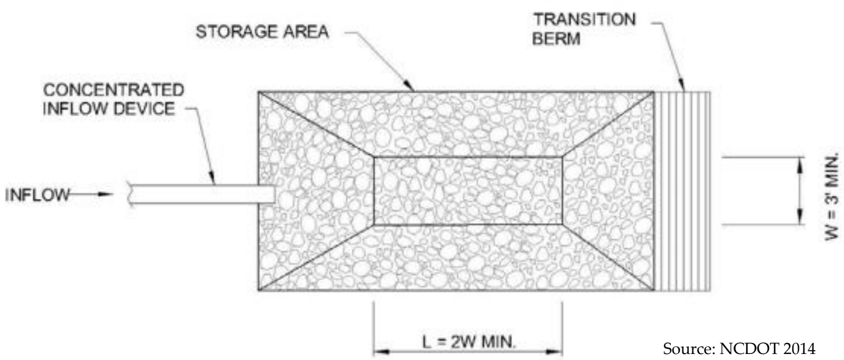
Design Guidance (for pipes ≤ 18" diameter and flows ≤ 9 ft^3/s):

- Where diffuse flow is a primary goal, plunge pools must be installed level in relatively flat areas. To avoid shifting of the plunge pool after installation, the plunge pool should be installed in undisturbed soil instead of in fill material.
- Confirm that the location of the plunge pool is outside of clear recovery zones and environmentally sensitive areas.
- Check the available right-of-way when determining the plunge pool footprint and orientation.
- Confirm that the apron is flush with the natural ground. The elevation of the top of the plunge pool should be the same as the elevation of the PSRM.
- Confirm that riprap consists of a well-graded mixture of stone. Smaller-size riprap stones should be used to fill voids between larger stones.
- Where practical, route off-site runoff away from the plunge pool.

- Immediately after construction, stabilize the exit areas with vegetation. Clear the area of all construction debris and check the exit areas for any potential obstructions that could promote channelized flow.
- When selecting the plunge pool location, the designer must take into account topography. The plunge pool should be oriented to conform to the contours of the site. Typically, the plunge pool is placed at the highway drainage system outlet. Alternatives should be considered when steep slopes are located at a discharge point. For example, a riprap lined channel can be constructed at a pipe outlet to then discharge into a plunge pool. This method is sometimes applied in gore areas at highway interchanges.
- Confirm that the plunge pool has easy access for maintenance.

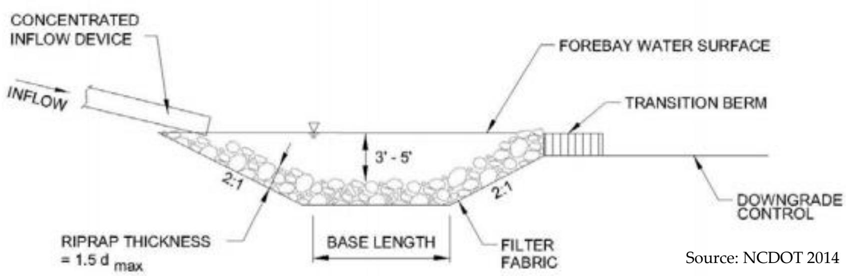
Design Guidance (additional, for pipes > 18" diameter and flows > 9 ft^3/s):

- Contributing drainage area should be delineated to determine the Q_{10} discharge.
- The plunge pool size should be based on the volume associated with 0.1 inches of runoff for the impervious area within the contributing drainage area. Once the volume is determined, the plunge pool configuration is determined.
- Rectangular plunge pools should have a minimum length-to-width ratio of 2:1, where practical, to promote sedimentation, with a maximum ratio of 6:1 (Figure 6-10).
- Rectangular plunge pools width should be a minimum of 3 feet. Circular plunge pools should have a minimum diameter of 5 feet.
- Depth of the plunge pool should be between 3 and 5 feet.
- Plunge pool side slopes should be flatter than or equal to 2:1 (Figure 6-11).
- Transition berms should have a minimum top width of 5 feet (in the direction of flow).
- Outflow control structures should be considered to reduce peak flows to downstream conveyances or receiving waters.
- The transition berm between the plunge pool and the downstream STP, conveyance or receiving water should be made of a non-erodible material designed to minimize exit velocities and diffuse flow downstream.



Source: NCDOT 2014

Figure 6-10. Plunge Pool, Rectangular (Plan View)



Source: NCDOT 2014

Figure 6-11. Plunge Pool, Rectangular (Profile View)

6.5.2.3. Plunge Pool Inspection and Maintenance

Design Guidance:

- Plunge pools are to be inspected for downstream erosion, improper construction, structural damage and sediment deposition. If the plunge pool is considered functional without significant buildup of sediment during this inspection, no maintenance activities are performed. If the plunge pool is considered non-functional or has a significant accumulation of sediment at this inspection, sediment will be removed and functional improvements and repairs will be made. Figure 6-12. Plunge Pool Maintenance illustrates the difference between a maintained plunge pool and a plunge pool in need of cleaning.

Figure 6-12. Plunge Pool Maintenance (NCDOT 2014)

- Where possible, provide an area on site where sediment removed from the plunge pool can be disposed. The area should be relatively flat to promote stabilization after sediment is deposited. The sediment disposal area should also be gently sloped away from the plunge pool to prevent deposited sediment from reentering. The sediment disposal area should be configured in a manner that prevents adverse effects to receiving waters or adjacent properties.

6.5.2.4. Plunge Pool Safety Considerations

Design Guidance:

- Plunge pools located in residential or public areas may present a drowning hazard. Consider fencing and signage around the area to ensure safety.

6.5.3. Check Dams

Water quality check dams are permanent structures that reduce the effective slope of a conveyance swale, and create small pools, dissipating the energy of flow, increasing hydraulic residence time, allowing suspended particles to settle trapping trash and debris, and promoting infiltration. The check~~s~~ dams should be used in series, with the toe of the upstream check dam at the same elevation as the top of the downstream check dam.

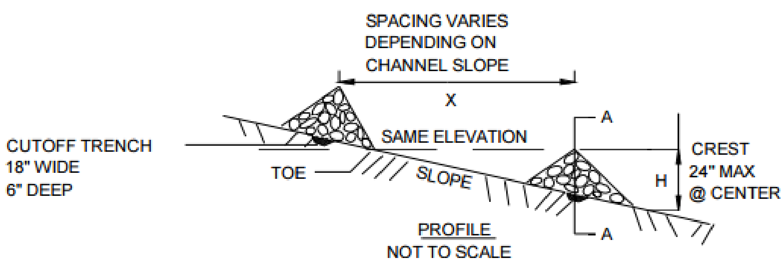


Figure 6-13. Check Dam (Profile View)

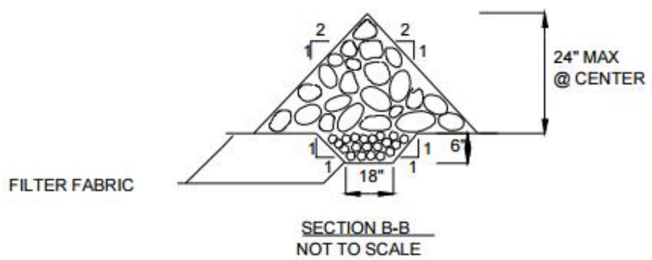


Figure 6-14. Check Dam (Detail)

6.5.3.1. Check Dam~~s~~ Feasibility

Required Elements:

- Check dams ~~are~~shall not ~~to~~ be installed in live streams or channels.

Design Guidance:

- Check dams can be used in most conveyance swales, ditches, and channels. Check dams should be used where conveyances discharge directly to receiving waters to promote sedimentation, infiltration, and energy dissipation. Check dams, in effect, reduce the slope in drainage ways. This may lead to an overall reduction in the capacity of the drainage way. This capacity reduction needs to be considered, so that the flows within the drainage way do not exceed volume capacities.

6.5.3.2. Check Dam~~s~~ Design

Required Elements:

- Check dams ~~are~~shall be spaced based on the channel slope. Spacing shall be ~~per~~pursuant to the requirements in the Vermont Standards and Specifications for Erosion Prevention and Sediment Control (2006 or most recent edition).
- The maximum ~~desired~~ check dam height is 24 inches (for maintenance purposes).
- Check dam materials shall be designed appropriately for the design channel velocities.
- Armoring may be needed at the downstream toe of the check dam to prevent erosion.
- Check dams ~~must~~shall be firmly anchored into the side-slopes to prevent outflanking; check dams ~~must~~shall also be anchored into the channel bottom so as to prevent hydrostatic head from pushing out the underlying soils. Maximum water elevation in channel (for 10-year design storm) shall be compared against anchoring height of check dam to ensure outflanking does not occur.
- Check dams ~~must~~shall be designed with a center weir sized to pass the channel design storm peak flow (10-year storm event for man-made channels). Capacity of the drainage conveyance shall be checked to ensure storm flows can pass with at least 6" of freeboard for a 10-year storm.

Design Guidance:

- The check dam should be designed so that it facilitates mowing and maintenance.
- Each check dam should have a weep hole or similar drainage feature so it can dewater after storms.
- Check dams should be composed of wood, concrete, stone, or other non-erodible material, or should be configured with elevated driveway culverts.
- Individual channel segments formed by check dams or driveways should generally be at least 25 to 40 feet in length.

6.5.3.3. Check Dams Safety Considerations

Required Elements:

- Check dams shall be installed in channels such that either they are located outside of the clear zone of the highwaypublic transportation project or they do not constitute a roadside hazard.

7.0 DEFINITIONS

As used in this Manual, the following terms shall have the specified meaning, unless a different meaning is clearly intended by the context. If a term is not defined, it shall have its common meaning.

"1-year storm" means a storm event which has a 1-year recurrence interval or statistically has a 100% chance on average of occurring in a given year.

"10-year storm" means a storm event which has a 10-year recurrence interval or statistically has a 10% chance of occurring in a given year.

"100-year storm" means a storm event which has a 100-year recurrence interval, or statistically has a 1% chance on average of occurring in a given year.

"Agency" means the Vermont Agency of Natural Resources.

"Anti-seep collar" means 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.

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

"Aquatic bench" means a 10~~ten~~ to 15~~fifteen~~ foot-wide bench which is located around the inside perimeter of a stormwater pond 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" means a geological formation that contains and transports groundwater.

"Authorization to discharge" means an authorization to discharge issued by the Secretary pursuant to a general permit.

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

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

"Berm" means a shelf that breaks the continuity of a slope; a linear embankment or dike.

"BMP" or "best management practice" means a schedule of activities, prohibitions or practices, maintenance procedures, green infrastructure, and other management practices to prevent or reduce water pollution, including the STPs set forth in this Manual.

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

"Channel Protection Standard," "channel protection," or "CPv" means the design criteria in this Manual that requires management of the post-development stormwater runoff from the 1-year, 24-hour storm event for the control of stream channel erosion.

"Check dam" means a small dam constructed in a gully, swale, or other channel to decrease the flow velocity, by reducing the channel gradient; minimize channel scour; and promote deposition of sediment. Check dams may be constructed of wood, small diameter stone, concrete, or earth.

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

"Clay" or "clay soil" means: (1) a mineral soil consisting of particles less than 0.002 millimeter in equivalent diameter, (2) a soil texture class, or (3) for 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

"CN" see definition of "curve number."

"Common plan of development" means a development that is completed in phases or stages when such phases or stages share a common state or local permit related to the regulation of land use, the discharge of wastewater or a discharge to surface waters or groundwater, or a development designed with shared common infrastructure. Common plans of development include subdivisions, industrial and commercial parks, university and other campuses, and ski areas.

"Compaction" means 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" means any channel intended for the conveyance of water, whether open or closed.

"Contour" means: (1) an imaginary line on the surface of the earth connecting points of the same elevation, or (2) a line drawn on a map connecting points of the same elevation.

"CPv" see definition of "Channel Protection Standard."

"Crest" means the top of a dam, dike, spillway, or weir, frequently restricted to the overflow portion.

"Curve number" or "CN" means 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" means a 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" means a process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

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

"Dam" means 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.

"Department" means the Vermont Department of Environmental Conservation.

"Detention" means 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" means 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" means the construction of impervious surface on a tract or tracts of land.

"Dike" means an embankment to confine or control water.

"Disturbance" means removal of stable surface treatment leaving exposed soil susceptible to erosion.

"Disturbed area" means an area in which the natural vegetative or other soil cover has been removed or altered and, therefore, is susceptible to erosion.

"Diversion" means 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" means: (1) the removal of excess surface water or groundwater from land by means of surface or subsurface drains, or (2) soil characteristics that affect natural drainage.

"Drainage area" means all land and water area from which runoff may run to a common (design) point.

"ED" see definition of "extended detention."

"Emergency spillway" means a dam spillway designed and constructed to discharge flow in excess of the principal spillway design discharge.

"Energy dissipator" means 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" means: (1) the wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep, or (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"** means 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"** means 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"** means an erosion process in which numerous small channels only several inches deep are formed.
>
> **"Sheet erosion"** means 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" means 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" means 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" means an impervious surface that is in existence, regardless of whether it ever required a stormwater discharge permit.

"Expansion" and "expanded portion" means 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" or "ED" means a stormwater design feature that provides for the gradual release of a volume of water over a period of time as specified in this Manual, to increase settling of pollutants and protect downstream channels from frequent storm events.

"Extended Detention Method" means a method for meeting the Channel Protection Standard for those sites where the practice or suite of practices is insufficient to achieve the HCM for meeting Channel Protection Standard.

"Extreme Flood Protection Standard," "extreme flood control," or "Q_{P100}" means the design criteria in this Manual that requires management of the post-development stormwater runoff from the 100-year, 24-hour storm event for the control of overbank flooding that results from that storm event.

"Filter bed" means the section of a constructed filtration device that houses the filter media and the outflow pipes.

"Filter media" means the sand, soil, or other material in a filtration device used to provide a permeable surface for pollutant and sediment removal.

"Fines" means the silt- and clay-size particles in soil.

"Flow splitter" means 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.

"Freeboard" means 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" means a type of drain consisting of an excavated trench refilled with pervious material, such as coarse sand, gravel, or stone, through whose voids water percolates and flows to an outlet.

"Gabion" means a flexible woven-wire basket filled with small stones. Gabions may be assembled into many types of structures such as revetments, retaining walls, channel liners, and groins.

"Grade" means: (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, or (3) to finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation.

"Gravel" means: (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, or (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.

"Ground cover" means plants that are low growing and provide a thick growth that protects the soil as well as providing some beautification of the area occupied.

"**Groundwater Recharge Standard", "Recharge Volume", or "Re$_v$"** means ~~a design criteria~~a design criterion that requires infiltration of the recharge volume to ensure annual average recharge rates are maintained at a development site to preserve existing water table elevations.

"Gully" means 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 a gully and a 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.

"HCM" see definition of "Hydrologic Condition Method."

"HCv" or "hydrologic condition volume" means the difference between the pre-development and post-development site runoff volume for the 1-year, 24-hour storm.

"Head" means: (1) the height of water above any plane of reference, or (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. "Head" is used in various terms such as "pressure head," "velocity head," and "head loss."

"Healthy soil" means soil that has a well-developed, porous structure, is chemically balanced, supports diverse microbial communities, and has abundant organic matter.

"High marsh" means a pondscaping zone within a stormwater wetland that exists from the surface of the normal pool to a 6~~six~~-inch depth and typically contains the greatest density and diversity of emergent wetland plants.

"Hotspot" means an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

"HSG" see definition of "hydrologic soil group."

"Hydraulic gradient" means the slope of the hydraulic grade line. The slope of the free surface of water flowing in an open channel.

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

"Hydrologic Condition Method" or "HCM" means a method for meeting the Channel Protection Standard, intended to determine a suite of practices, which when implemented, will approximate runoff characteristics of "woods in good condition" for the 1-year, 24-hour storm event.

"Hydrologic soil group" or "HSG" means 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" means seed or other material applied to areas to revegetate them after a disturbance.

"Impervious surface" or "I" means those manmade surfaces, including paved and unpaved roads, parking areas, roofs, driveways, and walkways, from which precipitation runs off rather than infiltrates

"Infiltration rate" or "(f_c)" means the rate at which stormwater percolates into the subsoil measured in inches per hour.

"Manual" see definition of "Vermont Stormwater Management Manual."

"Microtopography" means 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" means a covering on surface of soil to protect and enhance certain characteristics, such as water retention qualities.

"Municipality" means 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.

"New development" means the construction of new impervious surface on a tract or tracts of land where no impervious surface previously existed.

"Normal depth" means depth of flow in an open conduit during uniform flow for the given conditions.

"Off-line" means a stormwater management system designed to manage a storm event by diverting a percentage of stormwater events from an STP or storm drainage system.

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

"On-line" means a stormwater management system designed to manage stormwater in a STP or storm drainage system without diversion.

"Outfall" means the point where water flows from a conduit, stream, or drain.

"Outlet" means the point at which water discharges from a, pipe, channel, or drainage area.

"Overbank Flood Protection Standard, "overbank flood control," or "Q_{P10}" means the design criteria in this Manual that requires management of the post-development stormwater runoff from the 10-year, 24-hour storm event for the control of overbank flooding that results from that storm event.

"Peak discharge rate" means the maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

"Permanent seeding" means establishing perennial vegetation that may remain on the area for many years.

"Permeability" means the rate of water movement through the soil column under saturated conditions

"Person" means 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" means 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.

"Pond drain" means a pipe or other structure used to drain a permanent pool within a specified time period.

"Pondscaping" means 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 or soil saturation.

"Porosity" means the ratio of pore volume to total solids volume.

"**Post-Construction Soil Depth and Quality Standard**" means the suite of practices and management techniques required under this Manual that pertain to restoring healthy soils after soils are subject to compaction and other impacts incurred during construction. **"Pre-treatment"** means techniques employed in STPs to provide storage or filtering to help trap coarse materials before they enter the system.

"Principal spillway" means the primary pipe or weir that carries baseflow and storm flow through the embankment.

"Project" means new development, expansion, or redevelopment of impervious surface.

"Public transportation project" means a state highway project, town highway project, or other public road project; or a linear public transportation project, such as a trail, bicycle path, or sidewalk project.

"Q_{10}" see definition of "10-year storm."

"Q_{100}" see definition of "100-year storm."

"Q_{P10}" see definition of "Overbank Flood Control Standard".

"Q_{P100}" see definition of "Extreme Flood Protection Standard".

"Recharge rate" means annual amount of rainfall that contributes to groundwater as a function of hydrologic soil group.

"Redevelopment" or "redevelop" means the construction or reconstruction of an impervious surface where an impervious surface already exists when such new construction involves substantial site grading, substantial subsurface excavation, or substantial 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 public road 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" means 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" means 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" means 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" means 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" means broken rock, cobbles, or boulders placed to prevent erosion.

"Riser" means 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" or "Rv" means 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" means 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" means:- (1) (Agronomy) a soil particle between 0.05 and 2.0 millimeters in diameter, (2) a soil textural class, or (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" means the Secretary of the Agency of Natural Resources or the Secretary's duly authorized representative.

"Sediment" means 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" means (1) water escaping through or emerging from the ground, or (2) the process by which water percolates through the soil.

"Seepage length" means 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.

"Sheet flow" means water, usually stormwater runoff, flowing in a thin layer over the ground surface.

"**SHGWT"** means seasonal high groundwater table.

"Side lopes" means the slope of the sides of a channel, dam, or embankment. It is customary to name the horizontal distance first, as 3 to 1, or frequently, 3:1, meaning a horizontal distance (H) of 3 feet to 1 foot vertical (V).

"Silt" means: -(1) (Agronomy) a soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter, (2) a soil textural class, or (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" means 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 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 Piping" means removal of soil material through subsurface flow channels or "pipes" developed by seepage water.

-**"Spillway"** means 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" means providing adequate measures, vegetative or structural that will prevent erosion from occurring.

"Stage" means, for purposes of hydraulics, the variable water surface or the water surface elevation above any chosen datum.

"Stilling basin" means 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.

"Stone diaphragm" means a stone trench filled with small stone used as pre-treatment and inflow regulation in stormwater filtering systems.

"Stone trench" means a shallow excavated channel backfilled with stone and designed to provide temporary storage and permit percolation of runoff into the soil substrate.

"Stormwater discharge permit" or "stormwater permit" means a permit issued by the Secretary for the discharge of regulated stormwater runoff.

"Stormwater runoff," "stormwater," or "runoff" for purposes of this Manual, means precipitation and snowmelt that does not infiltrate into the soil, including material dissolved or suspended in it, but does not include wastes from combined sewer overflows.

"Stormwater treatment practices" or "STPs" means devices that are constructed to provide temporary storage and treatment of stormwater runoff.

"STP" see definition of "stormwater treatment practices."

"Stream buffers" means zones of variable width that are located along both sides of a stream and are designed to provide a protective natural area along a stream corridor.

"Structures" means buildings such as houses, businesses, pump houses, and storage sheds and infrastructure such as roadways, culverts, bridge abutments, and utilities.

"Subgrade" means the soil prepared and compacted to support a structure or a pavement system.

"Swale" means 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.

"Tailwater" means water, in a river or channel, immediately downstream from a structure.

"Time of concentration" or "t_c" means the time required for water to flow from the hydraulically most remote point of a watershed to the outlet.

"Toe" means where the slope stops or levels out; bottom of the slope.

"Topsoil" means fertile or desirable soil material used to top dress road banks, subsoils, parent material, etc.

"Total Maximum Daily Load" or "TMDL" means the calculations and plan for meeting water quality standards approved by the U.S. Environmental Protection Agency and prepared pursuant to 33 U.S.C. § 1313(d) and federal regulations adopted under that law.

"Total suspended solids" or "TSS" means the total amount of soil particulate matter that is suspended in the water column.

"TR-20" or "Technical Release No. 20" means 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 or ponds.

"TR-55" or "Technical Release No. 55" means 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.

"Tract" or "tracts of land" means a portion of land with defined boundaries created by a deed. A deed may describe one or more tracts.

"Trash rack" means a 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.

"TSS" see definition of "total suspended solids."

"Velocity head" means 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" or "VSMM" means the Agency of Natural Resources' stormwater management manual, as adopted and amended by rule.

"VSMM" see definition of "Vermont Stormwater Management Manual."

"**Water Quality Treatment Standard" or "WQTS"** means that standard in this Manual that pertains to the treatment of the Water Quality Volume using appropriately sized practices identified in this Manual as suitable for water quality treatment.

"Water quality volume" or "WQv" means the storage needed to capture and treat 90% of the average annual stormwater runoff volume.

"Water surface profile" means the longitudinal profile assumed by the surface of a stream flowing in an open channel; the hydraulic grade line.

"Waters of the State" means 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.

"Watershed" means the total area of land contributing runoff to a specific point of interest within a receiving water.

"Wedges" means design feature in stormwater wetlands, which increases flow path length to provide for extended detention and treatment of runoff.

"Wing wall" means sidewall extensions of a structure used to prevent sloughing of banks or channels and to direct and confine flow.

8.0 REFERENCES

Commented [SE71]: References were previously at the end of each section but have been compiled here. This section does not appear in the version submitted to rulemaking.

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