Thurston County
Drainage Design and Erosion Control Manual

Volume V
Stormwater BMPs

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Chapter 1 - Introduction to Volume V

1.1 What is the Purpose of this Volume?

This volume of the *Drainage Design and Erosion Control Manual* provides best management practices (BMPs) for designing and maintaining permanent stormwater management facilities.

BMPs are schedules of activities, prohibitions of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce adverse impacts to waters of Washington State. As described in Volume I, BMPs for long-term stormwater management at developed sites can be divided into three categories:

1. **Flow control**: BMPs that address the volume and timing of stormwater flows
2. **Source control**: BMPs that address prevention of pollution from potential sources
3. **Runoff treatment**: BMPs that address treatment of runoff to remove sediment and other pollutants

This volume addresses flow control and runoff treatment, and includes BMPs considered to be low impact development (LID). Source control BMPs are described in Volume IV. Temporary BMPs for erosion and sediment control are found in Volume II.

BMPs included in this volume are summarized in Table 1.1.

The check mark (√) in the column(s) next to each BMP indicates the BMP type (low impact development, flow control, or runoff treatment) and the level of treatment (basic, enhanced, phosphorus, or oil control). The BMP selection process, which explains each of these categories in detail and helps the manual user to select BMPs depending on project and site characteristics, is provided in Volume I.

Where a BMP type or level of runoff treatment has been indicated with an asterisk (*), the standard BMP meeting minimum design criteria does not provide the level of runoff treatment noted, but the standard design may be modified to provide the additional treatment indicated. Refer to the individual BMP design guidelines for more information.

Many of the BMP design guidelines have been adapted from design criteria from *Low Impact Development: Technical Guidance Manual for Puget Sound* (PSAT 2005), the *King County, Washington Surface Water Design Manual* (King County DNRP 2009), and the *Pierce County Stormwater Management and Site Development Manual* (Pierce County Surface Water Management 2008).

Table 1.1. Thurston County Stormwater BMPs.

BMP No.	Title	Type of BMP					
				Runoff Treatment			
		LID	Flow Control	Basic	Enhanced	Phosphorus	Oil Control
LID Stormwater Management BMPs							
LID.01	Native Vegetation Protection, Reforestation, and Maintenance	√					
LID.02	Post-Construction Soil Quality and Depth	√					
LID.03	Reduce Effective Impervious Areas Associated with Roads, Shared Accesses, Alleys, Sidewalks, Driveways, and Parking Areas	√					
LID.04	Downspout Infiltration Systems	√					
LID.05	Downspout Dispersion Systems	√					
LID.06	Sheet Flow Dispersion	√					
LID.07	Concentrated Flow Dispersion	√					
LID.08	Bioretention Facilities	√	√	√	√		
LID.09	Alternative Paving Surfaces	√					
LID.10	Vegetated Roofs	√					
LID.11	Full Dispersion	√					
LID.12	Rural Roads Natural Dispersion	√					
LID.13	Rural Roads Engineered Dispersion	√					
Infiltration BMPs							
IN.01	Infiltration Basins		√	*	*	*	
IN.02	Infiltration Trenches		√	*	*	*	
IN.03	Infiltration Vault		√	*	*	*	
IN.04	Bio-Infiltration Swale		√	*	*	*	
Detention BMPs							
D.01	Detention Ponds		√				
D.02	Detention Tanks		√				
D.03	Detention Vaults		√				
D.04	Use of Parking Lots for Detention		√				
Biofiltration BMPs							
BF.01	Basic Biofiltration Swale			√			
BF.02	Wet Biofiltration Swale			√			
BF.03	Continuous Inflow Biofiltration Swale			√			
BF.04	Vegetated Filter Strip/CAVFS			√	*		*
BF.05	Narrow Area Filter Strip			√			

Table 1.1 (continued). Thurston County Stormwater BMPs.

BMP No.	Title	Type of BMP					
				Runoff Treatment			
		LID	Flow Control	Basic	Enhanced	Phosphorus	Oil Control
Wet Pool BMPs							
WP.01	Stormwater Treatment Wetland			√	√		
WP.02	Wet Pond			√		*	
WP.03	Wet Vault			√			*
WP.04	Combined Detention/Wet Pool Facilities		√	√	*	*	
WP.05	Presettling Basin						
Media Filtration BMPs							
MF.01	Sand Filter Basin			√	*	*	
MF.02	Sand Filter Vault			√	*	*	
MF.03	Linear Sand Filter			√	*	*	√
MF.04	Media Filter Drain			√	√	√	
Oil and Water Separation BMPs							
OW.01	API (Baffle type) Separator Bay						√
OW.02	Coalescing Plate (CP) Separator Bay						√
OW.03	Oil Containment Booms						√

√ Meets criteria
* Design option allows BMP to meet criteria

1.2 How This Volume is Organized

Volume V is organized as follows:

- **Chapter 1**: Introduction
- **Chapter 2**: Low Impact Development (LID)
- **Chapter 3**: Infiltration BMPs
- **Chapter 4**: Detention BMPs
- **Chapter 5**: Biofiltration BMPs
- **Chapter 6**: Wet pool BMPs
- **Chapter 7**: Media filtration BMPs
- **Chapter 8**: Oil and water separation BMPs
- **Chapter 9**: Emerging Technologies
- **Appendix V-A**: Control structures, including flow control structures, bypass/diversion manholes, and emergency overflows
- **Appendix V-B**: Facility liner design guidance
- **Appendix V-C**: Maintenance guidelines
- **Appendix V-D**: Access roads and ramps
- **Appendix V-E**: Site design elements, including setbacks, landscaping, fencing, and signage.

1.3 How Do I Get Started?

First, consult Chapter 2 of Volume I to determine minimum requirements for flow management (Minimum Requirements #4 through #8) and selection of stormwater BMPs. After determining minimum requirements for your project and selecting BMPs, use this volume (V) to design BMPs. Consult Volume III (Hydrologic Analysis and Stormwater Conveyance) for guidance on methods to appropriately size flow management facilities. These facilities can then be included in any required stormwater submittals (see Volume I, Chapter 3).

Chapter 2 - Low Impact Development (LID)

Low Impact Development (LID) is a development approach that seeks to minimize the stormwater impacts of development by mimicking natural hydrologic processes.

The LID BMPs in this chapter can help you comply with Minimum Requirement #5 (Onsite Stormwater Management), #6 (Runoff Treatment), and #7 (Flow Control). Minimum Requirement #5 requires the use of onsite stormwater BMPs to infiltrate, disperse, and retain stormwater runoff onsite to the maximum extent feasible, without causing flooding or erosion impacts. For more information about Minimum Requirement #5, see Volume I.

2.1 LID Site Design BMPs

Site design plays an important role in the amount of stormwater runoff generated by a project site. Reductions in impervious areas result in smaller runoff treatment and flow control facilities, thereby reducing stormwater control and treatment requirements and management costs.

This section describes LID site design practices that can reduce impervious areas and improve infiltration and treatment capacity of soils. LID planning and design considerations are also described in Volume I of this manual and in the *Low Impact Development: Technical Guidance Manual for Puget Sound* (PSAT 2005).

The following BMPs are described in this section:

- **LID.01**: Native Vegetation Protection, Reforestation, and Maintenance
- **LID.02**: Post-Construction Soil Quality, and Depth
- **LID.03**: Reduce Effective Impervious Areas Associated with Roads, Shared Accesses, Alleys, Sidewalks, Driveways, and Parking Areas.

2.1.1 LID.01 Native Vegetation Protection, Reforestation, and Maintenance

Preserving native vegetation and soils is an effective and efficient tool for managing stormwater quantity and quality. Puget Sound area research found that preserving native vegetation and reducing the development envelope were the most effective LID strategies in terms of reducing storm flows (AHBL 2002).

The goal of preserving and restoring native vegetation in low impact development is to promote infiltration for overland flow generated in adjacent developed portions of the site and more closely mimic the site's natural hydrologic function. This BMP can be highly effective when used in conjunction with BMP LID.03, reducing effective impervious areas.

In areas where development or disturbance has occurred, the goal is to restore the hydrologic functions of a native forested site, including infiltration, evapotranspiration, and canopy interception.

Applicability

Preserving existing native vegetation shall be the first priority whenever feasible. Preserving vegetation is much easier than restoring it. Restoring native vegetation may be used in situations where an applicant wishes to convert a previously developed surface to a native vegetated surface for purposes of meeting dispersion requirements or code requirements for forest retention. Restoring native vegetation may also be required in cases where an area designed for native vegetation preservation such as a critical area buffer has been disturbed and requires restoration.

Native vegetation preservation and restoration areas should be incorporated to the maximum extent possible, and where most effective (i.e., where there is intact native vegetation and soils and/or unconcentrated flow from developed areas). Where possible, the goal for native vegetation preservation or restoration shall be as follows:

- Rural and large lot development: 65 percent minimum
- Medium density (4 to 6 dwelling units per acre): 50 percent minimum
- High density (more than 6 dwelling units per acre): Protect or restore native vegetation to the maximum extent practical.

Native vegetation retention areas may be required as part of a plan of development for any of the following reasons:

- Stormwater dispersion areas reserved for stormwater quality and quantity treatment as part of on-site measures

- Wetland and other critical area buffers required by Code
- Riparian areas and buffers and habitat areas
- Minimum native vegetation areas required by zoning codes (for example in the Green Cove Basin).

Limitations

Preserving or restoring native vegetation depends heavily on establishing optimal soil and moisture conditions for the vegetation. A moisture-loving plant, even if native, will not thrive in an environment turned dry by rerouting of watershed flows.

Careful selection of areas for native tree preservation should be made with the advice of a landscape architect or tree arborist. Items to consider in this process include:

- Impact of removal of adjacent vegetation on survivability of trees during wind storms
- The health of tree stands including incidence of disease or infestation
- Conifers with live crown ratios of 50 percent or greater have better survivability in wind and sun exposure
- Trees and native vegetation that developed in forests are best retained in groups of sufficient size to maintain adequate growing space characteristics and maintain the integrity of the unit.
- Avoid areas around structures, roadway intersections or immediately adjacent to the roadway where trees may create a future danger, sight distance or clear zone issue and may result in future removal of trees for safety reasons.

Prioritize native vegetation and soil protection areas by location and type of area as follows:

1. Large tracts of riparian areas that connect and create contiguous riparian protection areas
2. Large tracts of critical and wildlife habitat area that connect and create contiguous protection areas
3. Tracts that create common open space areas among and/or within developed sites

4. Protection areas on individual lots that connect to areas on adjacent lots or common protection areas

5. Protection areas on individual lots.

Submittals and Approval

Clearing limits and areas for vegetation restoration shall be shown on the drainage plans for the project. Clearing limits shall be marked in the field and verified by Thurston County prior to clearing. Protective fencing shall be installed to protect native areas to be preserved; examples include orange construction fencing, temporary chain link fence, or equivalent. For revegetation areas, a plants list shall be provided indicating the type of plant, quantity, any planting requirements and location of plantings.

Areas designated to be preserved as native vegetation for stormwater dispersion shall be designated as separate tracts or shall be protected by easement. The areas shall be protected from disturbance by signage and/or fencing. A signage and fencing plan shall be prepared and included in the drainage report submittal.

Permanent signs shall explain the purpose of the area, the importance of vegetation and soils for managing stormwater and that the removal of trees or vegetation and compaction of soil is prohibited.

Design Criteria

During construction protect native tree preservation areas from disturbance. See Volume II for additional requirements related to site clearing and protecting native vegetation.

At a minimum, the applicant shall comply with provisions for native vegetation preservation and/or replacement as set forth in applicable Thurston County Code including critical areas, zoning, grading and forest practices.

Vegetation restoration and planting methods shall conform to published standards. The following guidance documents are provided as an example:

Riparian Areas

- *Restoring the Watershed A Citizen's Guide to Riparian Restoration in Western Washington*, Washington State Department of Fish and Wildlife, 1995

- *Streamside Planting Guide for Western Washington*, Cowlitz County Soil and Water Conservation District

- *Plant It Right: Restoring Our Streams,* WSU Cooperative Extension, 2002
- *Integrated Streambank Protection Guidelines*, Washington State Department of Fish and Wildlife, 2000.

Marine Bluff

- *Surface Water and Groundwater on Coastal Bluffs: A Guide for Ecology*, Washington State Department of Ecology, Shorelands and Coastal Zone Management Program Publication No. 95-107, 1995
- *Vegetation Management: A Guide for Puget Sound Bluff Property Owners*, Washington State Department of Ecology, Shorelands and Coastal Zone Management Program Publication No. 93-31, 1993.

Tree conservation areas should be designated for the site in areas not adjacent to or impacting structures (one tree height separation) or sight distance/clear area for roadways and shall be protected, or restored to follow natural successional patterns and to develop diverse multilayer canopy structure, snags, large woody debris, understory vegetation, and forest duff.

Conversion of Previously Developed Surfaces to Native Vegetation

Conversion of a previously developed surface to native vegetated landscape or restoration of disturbed areas required to be native vegetation requires the removal of impervious surface and ornamental landscaping, de-compaction of soils, and the planting of native trees, shrubs, and ground cover in compost-amended soil according to all of the following specifications:

1. Existing impervious surface and any underlying base course (e.g., crushed rock, gravel, etc.) must be completely removed from the conversion area(s).
2. Underlying soils must be broken up to a depth of 18 inches. This can be accomplished by excavation or ripping with either a backhoe equipped with a bucket with teeth, or a ripper towed behind a tractor.
3. At least 4 inches of well-decomposed compost must be tilled into the broken up soil as deeply as possible. The finished surface should be gently undulating and must be only lightly compacted.
4. The area of native vegetated landscape must be planted with native species trees, shrubs, and ground cover according to the

specifications in Table 2.1. Species must be selected as appropriate for the site shade and moisture conditions, and in accordance with the following requirements:

Table 2.1. Selected Native Vegetation, Size, and Spacing Requirements

Species	Type	Sun and Moisture Preferences	Planted Size	Spacing
Trees				
Douglas fir (*Pseudotsuga menziesii*)	Conifer	Sun, dry to moist soil	5 gallon, 6'-7' B&B	12' o.c.
Western red cedar (*Thuja plicata*)	Conifer	Sun or shade, moist to wet soil	5 gallon, 6'-7' B&B	12' o.c.
Western hemlock (*Tsuga heterophylla*)	Conifer	Sun or shade, well-drained soil	5 gallon, 6'-7' B&B	12' o..c.
Sitka spruce (*Picea sitchensis*)	Conifer	Sun or shade, moist mineral soils to wet soils	5 gallon, 6'-7' B&B	12' o.c.
Red alder (*Alnus rubra*)	Tree	Sun, a nitrogen fixer	5 gallon, 5'-6' B&B	12' o.c.
Bigleaf maple (*Acer macrophyllum*)	Tree	Sun or shade, dry to moist soil	5 gallon, 5'-6' B&B	12' o.c.
Black cottonwood (*Populus trichocarpa*)	Tree	Sun, wet soil	5 gallon, 5'-6' B&B	12' o.c.
Cascara (*Rhamnus purshiana*)	Tree/shrub	Sun to partial shade, dry to moist soil	5 gallon, 5'-6' B&B	8' o.c.
Pacific willow (*Salix lucida*)	Tree/shrub	Sun, damp soil	1 gallon 2 gallon 5 gallon	4' o.c. 6' o.c. 8' o.c.
Shrubs				
Sitka willow (*Salix sitchensis*)	Shrub	Sun or shade, dry to damp soil	1 gallon 2 gallon 5 gallon	4' o.c. 6' o.c. 8' o.c.
Vine maple (*Acer circinatum)*	Shrub	Shade, moist to damp soils	1 gallon 2 gallon 5 gallon	4' o.c. 6' o.c. 8' o.c.
Filbert (hazelnut) (*Corylus cornuta)*	Shrub	Sun to shade, dry soil	1 gallon 2 gallon 5 gallon	4' o.c. 6' o.c. 8' o.c.
Salmonberry (*Rubus spectabilis)*	Shrub	Sun to shade, moist to wet soil	1 gallon 2 gallon 5 gallon	4' o.c. 6' o.c. 8' o.c.
Thimbleberry (*Rubus parviflorus)*	Shrub	Sun to partial shade, dry to moist soil	1 gallon 2 gallon 5 gallon	4' o.c. 6' o.c. 8' o.c.
Ocean spray (*Holodiscus discolor)*	Shrub	Sun to partial shade, dry	1 gallon 2 gallon 5 gallon	4' o.c. 6' o.c. 8' o.c.

Table 2.1 (continued). Selected Native Vegetation, Size, and Spacing Requirements

Species	Type	Sun and Moisture Preferences	Planted Size	Spacing
Shrubs (continued)				
Tall Oregon graps (*Berberis aquifolium)*	Shrub	Sun to shade, dry to moist soil	1 gallon	4’ o.c.
Snowberry (*Symphoricarpos albus)*	Shrub	Sun to shade, dry to wet soil	1 gallon, 30-36”	4’ o.c.
Service berry (*Amelanchier alnifolia)*	Shrub	Sun to shade, dry to wet soil	1 gallon	6’ o.c.
Indian plum (*Oemleria cerasiformis)*	Shrub	Sun to shade, moist soil	1 gallon	4’ o.c.
Twinberry (*Lonicera involucrate)*	Shrub	Sun to partial shade, moist soil	1 gallon	4’ o.c.
Ground Cover				
Evergreen huckleberry (*Vaccinium ovatum)*	Groundcover	Sun to partial shade, moist soil	1 gallon	2’ o.c.
Kinnikinick (*Arctostaphyllos uva-ursa)*	Groundcover	Sun to partial shade, dry soil	1 gallon	2’ o.c.
Salal (*Gaultheria shallon)*	Groundcover	Sun to shade, dry to moist soil	1 gallon	18” o.c.
Low Oregon graps (*Mahonia repens)*	Groundcover	Sun to partial shade, dry to moist soil	9-12”	18” o.c.
Sword fern (*Polystichum munitum)*	Groundcover	Sun to deep shade, dry to moist soil	2 gallon	3’ o.c.

Source: King County Surface Water Design Manual (King County DNRP 2009).

Note:

B&B: Balled and Burlapped

a. Trees: a minimum of two species of trees must be planted, one of which is a conifer. Conifer and other tree species must cover the entire landscape area at the spacing given in Table 2.1.

b. Shrubs: a minimum of two species of shrubs shall be planted. Space plants to cover the entire landscape area, excluding points where trees are planted.

c. Groundcover: a minimum of two species of ground cover shall be planted. Space plants so as to cover the entire landscape area, excluding points where trees or shrubs are planted.

Note: *For landscape areas larger than 10,000 square feet, planting a greater variety of species than the minimum suggested above is strongly encouraged. For example, an acre could easily accommodate three tree species, three species of shrubs, and two or three species of groundcover.*

5. At least 4 inches of hog fuel or other suitable mulch must be placed between plants as mulch for weed control. It is also possible to mulch the entire area before planting; however, an 18-inch diameter circle must be cleared for each plant when it is planted in the underlying amended soil.

   Note: *Plants and their root systems that come in contact with hog fuel or raw bark have a poor chance of survival.*

6. Plantings must be watered consistently once per week during the dry season for the first 3 years.

7. The plantings must be well established on at least 80 percent of the converted area after 2 years in order to be considered a native vegetated surface.

Materials

Developments shall use native trees for replacement in areas separate from residential lots, or storm drainage areas adjacent to roadway or parking lots. Species selection shall be based on the underlying soils and the historic, native indigenous plant community type for the site, if existing conditions can support the plant community.

Trees selected for replacement purposes must be free from injury, pests, diseases, and nutritional disorders. Trees must be fully branched and have a healthy root system. Coniferous and broad leaf evergreen trees shall be no less than 3 feet in height at time of planting. Deciduous trees shall be a minimum of 5 feet in height or have a minimum caliper size of 1 inch at time of planting.

Note: Avoid the use of a single species of tree for replacement purposes. No individual species of replacement tree should exceed 50 percent of the total, and no individual species should be less than 10 percent of the total.

Construction and Maintenance

Maintenance of native vegetation restoration areas shall include monitoring the survival of planted species, weed control and soil amendment as necessary to ensure the establishment of the native vegetation. A minimum 80 percent survival of all planted vegetation at the end of 2 years is required. Ongoing maintenance shall include weeding and watering for a minimum of 3 years from installation.

If during the 2-year period survival of planted vegetation falls below 80 percent, additional vegetation shall be installed as necessary to achieve the required survival percentage. The likely cause of the high rate of plant mortality shall also be determined and corrective actions taken to ensure plant survival. If it is determined that the original plant choices are not well suited to site conditions, these plants shall be replaced with plant species that are better suited to the site.

Native vegetation and soil protection areas serve as stormwater management facilities and should be managed as are other stormwater facilities. The Maintenance Plan for the stormwater facilities shall include a written vegetation management plan and protection mechanisms as necessary to maintain the benefit of these areas over time.

2.1.2 LID.02 Post-Construction Soil Quality and Depth

Naturally occurring, undisturbed soil and vegetation provides important stormwater functions, including:

- Water infiltration
- Nutrient, sediment, and pollutant adsorption
- Sediment and pollutant biofiltration
- Water interflow storage and transmission
- Pollutant decomposition.

These functions are largely lost when development removes native soil and vegetation and replaces it with minimal topsoil and sod. And not only are these stormwater functions lost, but such landscapes then become pollution-generating pervious surfaces, due to increased use of pesticides, fertilizers and other landscaping and chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

Reestablishing a minimum soil quality and depth after development regains some of these stormwater functions, providing increased treatment of pollutants and sediments from development and habitation and minimizing the need for some landscaping chemicals, thus reducing pollution.

Applicability

This BMP is required in projects subject to Minimum Requirement #5, Onsite Stormwater Management. The following surfaces of a project site shall be required to implement this BMP:

- Areas that are to be incorporated into the stormwater drainage system such as surface BMPs. Note that BMP LID.08 – Bioretention has alternate soil requirements.
- All new lawn and landscape areas. Except that the areas of the project implementing BMP LID.11, “Full Dispersion” are not required to implement this BMP, however, it is still recommended.
- Disturbed areas that are to be restored to native vegetation (See BMP LID.01).
- Existing lawn and landscape areas of a redevelopment project where the project is required to retrofit the entire site to current stormwater standards (see Chapter 2 of Volume I).

Establishing minimum soil quality and depth is not the same as preservation of naturally occurring soil and vegetation. However, establishing a minimum soil quality and depth will provide improved onsite management of stormwater flow and water quality.

If soils must be amended to increase the organic content, several sources of organic matter (e.g., compost, composted woody material, biosolids, and forest product residuals) can be used. It is important that the materials used to meet the soil quality and depth requirements be appropriate and beneficial to the plant cover being established. It is also important that imported topsoils improve soil conditions and do not have an excessive percent of clay fines.

Limitations

Native soils with robust native landscapes must be protected from disturbance whenever possible, especially where no post-construction soil rehabilitation is planned.

In designated Well Head Protection Areas (WHPA) for public water systems with over 1,000 connections, compost used within the site shall be comprised entirely of vegetative materials only. Biosolids and animal manure components can result in large concentrations of nitrates leaching into groundwater aquifers and are consequently prohibited within the WHPA.

Poorly Draining Sites

If the site being considered for turf establishment does not drain well, consider an alternative to planting a lawn. If the site is not freely draining, and turf replacement is still being attempted, compost amendment will still provide stormwater benefits but should be incorporated into the soil at a reduced ratio of no more than 30 percent by volume. This upper limit is suggested in the Pacific Northwest because the region's extended saturated winter conditions may create water logging of the lawn. The landscape professional should also provide a drainage route or subsurface collection system as part of their design.

Existing Steep Slope Areas

Increasing soil moisture content may increase soil instability in areas with steep slopes. However, the Washington State Department of Transportation (WSDOT) has incorporated compost-amendment in almost all of its vegetated sites since 1992 without problems, even on the steepest sites (33 percent slope), as a result of the increased moisture holding capacity within the soils. (See design criteria below for requirements of steep slope soil amendment.)

- Onsite steep slope areas with native soils and robust native landscapes should be protected from disturbance, which is preferable to re-grading and augmenting the disturbed soil with soil amendment. Also, steep slope areas may be subject to critical area protection per TCC 17.15, which outlines criteria for classification of erosion and active landslide hazard areas.

- Where native soils and vegetation is sparse, steep slopes that remain on site that are not constructed as part of the development, should be amended by planting deep rooting vegetation. Soil amendments shall be applied with a pit application at least twice as wide as the root ball of the vegetation being planted, using a mix of 50 percent compost and 50 percent soil mixture.

Submittals and Approvals

A site specific Soil Management Plan (SMP) shall be submitted and must be approved as part of the permitting process for the project. The SMP shall be prepared per the Soils for Salmon guidance document (see Design Guidelines below) and includes:

- A scale-drawing (11” x 17” or larger) identifying area where native soil and vegetation will be retained undisturbed, and which soil treatments will be applied in landscape areas.

- A completed SMP form identifying treatments and products to be used to meet the soil depth and organic content requirements for each area.

- Computations of compost or topsoil volumes to be imported (and/or site soil to be stockpiled) to meet “pre-approved” amendment rates; or calculations by a qualified professional to meet organic content requirements if using custom calculated rates. Qualified professionals include certified Agronomists, Soil Scientists or Crop Advisors; and licensed Landscape Architects, Civil Engineers or Geologists.

- Copies of laboratory analyses for compost and topsoil products to be used, documenting organic matter contents and carbon to nitrogen ratios.

The steps involved in preparing the SMP include the following:

- Step 1: Review site Landscape Plans and Grading Plans
    - Assess how grading and construction will impact soil conditions

  - Identify which areas are to receive which type of soil treatment options (1 through 4).

- Step 2: Visit Site to Determine Soil Conditions
  - Identify compaction of subgrade by digging down to a level 12 inches below finished grade and use a shovel or penetrometer to determine compaction.
  - Assess condition of native areas that are to remain undisturbed.
  - Assess soil conditions in each area to be cut, filled, or otherwise disturbed and establish scarification and amendment recommendations for each area.

- Step 3: Select Amendment Options
  - Identify areas where each amendment option will be applied and outline these areas on the SMP site plan and on the SMP form.
  - Assign each area an identifying number or letter on the SMP site plan and on the SMP form.

- Step 4: Identify Compost, Topsoils, and Other Organic Materials for Amendment and Mulch.
  - Products for soil amendment must be identified on the SMP form and recent product test results provided showing they meet the requirements of the Soil for Salmon guidance document (see Design Guidelines below).
  - Compost shall meet requirements of WAC 173-350, Section 220 "Composted Materials".

- Step 5: Calculate Amendment, Topsoil and Mulch Volumes on SMP Form
  - Calculate required cubic yards of amendment for the pre-approved amendment areas.
  - Compute custom calculated amendment rates to achieve the target Soil Organic Matter content (10 percent for landscape beds, 5 percent for turf areas).

Hydrologic and Hydraulic Design Considerations

Flow Credit for Dispersion

While hydrologic modeling credits cannot be applied for application of this BMP, credits can be taken in runoff modeling when the BMP is applied as part of a dispersion design under the conditions described in:

- BMP LID.05 Downspout Dispersion
- BMP LID.06 Sheet Flow Dispersion
- BMP LID.07 Concentrated Flow Dispersion
- BMP LID.11 Full Dispersion
- BMP LIS.12 Rural Roads Natural Dispersion
- BMP LID.13 Rural Roads Engineered Dispersion.

Design Guidelines

Guidance on implementing this BMP is still evolving as continued research is conducted and experience is gained in its use. An applicant can demonstrate compliance with this BMP by following the guidance provided in the most current edition of "*Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington*". This document is available at no charge from the following web sites: <www.SoilsforSalmon.org> and <www.BuildingSoil.org>.

Soil Retention

The duff layer and native topsoil should be retained in an undisturbed state to the maximum extent practicable. In any areas requiring grading remove and stockpile the duff layer and topsoil on site in a designated, controlled area, not adjacent to public resources and critical areas, to be reapplied to other portions of the site where feasible.

Soil Quality

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

- A topsoil layer with a minimum organic matter content of 10 percent dry weight in planting beds, and 5 percent organic matter content in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the original undisturbed soil. The topsoil layer shall have a minimum depth of 8 inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer shall be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.

- Planting beds must be mulched with 2 inches of organic material

The resulting soil should be conducive to the type of vegetation to be established.

Materials

Quality requirements for compost and other materials include the following:

- The organic content for “pre-approved” amendment rates can be met only using compost that meets the definition of “composted materials” in WAC 173-350-220. This code is available online at: <http://www.ecy.wa.gov/programs/swfa/facilities/350.html>.
- The compost must also have an organic matter content of 35 percent to 65 percent, and a carbon to nitrogen ratio below 25:1.
- The carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.
- Calculated amendment rates may be met through use of composted materials as defined above; or other organic materials amended to meet the carbon to nitrogen ratio requirements, and meeting the contaminant standards of Grade A Compost.

Implementation Options

The soil quality design guidelines listed above can be met by using one of the methods listed below which are described in detail in the Soils for Salmon guidance document (see Design Guidelines above):

- **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 these areas to prevent impacts during construction (see BMPs C101, C252, and C103 in Volume II). If neither soils nor vegetation are disturbed, these areas do not require amendment.

- **Option 2**. Amend existing site topsoil or subsoil in place at default "pre-approved" rates, or at custom calculated rates based on tests of the soil and amendment. Scarify or till the subgrade to a depth of 8 inches (or depth needed to achieve a total depth of 12 inches of uncompacted soil after calculated amount of amendments are added). Amend soil to meet required organic content dependent on the use (Planting area or Turf) and whether the pre-approved or calculated rate method is used.

- **Option 3**. Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements, either at a default "pre-approved" rate or at a custom calculated rate. If placed topsoil plus compost or other organic material will amount to less than 12 inches, then the subgrade will be scarified or tilled to achieve 12 inches of loosened soil after amendment. Replace stockpiled topsoil prior to planting. Amend stockpiled topsoil if needed to meet required organic content dependent on the use (Planting area or Turf) and whether the pre-approved or calculated rate method is used.

- **Option 4**. Import topsoil mix of sufficient organic content and depth to meet the requirements. Scarify or till subgrade in two directions to 6 inches depth. Use topsoil mix suitable for proposed use (planting bed or turf area). Place topsoil in layers per recommendations of Soils for Salmon guidance documents (see Design Guidelines above).

More than one method may be used on different portions of the same site. Soil that already meets the depth and organic matter quality standards, and is not compacted, does not need to be amended. See the Soils for Salmon (2009) website for further discussion of implementation and for pre-approved rates of soil amendment.

Construction and Maintenance

See the Soils for Salmon website and the guidance provided in the most current edition of "*Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington*" for details on implementing the Post-Construction Soil Quality and Depth BMP.

Maintenance

- Soil quality and depth should be established near the end of construction and, once established, protected from compaction (e.g., by large machinery use) and from erosion.

- Soil should be planted and mulched after installation.
- Plant debris or its equivalent should be left on the soil surface to replenish organic matter.
- Reduce irrigation and the application of fertilizers, herbicides and pesticides.

Table 2.2. Soil Management Plan for BMP LID.02

PROJECT INFORMATION **Page # ____ of ____ pages**

Complete all information on page 1; only site address and permit number on additional pages.

Site Address / Lot No.:_______________________________________	
Permit Type:	**Permit Number:**
Permit Holder:	**Phone:**
Mailing Address:_______________________________________	
Contact Person:	**Phone:**
Plan Prepared By:	

ATTACHMENTS REQUIRED (*Check off required items that are attached to this plan*)

___ **Site Plan showing, to scale:**	___ Areas of undisturbed native vegetation (no amendment required) ___ New planting beds and turf areas (amendment required) ___ Type of soil improvement proposed for each area
___ **Soil test results (required if proposing custom amendment rates)**	
___ **Product test results for proposed amendments**	

AREA #________ (*should match Area # on Site Plan*)

PLANTING TYPE ___ Turf ___ Undisturbed native vegetation ___ Planting Beds ___ Other: ______________________		
SQUARE FOOTAGE OF THIS AREA: _______ square feet		
SCARIFICATION ___ Subsoil will be scarified	___ inches (depth) of scarification needed to achieve finished total 12" loosened depth.	
PRE-APPROVED AMENDMENT METHOD: ___ Topsoil import ___ Amend with compost ___ Stockpile and amend (_____ cu. yds. stockpiled)	____inches of compost or imported topsoil applied X 3.1 (*conversion factor, inches to cubic yards*) _____= cu. yards per 1,000 sq. ft. X ___ ,000s sq.ft. in this area ____ = cubic yards of amendment → → → → → (*needed to cover this area to designated depth*)	PRODUCT:__________________ __________________________ QUANTITY:________CU. YDS.
CUSTOM AMENDMENT ___ Topsoil import ___ Topsoil & compost lift ___ Amend ___ Stockpile and amend (____ cu. yds. stockpiled)	**Attach test results and calculations.** ____ inches organic matter or topsoil import X 3.1 _____= cu. yards / 1,000 sq. ft. X ___ ,000s sq.ft. in this area ____ = cubic yards of amendment → → → → →	PRODUCT:__________________ __________________________ QUANTITY:________CU. YDS.
MULCH	___ ,000 sq.ft. X 6.2 (*conversion, to give 2 inch mulch depth*) ____ = cubic yards of mulch → → → → → →	PRODUCT:__________________ QUANTITY:________CU. YDS.

TOTAL AMENDMENT/TOPSOIL/MULCH FOR ALL AREAS (*complete on page 1 only, totaling all areas/pages in this Plan*)

- ❑ **Product #1:**_______________________________ ❑ **Quantity:** _________**cu. yds.**
- ❑ **Test Results:** ___ **% organic matter** ____**C:N ratio <25:1** (except mulch, or <35:1 for native plants) ____ **"stable"** (yes/no)

- ❑ **Product #2:**_______________________________ ❑ **Quantity:** _________**cu. yds.**
- ❑ **Test Results:** ___ **% organic matter** ____**C:N ratio <25:1** (except mulch, or <35:1 for native plants) ____ **"stable"** (yes/no)

- ❑ **Product #3:**_______________________________ ❑ **Quantity:** _________**cu. yds.**
- ❑ **Test Results:** ___ **% organic matter** ____**C:N ratio <25:1** (except mulch, or <35:1 for native plants) ____ **"stable"** (yes/no)

Date:	**Inspector:**	**Approved:**	**Revisions Required:**
Date:	**Inspector:**	**Approved:**	**Revisions Required:**

COMMENTS:

2.1.3 LID.03 Reduce Effective Impervious Area of Roads, Shared Accesses, Alleys, Sidewalks, Driveways, and Parking Areas

Roads, shared accesses, alleys, sidewalks, driveways, and parking areas are a substantial portion of total urban impervious area and usually have highly efficient drainage systems. Reducing the effective amount of these impervious areas and the amount of runoff they generate is a key concept of LID.

Applicability

The following sections describe strategies for reducing the impacts of impervious surfaces associated with transportation related networks, including roadways, parking lots, alleys, driveways, and sidewalks.

Limitations

Road designs must comply with the latest edition of Thurston County Road Standards for projects outside of Urban Growth Areas. Within Urban Growth Areas, for those municipalities with an agreement in place with Thurston County (currently only City of Olympia) the more stringent of the Thurston County Road Standards or the applicable municipalities road standards would apply depending on the project location., Road Standards include maximum grade, minimum roadway width, emergency access, compliance with the Americans with Disabilities Act (ADA) and safety restrictions (clear zone, stopping sight distance, etc.). If a developer or designer is interested in deviating from the road standards, they will need to request a variance. Contact Thurston County Public Works for information on variances.

Because appropriate strategies for reducing impervious areas are different in rural and urban areas, they are broken out as “urban strategies” and “rural strategies” under design criteria, below.

Submittals and Approval

As noted above, a variance is required for road design changes that deviate from the governing road standards. Several techniques are listed under “design criteria”. Those that are likely to require a variance are noted. Requests for variance from road standards shall be in a form and contain the information required by the most current version of the Thurston County Road Standards.

Design Criteria

Urban Strategies

Urban areas in Thurston County are normally under the jurisdiction of cities (Olympia, Lacey, Tumwater, Yelm) with the exception of Grand

Mound. Depending on your project location and the proposed road design strategies, a variance may be required. Contact Thurston County and the appropriate jurisdiction for additional information.

Reduce Roadway Widths

Design roads with the minimum width permissible under the applicable road design standards.

Permeable Pavement

The use of permeable paving surfaces (see BMP LID.09) is a good strategy for reducing impervious areas associated with transportation facilities. For private roads, porous paving surfaces may be used adjacent to the traveled lane (e.g., in pull-out parking, shoulders, and sidewalks) with acceptance by Thurston County and the local jurisdiction. Use of porous pavement on County-maintained roads is not allowed.

Cul-de-sacs

Where cul-de-sacs are used, techniques should be used to reduce or disconnect the impervious turnaround area. This can be accomplished by increasing the diameter of the cul-de-sac and including a pervious or bioretention landscaped area in the center where stormwater can be directed.

Sidewalks

Sidewalks on Single Side of the Road

Thurston County road standards require sidewalks on both sides of arterials, collectors, and local roads. Where pedestrian safety, ADA-compliance, and access are not compromised, developers may request a variance from this standard, proposing sidewalks on only one side of the roadway, to reduce the impervious area associated with sidewalks. To be considered for a variance, the developer must demonstrate that every lot will have pedestrian access to an abutting trail or to a sidewalk located on at least one side of the road.

Reverse Slope Sidewalks

Sidewalks and trails should be disconnected from the traveled way portion of the road, when possible. Where feasible, sidewalks should be “reverse slope”, where they slope *away* from the road and onto adjacent vegetated areas. If a sidewalk drains onto a vegetated area that is greater than or equal to 10 feet in width and the soils are either native soils or meet the criteria of BMP LID.02, “Post Construction Soil Quality and Depth” then the sidewalk area may be modeled as landscaped area over the underlying soil type.

Sidewalk Materials

Sidewalks and trails may be constructed of porous materials for private developments and roadways. Porous sidewalks within the public right-of-way would require Thurston County acceptance and a variance from the Road Standards. Porous materials for sidewalks and trails shall be ADA-compliant. See BMP LID.09, "Alternate Paving Surfaces" for guidance on these materials.

Parking

Parking Lots

Use the minimum off-street parking requirements outlined in Title 20.44.030 TCC for non-residential uses. Pervious materials should be considered for parking lots where feasible.

Shared Parking

The total amount of impervious area can be reduced by utilizing shared parking. This strategy is appropriate for land uses with non-competing hours of operation, such as a church and a school or office. See Title 23.38.180 TCC for restrictions and requirements on shared parking.

Driveways

Driveways are typically constructed with impervious surfaces and should be considered in the total stormwater runoff reduction strategy. The following are methods to reduce the amount of impervious driveway surfaces (variances may be required):

- Minimize driveway width
- Reduce driveway length where possible. This may be achieved by locating the house closer to the road or by using alley access directly into a garage.
- When possible, design clusters of homes to use shared driveways. On lots that accommodate multiple family dwellings, such as townhouses, the courtyard between garages and the stem of the driveway can be shared space.
- Consider constructing driveways using pervious materials.

Rural Strategies

Thurston County has well-draining outwash soils in many areas. The County has adopted strategies to preserve existing drainage and take advantage of the infiltration and treatment capacity of existing soils by avoiding curb and gutter where possible to promote dispersion and infiltration into roadside ditches. For rural roads, special sheet flow dispersion BMPs are provided for sites that meet specific conditions (see BMP LID.12 and BMP LID.13).

2.2 LID Stormwater Management BMPs

BMPs in this chapter include:

- LID.04 Downspout Infiltration Systems (Trenches, Drywells)
- LID.05 Downspout Dispersion Systems
- LID.06 Sheet Flow Dispersion
- LID.07 Concentrated Flow Dispersion
- LID.08 Bioretention Facilities
- LID.09 Alternative Paving Surfaces
- LID.10 Vegetated Roofs
- LID.11 Full Dispersion
- LID.12 Rural Road Natural Dispersion
- LID.13 Rural Road Engineered Dispersion

2.2.1 LID.04 Downspout Infiltration Systems

Downspout infiltration systems are used for infiltrating runoff from roof downspouts and include infiltration trenches and drywells.

Applicability

Application of rooftop downspout controls (this BMP, BMP LID.05, “Downspout Dispersion Systems”) is required to meet Minimum Requirement #5. This BMP is the preferred method of rooftop downspout control, and must be considered before the other measures.

Limitations

Downspout infiltration systems may not be used to directly infiltrate runoff from pollutant-generating impervious surfaces, such as uncoated metal roofs.

Downspout infiltration systems are not allowed for properties along the Marine Bluff without special acceptance.

Submittals and Approval

UIC Registration

Infiltration drywells are considered underground injection chambers (UIC) and are therefore subject to Ecology UIC registration requirements. See Chapter 3.

Infiltration trenches are not considered UICs, unless they include perforated pipe used to disperse and inject flows (see Chapter 3).

Infiltration drywells for single family residences which only infiltrate clean roof runoff are not currently required to register as a UIC.

Soil Testing and Report

See Volume III, Chapter 3 for general soil testing requirements for infiltration.

Pretreatment

No pretreatment is required.

Hydraulic, Hydrologic and Soil Design Considerations

Flow Credit for Roof Downspout Infiltration

If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the project area used for sizing stormwater facilities and determining the effective impervious area thresholds of Minimum Requirements #7 (Flow Control).

Hydraulic Design Elements

A structure with a sump (see Figure 2.2) shall be located upstream of the trench, which provides a minimum of 12 inches of depth below the outlet riser. The outlet riser pipe bottom shall be designed so as to be submerged at all times, and a screening material shall be installed on the pipe outlet.

Design Criteria for Downspout Infiltration Systems

Downspout Infiltration Trench

Figures 2.1 and 2.2 present alternative design options for the downspout infiltration trench systems. These systems are designed as specified below.

Geometry

- Length of trench must not exceed 100 feet from the inlet sump
- Minimum spacing between distribution pipe centerlines must be 6 feet.

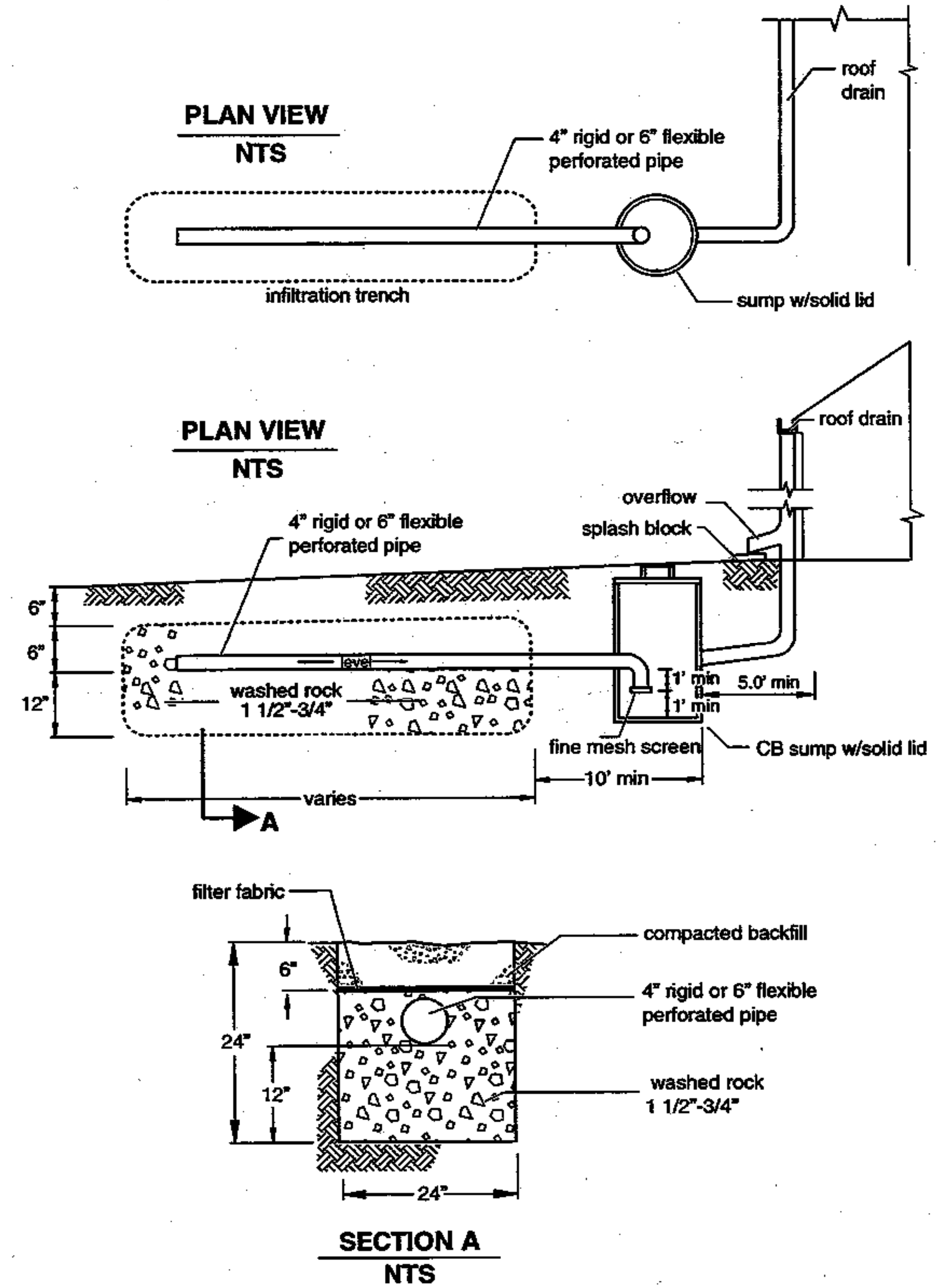
Materials

- The aggregate material for the infiltration trench shall consist of 1.5- to three-fourth-inch washed round rock.
- Geotextile filter fabric shall be wrapped entirely around trench drain rock prior to backfilling EXCEPT that a 6-inch layer of sand below the trench bottom may be used in-lieu of a filter fabric liner on the bottom.
- Infiltration trenches may be placed in fill material if the fill is placed and compacted under the direct supervision of a geotechnical engineer or professional civil engineer with geotechnical expertise, and if the measured infiltration rate is at least 8 inches per hour. Infiltration rates can be tested using the methods described in Volume III.

Other Design Criteria

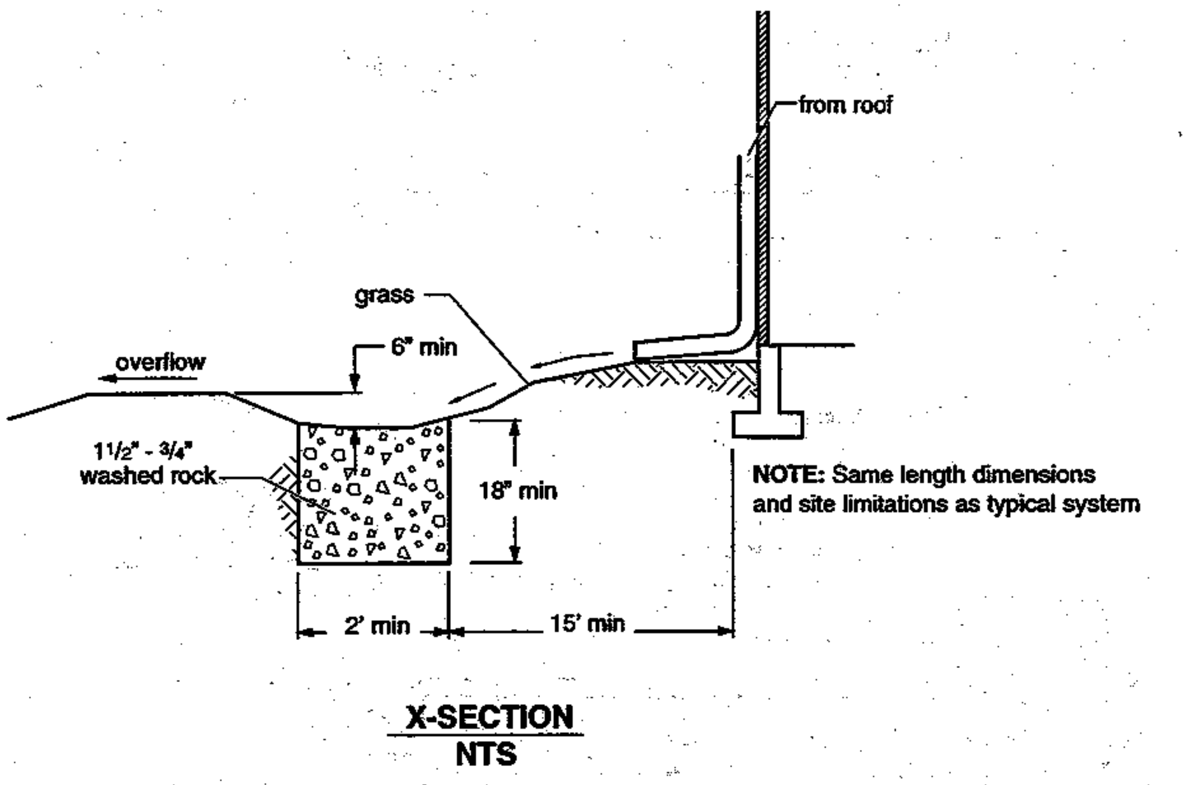
- Trenches shall be covered the same day they are opened.
- Trenches shall be no wider than can be excavated by a backhoe straddling the trench.
- Parallel trenches shall be spaced no closer than 10 feet except that trenches whose target for discharge is the interflow zone. If

hardpan is less than 6 feet below finished grade, or the trench is excavated to closer than 3 feet of hardpan (whatever the depth), then the target for infiltration is the interflow zone and:



Source: King County

Figure 2.1. Typical Downspout Infiltration Trench.



Source: King County

Figure 2.2. Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel.

- Trenches must, as nearly as practical, follow a contour line.
- Parallel trenches shall be spaced no closer than 25 feet apart.

Design Criteria for Infiltration Drywell Systems

Figure 2.3 presents the design of a typical downspout infiltration drywell system. The drywell shall include a catch basin (as shown in Figure 2.3), or its equivalent upstream of the drywell for particulate removal. These systems are designed as specified below:

Simplified Sizing for Drywells

The following table (Table 2.3) may be used for drywell sizing for projects that are not subject to Minimum Requirement #7 (Flow Control – see Volume I, Chapter 2).

Table 2.3. Roof Drywell Sizes by Soil Hydrologic Group

Soil Hydrologic Group	Total Volume Required Per 1,000 Square Feet of Roof [1]
A or B (Sand, loamy sand, sandy loam, loam)	125 cubic feet
C (Silt loam, sandy clay loam, "till" soils with Group A or B surface horizons)	250 cubic feet
D (Silts, clays, rock outcroppings, "till" soils with Group C or D surface horizons) [2]	750 cubic feet

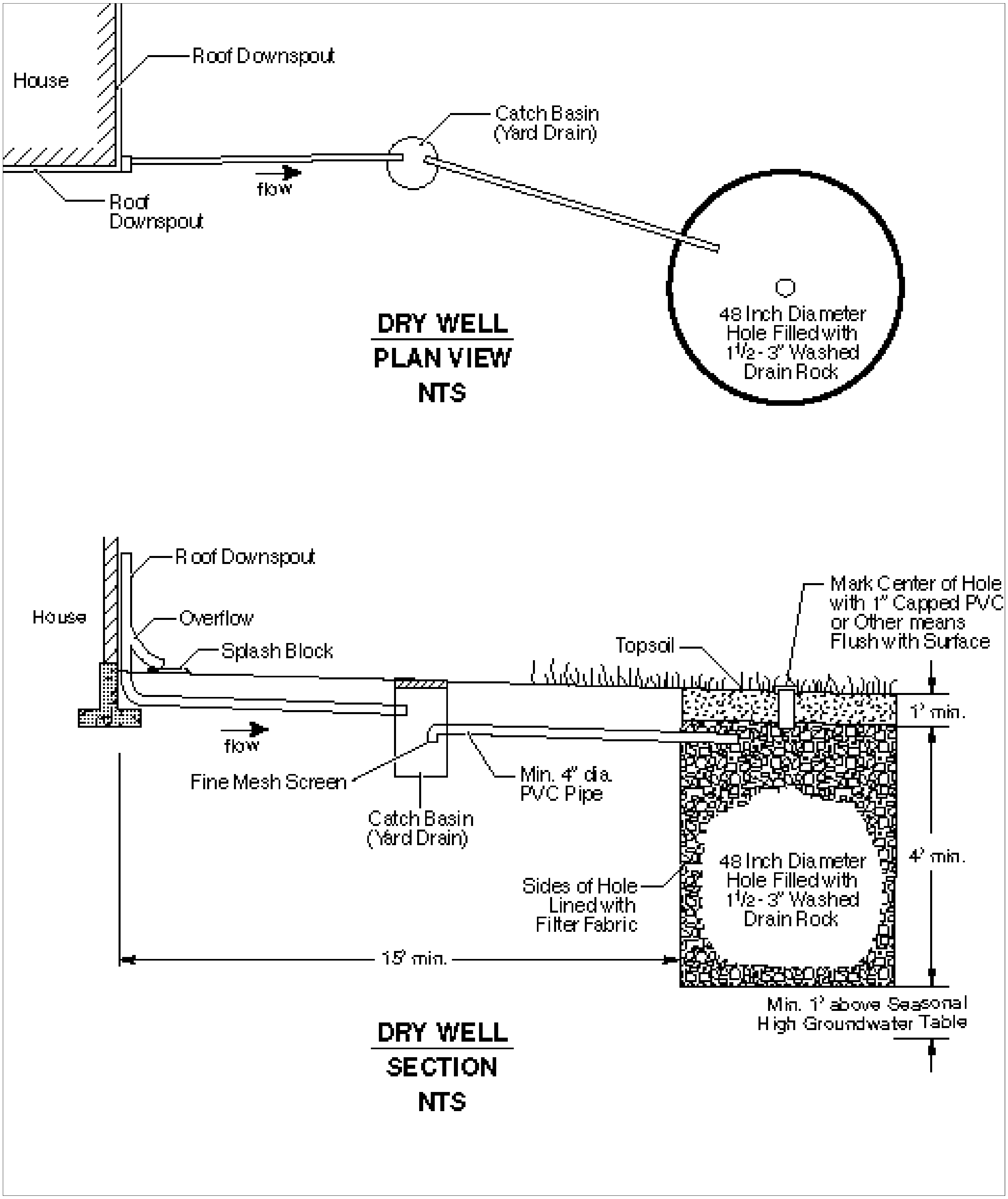
Source: Thurston County 1994.
[1] Volume includes rock backfill. Trench size may be reduced if pipe or other open structure replaces a portion of the rock backfill; contact Thurston County for guidance.
[2] Drywells are not recommended for Hydrologic Group D soils due to extremely slow percolation rates. Drywells should be used only if other reasonable alternatives are infeasible.

Geometry

- Drywell bottoms must be a minimum of 1 foot above seasonal high groundwater level or impermeable soil layers.
- Drywells shall be 48 inches in diameter (minimum) and have a depth of 5 feet (4 feet of gravel and 1 foot of suitable cover material).
- Spacing between drywells shall be a minimum of 4 feet.

Materials

Filter fabric (geotextile) must be placed on top of the drain rock and on trench or drywell sides prior to backfilling. See Appendix V-B (Facility Liners).



Source: King County

Figure 2.3. Typical Downspout Infiltration Drywell.

Structural Design Considerations

Trenches may be located under pavement, if designed by a professional engineer. Trenches must include an overflow at least 1 foot below the pavement, and be in a location that can accommodate overflow without creating a significant adverse impact to downhill properties or drainage systems. This is intended to prevent saturation of the pavement in the event of system failure. The trench depth must be measured from the overflow elevation, not the ground surface elevation.

Site Design Elements

See Appendix V-E (Site Design Elements) for setbacks for infiltration facilities.

Downspout infiltration drywells must not be built on slopes greater than 25 percent (4H:1V). Drywells may not be placed on or above an active landslide hazard area or slopes greater than 15 percent without evaluation by a professional engineer with geotechnical expertise, or a licensed geologist, hydrogeologist, or engineering geologist, and with Thurston County acceptance.

Where individual lot drywells are to be installed in a residential subdivision, the project engineer shall determine the required size of each drywell for each lot or group of lots with similar soils. The project engineer shall then record these sizes as necessary to ensure that they become restrictions for future building applications (e.g., record written conditions for lots and/or dictate drywell size on the face of the final plat mylar, etc.).

2.2.2 LID.05 Downspout Dispersion Systems

Downspout dispersion systems are gravel-filled trenches or splash blocks that spread roof runoff over vegetated, pervious areas. Dispersion attenuates peak flows by slowing entry of runoff into the conveyance system, allowing some infiltration and providing some water quality benefits, such as filtration and vegetative uptake.

Applicability

Rooftop downspout controls (this BMP, BMP LID.04, "Downspout Infiltration Systems", or BMP LID.08, "Bioretention Facilities") are required to meet Minimum Requirement #5. Downspout Infiltration (BMP LID.04) is the preferred rooftop downspout control. If infiltration is not feasible, bioretention facilities (BMP LID.08) are preferred over downspout dispersion.

Limitations

No erosion or flooding of downstream properties may result.

See Appendix V-E (Site Design Elements) for setbacks. For dispersion systems located within 50 feet of the top of a slope of 15 percent or greater with a height of 10 feet, a geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope. The Administrator or designee may require a geotechnical report to evaluate whether a slope exceeding 15 percent is a landslide hazard area. Increased setbacks or prohibition of infiltration facilities may result from this report.

Hydrologic and Hydraulic Design Considerations

Dispersion Trenches

If roof runoff is dispersed over a vegetative flow path 25 feet or longer through undisturbed native landscape or an area that meets the soils criteria outlined in BMP LID.02, the roof area may be modeled as landscape surface for determining thresholds for Minimum Requirement #7, Flow Control, and sizing stormwater facilities.

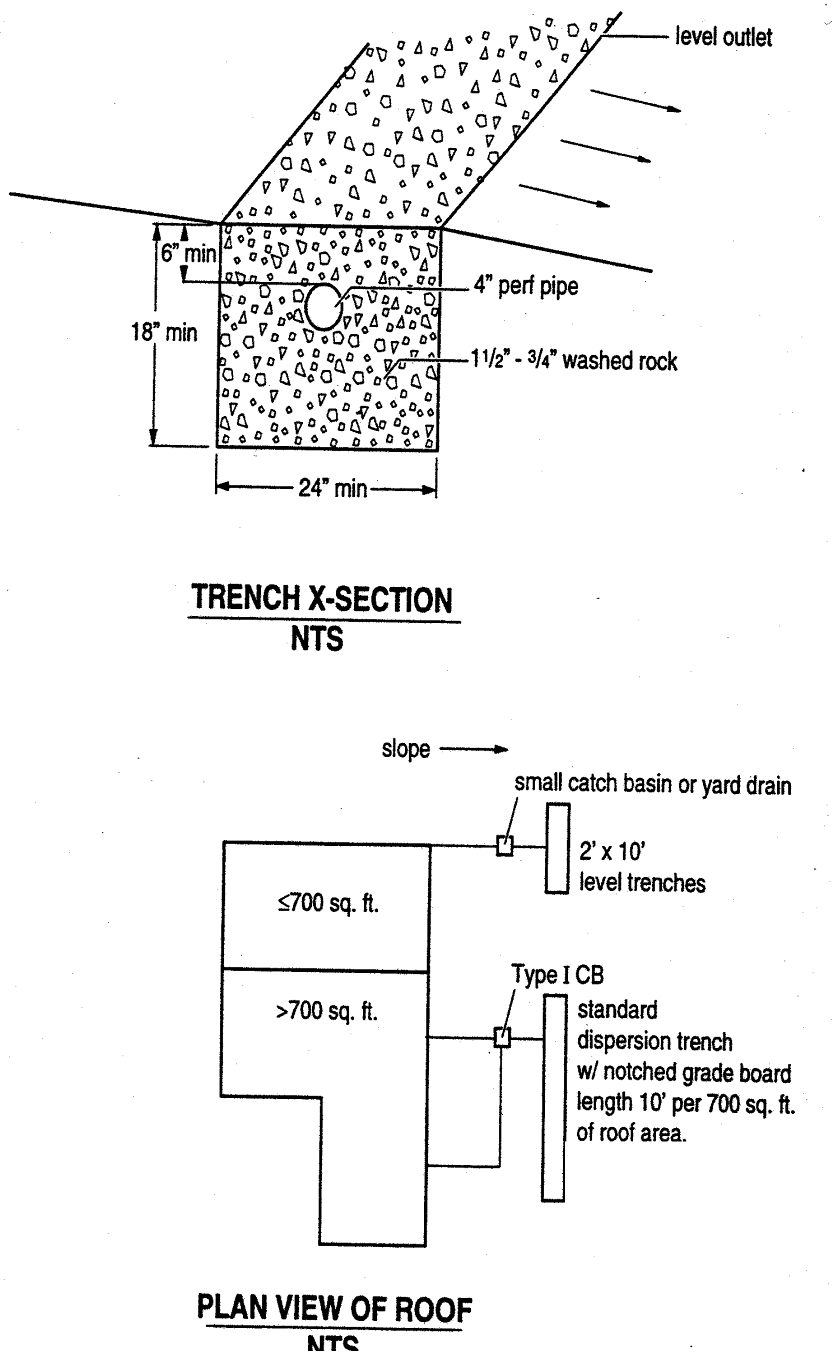
Splashblocks

If roof runoff is dispersed over a vegetative flow path 50 feet or longer through undisturbed native landscape or an area that meets the soils criteria outlined in BMP LID.02, the roof area may be modeled as landscaped surface for determining thresholds for Minimum Requirement #7, Flow Control, and sizing stormwater facilities.

Design Criteria

Dispersion Trenches

Dispersion trenches shall be designed as shown in Figure 2.4.



Source: King County

Figure 2.4. Typical Downspout Dispersion Trench.

A vegetated flow path at least 25 feet in length must be maintained between the outlet of a trench and any property line; structure; critical area (i.e., stream, wetland), or impervious surface. Critical area buffers may count towards flow path lengths. However, the area must be permanently protected from modification through a covenant or easement, or a tract dedicated by the proposed project. This does not include steep slopes. See steep slope setbacks below.

Trenches serving up to 700 square feet of roof area must be 10 foot long by 2-foot wide gravel filled trenches as shown in Figure 2.4. For roof areas larger than 700 square feet, a dispersion trench with notched grade board shall be used. The total length of this design must not exceed 50 feet, and must provide at least 10 feet of trench per 700 square feet of roof area. In both designs, it is important to include a cleanout structure prior to discharge into the dispersal area. Although the figures refer at times to a Type 1 catch basin, it is also acceptable to use an equivalent type structure which includes a lid, 1-foot minimum sump, and T-type outlet with screen.

Splashblocks

Splash blocks shall be designed as shown in Figure 2.5.

Splash blocks may be used for downspouts discharging to a vegetated flow path at least 10 feet in width and 50 feet in length as measured from the downspout to the downstream property line, structure, critical areas (i.e., stream, wetland), or other impervious surface. Flow path measurement may traverse a property line into an adjacent critical area buffer, provided that the area is permanently protected through a covenant, easement, or a tract dedicated as part of the proposed project. This does *not* include steep slopes. See *limitations*.

A maximum of 700 square feet of roof area may drain to each splash block. When flow paths of multiple splash blocks are combined, the vegetated flow path width shall increase by 50 percent with each additional splashblock.

Site Design Elements

Vegetated Flow path

For both dispersion trenches and splashblocks, the vegetated flow path must be covered with well-established vegetation to prevent erosion and promote partial infiltration. Vegetated flow paths shall consist of undisturbed native landscape area, or an area that meets the requirements of BMP LID.02, Soil Amendments, Quality and Depth.

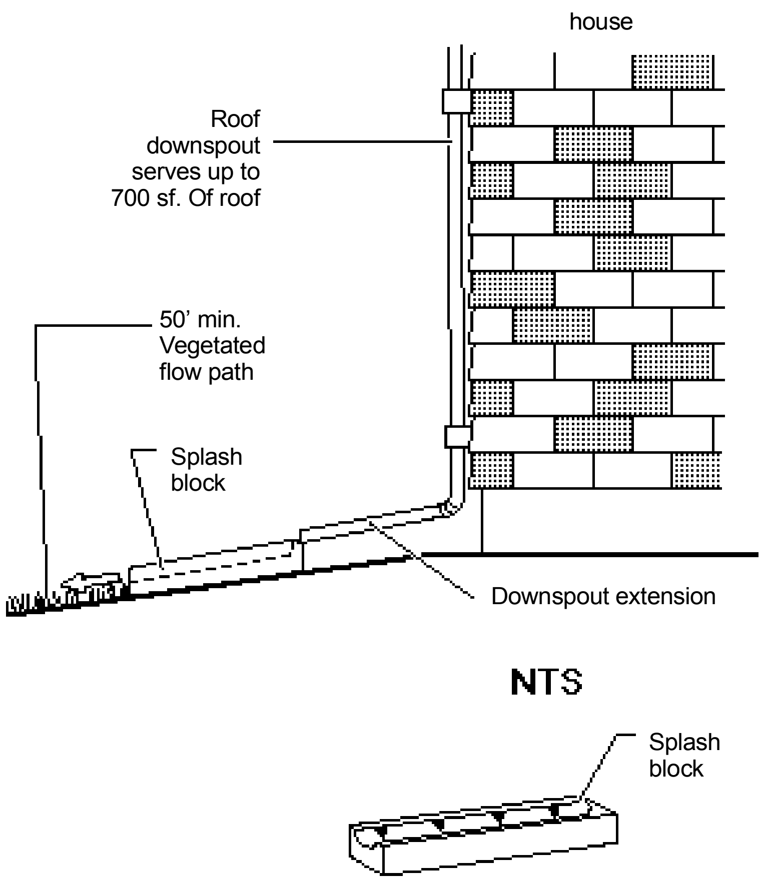


Figure 2.5. Typical Downspout Splashblock Dispersion.

Setbacks

Dispersion systems shall be set back at least 50 feet from top of slopes steeper than 15 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope. The Administrator or designee may require a geotechnical report to evaluate whether a slope exceeding 15 percent is a landslide hazard area. Increased setbacks or prohibition of infiltration facilities may result from this report.

For sites with septic systems, the discharge point must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield.

2.2.3 LID.06 Sheet Flow Dispersion

Sheet flow dispersion is the simplest method of runoff control, and can be used with any graded impervious or pervious surface to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective attenuation and treatment.

Applicability

Flat or moderately sloping (less than 15 percent) impervious surfaces such as driveways, private roadways, sport courts, patios, roofs without gutters, sloping cleared areas that are comprised of bare soil, non-native landscaping, lawn, or pasture, or any situation where concentration of flows can be avoided.

This BMP can be used to disperse unconcentrated site runoff when the project site cannot meet the requirements for full dispersion (see BMP LID.11) in terms of maximum impervious surface and native vegetation retention. If the minimum requirements of BMP LID.11 can be met for a project, then the less restrictive sheet flow dispersion criteria of that BMP can be used.

If the project is a roadway or other linear project and is in the rural area of Thurston County (outside an UGA or the NPDES Phase II permit boundary), then BMP LID.12 (Rural Roads Natural Dispersion) or BMP LID.13 (Rural Roads Engineered Dispersion) for rural roadways may be used for flow dispersion.

Limitations

No erosion or flooding of downstream properties may result.

Hydrologic and Hydraulic Design Considerations

Flow Credit for Sheet Flow Dispersion

Where sheet flow dispersion is used to disperse runoff into an undisturbed native landscape area, or an area that meets the requirements of BMP LID.02, “Soil Amendments, Quality and Depth”, the impervious area may be modeled as landscaped area for determining thresholds for Minimum Requirements #6 (Runoff Treatment) and #7 (Flow Control) and for designing stormwater facilities.

Design Criteria

See Figure 2.6 for details for driveways.

A transition zone (1-foot minimum) to discourage channeling shall be provided between the edge of the driveway pavement and the downslope vegetation, or under building eaves. This may be an extension of subgrade and shall be lower than the adjacent impervious surface by approximately 1-inch.

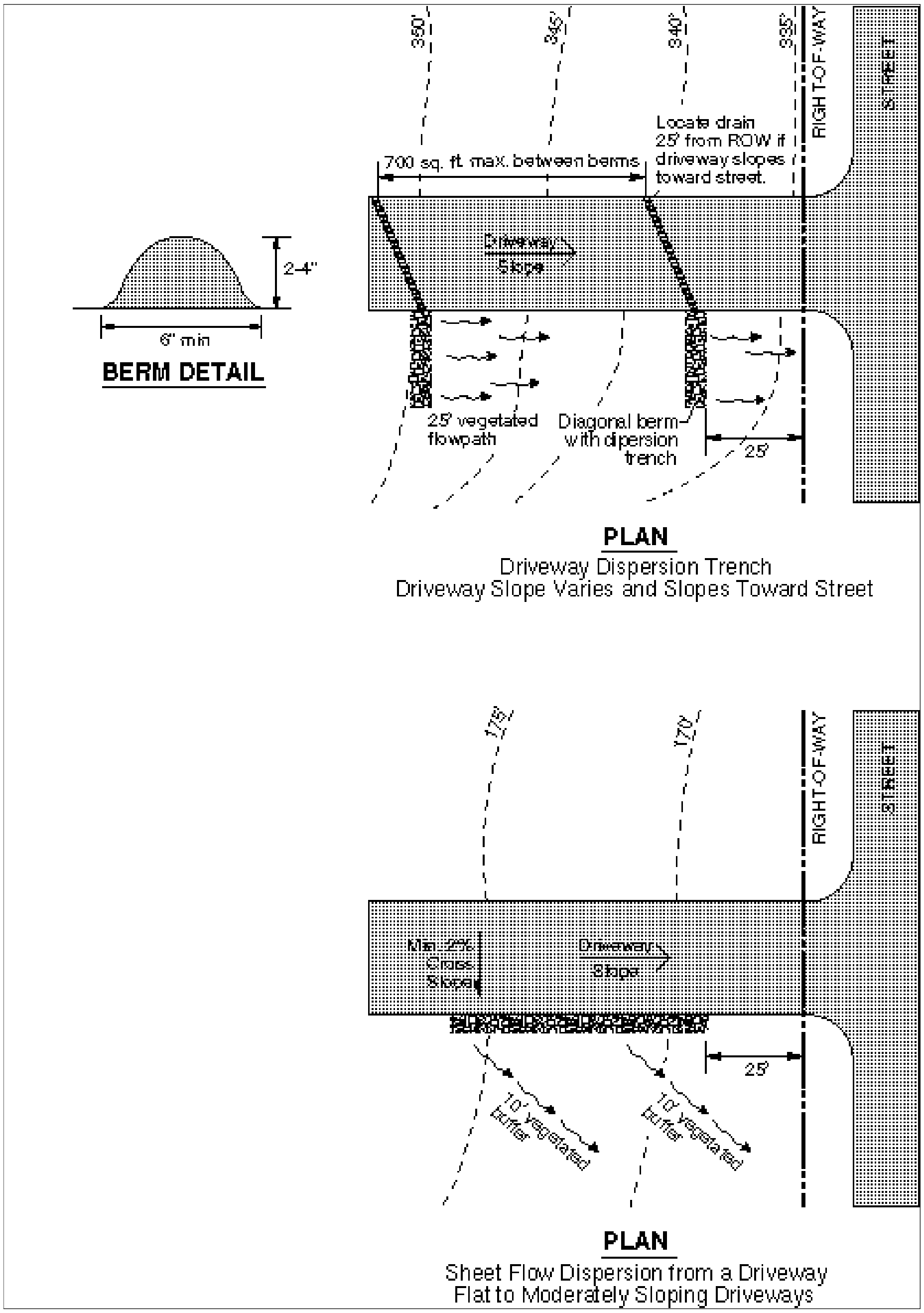


Figure 2.6. Sheet Flow Dispersion for Driveways.

material (crushed rock), modular pavement, drain rock, or other material approved by Thurston County.

A vegetated buffer width of 10 feet must be provided for up to 20 feet of width of paved or impervious surface. An additional 5 feet of width must be added for each additional 20 feet of width (or fraction thereof).

A vegetated buffer width of 25 feet of vegetation must be provided for up to 150 feet of contributing cleared area (i.e., bare soil, non-native landscaping, lawn, or pasture). Slopes within the 25-foot minimum flow path through vegetation must be no steeper than 8 percent. If this criterion cannot be met due to site constraints, the 25-foot flow path length must be increased 1.5 feet for each percent increase in slope above 8 percent, although the allowable slope shall not exceed 16 percent.

Site Design Elements

Sheet flow dispersion may not be appropriate where the drainage discharges toward slopes steeper than 15 percent or geologic hazard areas as defined by TCC 17.15. The Administrator or designee may require a geotechnical report to evaluate whether a slope exceeding 15 percent is a landslide hazard area. Increased setbacks or prohibition of dispersion toward the slope may result from this report. The geotechnical analysis and report shall address the potential impact of dispersion on the slope.

2.2.4 LID.07 Concentrated Flow Dispersion

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of runoff into the conveyance system, providing some infiltration and water quality benefits (i.e., sedimentation, filtration and vegetative uptake). See Figure 2.7.

Applicability

This BMP can be used to disperse concentrated site runoff when the project site cannot meet the requirements for full dispersion (see BMP LID.11) in terms of maximum impervious surface and native vegetation retention. If the minimum requirements of BMP LID.11 can be met for a project, then the less restrictive concentrated flow dispersion criteria of that BMP can be used.

If the project is a roadway or other linear project and is in the rural area of Thurston County (outside an UGA or the NPDES Phase II permit boundary), then BMP LID.12 (Rural Roads Natural Dispersion) or BMP LID.13 (Rural Roads Engineered Dispersion) may be used for flow dispersion.

Concentrated flow dispersion is appropriate for any situation where concentrated flow can be dispersed through vegetation.

Figure 2.7 shows two possible ways of spreading flows from steep driveways.

Limitations

Dispersion for driveways is usually effective only for single-family residences on large lots and in rural short plats. Lots proposed by short plats in urban areas are usually too small to provide effective dispersion of driveway runoff.

No erosion or flooding of downstream properties may result.

Submittals and Approval

Runoff discharged towards geologic or landslide hazard areas as defined by TCC 17.15 must be evaluated by a geotechnical engineer or qualified geologist. The discharge point shall not be placed on or above natural slopes greater than 15 percent and 10 feet in height, or above erosion or landslide hazard areas without evaluation by a geotechnical engineer or qualified geologist and acceptance by Thurston County.

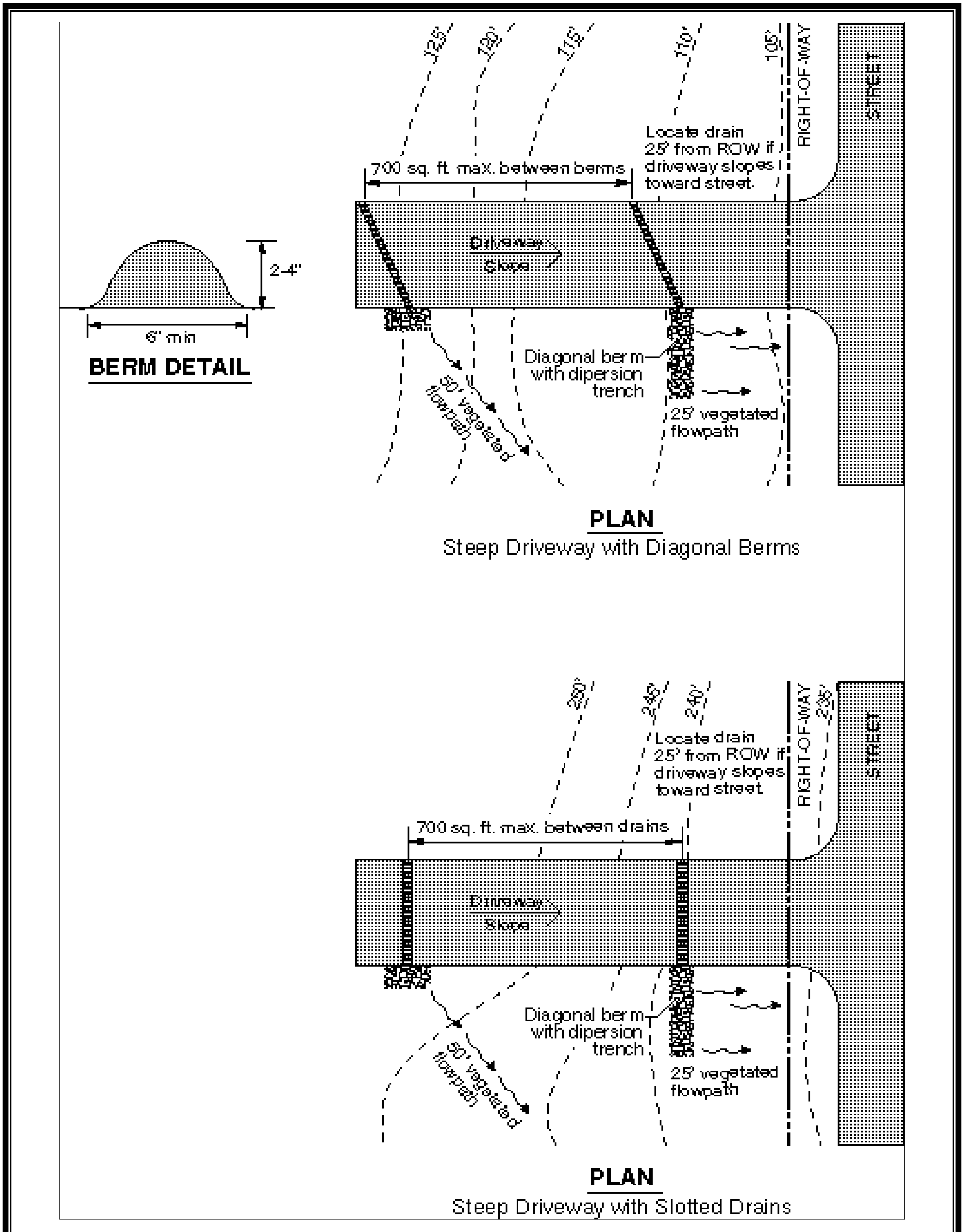


Figure 2.7. Typical Concentrated Flow Dispersion for Steep Driveways.

Native vegetation areas or landscape areas designed to meet BMP LID.02 (Post-Construction Soil Quality and Depth) which are used for dispersion of concentrated flows shall be identified on plans and plat maps and easements, tracts, or other means established to ensure their perpetual protection and maintenance of the dispersion area. Signage shall be provided to identify the extent of the area and the purpose of the area as a stormwater facility.

Hydrologic and Hydraulic Design Considerations

Flow Credit for Concentrated Flow Dispersion

Where concentrated flow dispersion is used to disperse runoff into an undisturbed native landscape area or an area that meets BMP LID.02 – Soil Amendments, Quality and Depth, and the vegetated flow path is at least 50 feet, the impervious area may be modeled as landscaped area for establishing thresholds for Minimum Requirements #6 (Runoff Treatment and #7 (Flow Control) and for stormwater facility design.

Design Criteria

A vegetated flow path of at least 50 feet must be maintained between the discharge point and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface.

A maximum of 700 square feet of impervious area may drain to each concentrated flow dispersion BMP.

A pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each discharge point.

Site Design Elements

For sites with septic systems, the discharge point must be downgradient of the drainfield primary and reserve areas. This requirement may be waived by Thurston County if site topography clearly prohibits flows from intersecting the drainfield.

2.2.5 LID.08 Bioretention Facilities

Bioretention facilities are shallow stormwater retention systems designed to mimic forested systems by managing stormwater through detention, infiltration, and evapotranspiration. Bioretention areas also provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation. Compared to traditional stormwater pond designs, these facilities are typically smaller in scale and integrated into the landscape to better mimic natural hydrologic systems.

Figure 2.8 provides an example illustration of a bioretention system.

Types of Bioretention Areas

Bioretention facilities can be configured in many ways, including the following:

- Rain gardens: Shallow depressions with a designed planting soil mix and variety of plant material, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells may or may not have an under-drain and are not designed as a conveyance system. Bioretention cells can be configured as depressed landscape islands, larger basins, planters, or vegetated curb extensions. They are most appropriate for small (10,000 sf or less) contributing areas.

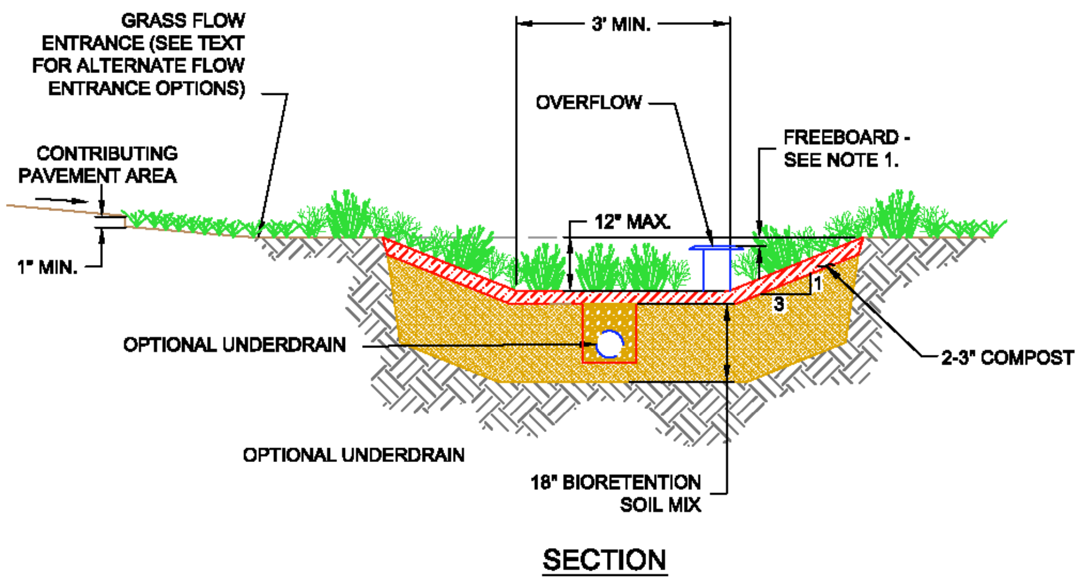
- Vegetated curb extensions: Bulb out areas along a road right-of-way containing a bioretention cell to accept roadway runoff.

- Bioretention swales/in-line bioretention: Long, linear facilities that incorporate the same design features as bioretention cells. Bioretention swales have relatively gentle side slopes and shallow flow depths.

Many other configurations of bioretention facilities are possible, but require different design methods than those described here. The following bioretention configurations require County acceptance, are discussed in the *Low Impact Development: Technical Guidance Manual for Puget Sound* (PSAT 2005).

- Biodetention: A design that uses vegetative barriers arranged in hedgerows across a slope to disperse, infiltrate, and treat stormwater.

- Sloped biodetention: use vegetative barriers are designed for a specific hydraulic capacity and placed along slope contours.



BIORETENTION FACILITY NOTES:

1. FREEBOARD DEPTH SHALL BE 2" MIN. FOR CONTRIBUTING AREAS < 1,000 SF; FREEBOARD DEPTH SHALL BE 6" MIN. FOR CONTRIBUTING AREAS ≥ 1,000 SF.

THURSTON COUNTY BMP LID.08
DETAIL: BIORETENTION FACILITY
SCALE: NTS

1
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Figure 2.8. Bioretention Area.

- Off-line bioretention: The bioretention facility is placed next to a swale with a common flow entrance and flow exit.

- Sloped or weep garden bioretention areas: Used for steeper gradients where a retaining wall is used for structural support and for allowing storm flows, directed to the facility, to seep out.

- Tree box filters: Street tree plantings with an enlarged planting pit for additional storage, a storm flow inlet from the street or sidewalk, and an underdrain system.

Applicability

- Bioretention facilities can be designed to meet Minimum Requirement #6 (Runoff Treatment) and Minimum Requirement #7 (Flow Control). Bioretention facilities meet the requirements for basic and enhanced treatment.

Potential applications for bioretention facilities are described as follows:

- Bioretention facilities are applicable in parking lots as concaved landscaped areas (i.e., lower than the parking lot surface height, so that stormwater runoff is directed as sheet flow into the bioretention area). This application, used with porous surfaces in the parking lot, can greatly attenuate stormwater runoff.

- Areas within loop roads or cul-de-sacs are another feasible location for a bioretention facility to collect runoff from adjacent areas and portions of the roadway.

- Within right-of-ways along roads (linear bioretention swales and cells, vegetated curb extensions and planters)

- Common landscape areas within apartment complexes or other multifamily housing designs.

- Shared facilities located in common areas for individual lots within a subdivision.

- On individual lots bioretention facilities should be used to receive rooftop runoff in areas where downspout infiltration systems (BMP LID.04) are not feasible and in preference to downspout dispersion systems (BMP LID.05), and may be integrated into the landscaped areas of the lot.

- On individual lots bioretention facilities can also be used to receive driveway and other on-lot impervious and pervious surfaces.

Limitations

A minimum clearance of 3 feet is necessary between the lowest elevation of the bioretention soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the facility meets or exceeds any of the following limitations:

- 5,000 square feet of pollution-generating impervious surface (PGIS)
- 10,000 square feet of impervious area
- Three-fourths of an acre (32,670 square feet) of lawn and landscape.

For bioretention systems and rain gardens with a contributing area less than the above thresholds, or for a bioretention swale on a linear project (roadway) with continuous sheet flow in-flow of runoff from the roadway surface a minimum of 1 foot of vertical clearance above the seasonal high groundwater level or other impermeable layer is acceptable.

Submittals and Approval

The applicant should consult with Thurston County at the pre-submittal meeting and the scoping report/meeting for the project to discuss the suitability of and requirements for a bioretention facility if one is proposed for the project.

Project submittal shall include the following in addition to the requirements of other sections:

- Source of bioretention soil mix and testing results of treatment soil
- Description of method used and results of infiltration testing of base soils and bioretention soil mix
- Hydrologic modeling results for the bio-retention facility demonstrating that the water quality treatment design storm is handled by the facility and how volumes greater than the water quality design flow are managed
- Project drawings shall include a typical cross-section of the facility and specifications for installation of treatment soils, seeding, sodding and other construction requirements
- Maintenance Plan shall include a discussion of maintenance requirements for the bio-retention facility

- The bioretention soils mix shall be tested for infiltration capacity using the following test method:
  - ASTM 2434 Standard Test Method for Permeability of Granular Soils (Constant Head) with a compaction rate of 80 percent using ASTM 1557 (Modified Proctor).
- Include in the Soils Management Plan prepared per BMP LID.02 the bioretention soils mix for any proposed bioretention facilities included in the project.

Pretreatment

If the catchment area contains unvegetated exposed soils or steep slopes, a presettling facility (e.g., filter strip, presettling basin, or vault) is required.

Hydrologic and Hydraulic Design Considerations

Infiltration Rate Determination

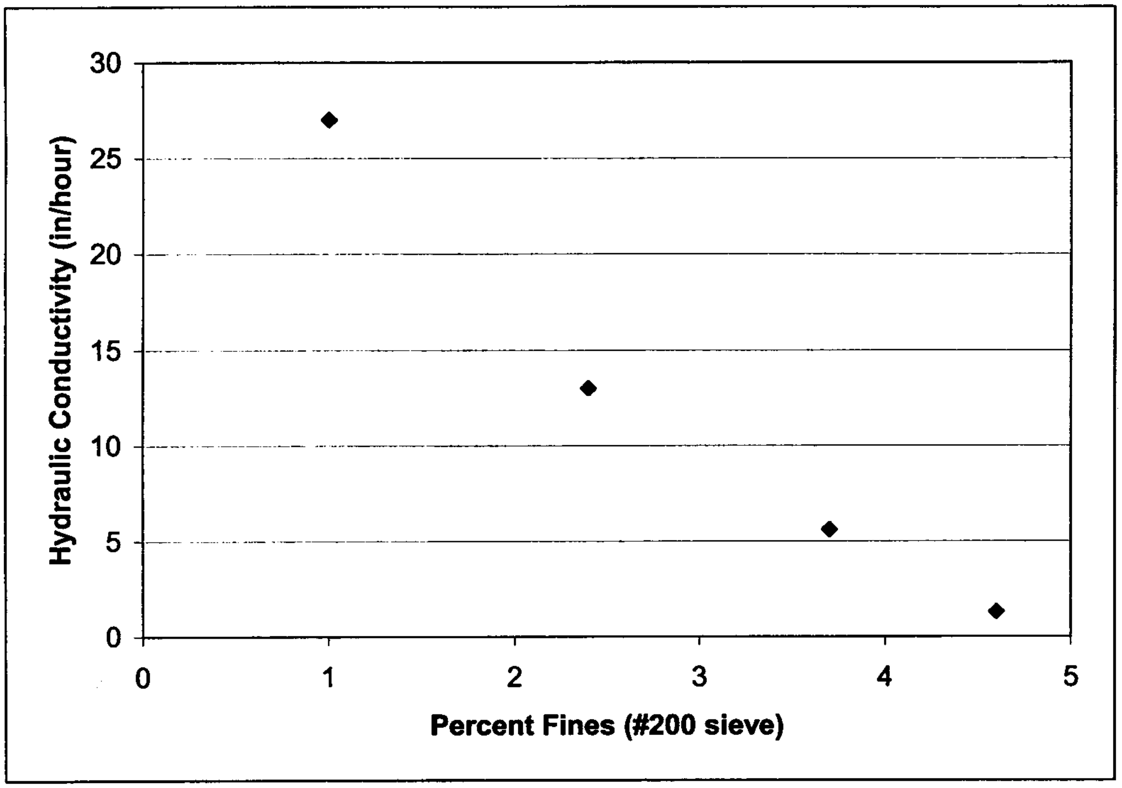
The design infiltration rate for the bioretention facility must be the lower of:

- Estimated long-term rate of the imported soil, or
- Initial infiltration rate of the underlying soil profile.

Imported Soil

The infiltration rate of imported soils can be determined using ASTM D2434 Standard Test Method for Permeability of Granular Soils (Constant Head) with a compaction rate of 80 percent using ASTM D1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. Alternately, the infiltration rate can be estimated from the proportion of fines (percent passing #200 sieve) in the aggregate portion of the imported soil. See Figure 2.9 for a relationship between measured hydraulic conductivity and percent fines (WSU 2009). If the design infiltration rate for the bioretention facility is determined by the imported soil, the quantitative method of determining the soil infiltration rate must be used.

The design infiltration rate for imported bioretention soil mix is estimated by applying a reduction factor to the measured value as discussed above. A reduction factor of 2 (multiply measured infiltration rate by 0.5) is applied where contributing areas are <5,000 sq. ft. of pollution generating surface, <10,000 sq. ft. of impervious area, and <3/4 acre of landscape area. Above these thresholds an infiltration reduction factor of 4 is applied.



Source: WSU (2009).

Figure 2.9. Percent Fines of the Four Aggregate Samples vs. Hydraulic Conductivity.

Underlying Soil

See Volume III for determination of the design infiltration rate of the underlying soil.

Modeling and Sizing

To be considered an enhanced treatment BMP, the bioretention facility must infiltrate at least 91 percent of the total volume of runoff in the inflow runoff file (based on a continuous simulation model). Otherwise, it provides basic treatment only.

If a bioretention facility is designed with an underdrain, its ability to meet the flow control criteria of Minimum Requirement #7 is limited to that area beneath the underdrain that has stormwater holding capacity.

Bioretention Facility Sizing

Bioretention facilities shall be sized by using an approved continuous simulation model and treating the facility as an infiltration facility with appropriate stage-storage and overflow/outflow rates.

When using continuous modeling to size bioretention facilities, the assumptions listed in Table 2.4 shall be applied. The tributary areas, cell bottom area, and ponding depth should be iteratively sized until the duration curves and/or peak values meet the applicable flow control requirements (see Volume I). Alternatively, bioretention systems that are not designed to fully meet applicable flow control requirements can discharge to a secondary flow control facility; as long as the net flow control requirement for the site is met through the combined performance of all facilities.

Table 2.4. Continuous Modeling Assumptions for Bioretention Cells

Variable	Assumption
Computational Time Step	5-minutes
Inflows to Facility	Surface flow and interflow from drainage area routed to facility
Precipitation and Evaporation Applied to Facility	Yes. If model does not apply precipitation and evaporation to facility, include the facility area in the basin area (note that this will significantly underestimate the evaporation of ponded water).
Bioretention Soil Infiltration Rate	See Infiltration Rate Determination, above
Bioretention Soil Porosity	40 percent
Bioretention Soil Depth	Minimum of 12 inches for flow control. Minimum of 18 inches for water quality treatment
Native Soil Design Infiltration Rate	Measured infiltration rate with correction factor applied, if applicable. If imported bioretention soil is used, a correction factor for plugging is not required.
Infiltration Across Wetted Surface Area	Yes if side slopes are 3H:1V or flatter. For steeper side slopes, only infiltration across the bottom area is modeled.
Underdrain (optional)	If underdrain is placed at bottom extent of the bioretention soil layer, all water which enters the facility must be routed through the underdrain. If there is no liner or impermeable layer and the underdrain is elevated within the bioretention soil, water stored in the bioretention soil below the underdrain may be allowed to infiltrate.
Outlet Structure	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over riser edge or notch. Note that total facility depth (including freeboard) must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge.

The professional version of WWHM includes a bioretention module that can be used to size the cell with or without an underdrain. It is anticipated that other modeling programs will develop similar modules to represent bioretention cells in the future.

Entrance Velocity

The velocity of flows entering a facility shall be less than 1 foot per second to minimize erosion potential. Engineered flow dissipation (e.g.

rock pad) shall be incorporated into curb-cut or piped (concentrated) flow entrances.

Ponding Depth

The ponding depth shall be a maximum of 12 inches (unless optional detention storage is incorporated – see below).

Drawdown Time

The surface pool drawdown time shall be a maximum of 24 hours. This can be estimated by dividing the maximum ponded depth by the design (long-term) infiltration rate.

Overflow

Unless designed for full infiltration of the entire continuous model runoff file, bioretention and rain garden facilities must include an overflow. Facility overflow can be provided by a drain pipe installed at the designed maximum ponding elevation (6 inches) and connected to a downstream BMP or an approved discharge point.

Overflow drainage facilities shall be designed to convey the 100-year recurrence interval flow. This assumes the facility will be full due to runoff rates far in excess of soil infiltration capacity. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

Optional Detention Storage

It is possible to design additional detention storage above the 12-inch design water surface (to a maximum of 30 inches total) by including an orifice control system within the overflow structure to help attenuate the flows. For example, a Type 1 Catch Basin with removable down-turned elbow (using properly designed orifices) could be used. This would allow the bioretention facility to meet the dewatering requirement of 24 hours, maximum.

If using this design, the plant selection must clearly reflect the additional proposed storage depth. This potential modified design is allowed only for large bioretention systems, not for facilities on individual lots. Care must be taken to still blend these larger and deeper facilities in with the surrounding landscape.

Underdrain

In the event that the downstream pathway of infiltration and interflow cannot be maintained, or the infiltration capacity is insufficient to handle the contributing area flows (e.g., a facility enclosed in a loop roadway system or a landscape island within a parking lot), an underdrain system can be incorporated into the facility. The underdrain system can then be connected to a nearby vegetated channel, another stormwater facility, or dispersed into a natural protection area.

Only the area below the under-drain invert and the bottom of the bioretention facility can be used in the WWHM for flow control benefit. The area above an underdrain pipe in a bioretention or rain garden facility provides attenuation and pollutant filtering. Underdrain systems should be installed only if the bioretention or rain garden is:

- Located where infiltration is not permitted and a liner is used
- In soils with infiltration rates that are not adequate to meet maximum pool drawdown time.

The underdrain can be connected to a downstream BMP such as another bioretention/rain garden facility as part of a connected system, or to an approved discharge point.

The underdrain pipe diameter will depend on hydraulic capacity required (4 to 8 inches is common). Within the public right-of-way any underdrain shall be a minimum of 12-inches with access to both ends. A geotextile fabric (specifications in Appendix V-A) must be used between the soil layer and underdrain.

The underdrain should be sloped at 0.5 percent unless otherwise specified by the project engineer.

A minimum of 6 inches of granular filter material shall be placed over the top of the underdrain pipe. Wrapping with geotextile is not recommended.

A 6-inch rigid non-perforated observation pipe or other maintenance access shall be connected to the underdrain every 250 to 300 feet to provide a clean-out port, as well as an observation well to monitor dewatering rates.

Design Criteria

Geometry

The cell ponding area shall meet the following criteria:

- The maximum side slope shall be 3H:1V. Steeper backslopes may be allowed for bioretention swales in roadway projects with limited right-of-way width with County acceptance. This criterion does not apply to bioretention planters.
- Vertical walls are not permitted except in bioretention planters

- The bottom width shall be no less than 2 feet
- The minimum freeboard measured from the invert of the overflow pipe or earthen channel to facility overtopping elevation shall be 2 inches for drainage areas less than 1,000 square feet (and linear projects with continuous inflow to a roadside bioretention swale) and 6 inches for drainage areas 1,000 square feet or greater
- If berming is used to achieve the minimum top elevation needed to meet ponding depth and freeboard needs, maximum slope on berm shall be 2H:1V, and minimum top width of design berm shall be 1 foot.

Materials

Soils

Soils shall consist of 60 percent aggregate and 40 percent compost by volume. Minimum depth of treatment soil is 18 inches.

Aggregate

Aggregate shall be well-graded utility or screened sand, and shall meet the following criteria:

- Percent passing the #200 sieve shall be between 2 and 5 percent (between 2 and 4 percent is preferred).
- Aggregate shall meet the gradation shown in Table 2.5.

Table 2.5. Bioretention Soil Aggregate Gradation

Sieve Size	Percent Passing
3/8”	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-5

- Coefficient of Uniformity ($C_u = D_{60}/D_{10}$) shall be 6 or greater.
- Coefficient of Curve ($C_c = (D_{30})^2/D_{60} \times D_{10}$) shall be between 1 and 3.

Compost

Compost shall meet the following criteria:

- Material shall be in compliance with WAC chapter 173-350, section 220, and be made from Type 1, 2, or 3 feedstock.
- Compost shall meet the gradation shown in Table 2.6.

Table 2.6. Bioretention Soil Compost Gradation

Sieve Size	Percent Passing
2”	100
1”	99-100
5/8”	90-100
#4	40-90

- The pH for the compost shall be between 5.5 and 8.0 as documented by test method TMECC 04.11-A “1:5 Slurry pH” or equivalent.
- Carbon:nitrogen (C:N) ratio between 20:1 and 25:1 for most landscapes. For native woody plantings, a C:N ratio between 30:1 and 35:1 is preferred.
- Organic matter content shall be between 45 percent and 65 percent as determined by test method TMECC 05.07A “Loss-on-ignition organic matter method” or equivalent.
- Electrical conductivity shall not be greater than 6 millimhos per centimeter (mmhos/cm).
- Moisture content shall be between 35 and 50 percent.
- Compost shall have no viable weed seeds.

Underdrain Pipe

Underdrain pipe shall be per WSDOT Standard Specifications Section 9-05.2 for Perforated PVC Underdrain pipe, Perforated Corrugated Polyethylene Drainage Tubing Underdrain Pipe or Perforated Corrugated Polyethylene Underdrain Pipe.

Gravel Filter Material

Gravel blankets and filter fabrics buffer the under-drain system from sediment input and clogging. Gravel Filter Material for underdrains shall be Gravel Backfill for Drains per WSDOT Standard Specifications 9-03.12(4).

Filter Fabric

Filter fabric for lining the underdrain (separation between gravel filter and native soil) shall be a non-woven geotextile fabric meeting WSDOT Standard Specifications Section 9-33 requirements for a "Separation" geotextile. See also Appendix V-B for geotextile specifications.

Alternative combinations of gravel filter material, underdrain pipe and filter fabric may be proposed if evaluated by a geotechnical or civil engineer for compatibility and suitability for the application.

Plants

A minimum of three tree, three shrub, and three herbaceous groundcover species shall be incorporated into the bioretention facility design. This is to protect against facility failure due to disease and insect infestations of a single species or environmental conditions affecting a single species.

Plants shall conform to the standards of the current edition of *American Standard for Nursery Stock* as approved by the American Standards Institute, Inc. All plant grades shall be those established by said reference.

All plant materials should have normal, well-developed branches and vigorous root systems, and be free from physical defects, plant diseases, and insect pests.

Plant size: Bioretention areas provide excellent soil conditions and should have well-defined maintenance agreements. In this type of environment small plant material provides several advantages and is recommended. Specifically, small plant material requires less careful handling, less initial irrigation, experiences less transplant shock, is less expensive, adapts more quickly to a site, and transplants more successfully than larger material. Small trees or shrubs are generally supplied in pots of 3 gallons or less.

All plants shall be tagged for identification when delivered.

Native species of plants should be selected over non-native. Appendix V-E provides lists of plants, trees, and ground covers, including native species that are appropriate for different soil moisture and inundation frequency zones within bioretention facilities.

Mulch

When used mulch should be:

- Compost in the bottom of the facilities (compost is less likely to float and is a better source for organic materials) and shredded or chipped hardwood or softwood in surrounding areas

- Free of weed seeds, soil, roots and other material that is not bole or branch wood and bark
- A maximum of 2 to 3 inches thick (thicker applications can inhibit proper oxygen and carbon dioxide cycling between the soil and atmosphere).

Mulch should not be:

- Grass clippings
- Pure bark.

Flow Entrance

The design of flow entrance to a bioretention or rain garden facility will depend upon topography, flow velocities, flow volume, and site constraints. Vegetated buffer strips are the preferred entrance type because they slow incoming flows and provide initial settling of particulates.

Four primary types of flow entrances can be used for bioretention/rain gardens:

1. Dispersed, low velocity flow across a grass or landscape area: this is the preferred method of delivering flows to the facility and can provide initial settling of particulates
2. Dispersed flow across pavement or gravel and past wheel stops for parking areas
3. Drainage curb cuts for roadway, driveway or parking lot areas: curb cuts shall include a concrete chute below the gutter grade to prevent sod from building up and backing flows into the roadway. Rock or other erosion protection material shall be installed at the outlet of the concrete gutter chute to dissipate energy
4. Pipe flow entrance: piped entrances shall include rock or other erosion protection material in the facility entrance to dissipate energy and/or provide flow dispersion.

Woody plants should not be placed directly in the entrance flow path as they can restrict or concentrate flows and can be damaged by erosion around the root ball.

Minimum requirements associated with the flow entrance/presettling design include the following:

- If concentrated flows are entering the facility, engineered flow dissipation (e.g., rock pad or flow dispersion weir) must be incorporated.
- A minimum 1-inch grade change between the edge of a contributing impervious surface and the vegetated flow entrance is required.
- Until the upstream catchment area is thoroughly stabilized, flow diversion and erosion control measures must be installed to protect the bioretention area from sedimentation.
- Dispersed flow should not be concentrated for presettling purposes.

Cell Ponding Area

The ponding area provides surface storage for storm flows, particulate settling, and the first stages of pollutant treatment within the facility. Ponding depth and draw-down rate requirements are to provide surface storage, adequate infiltration capability, and soil moisture conditions that allow for a range of appropriate plant species.

Soils must be allowed to dry out periodically in order to:

1. Restore hydraulic capacity of system,
2. Maintain infiltration rates,
3. Maintain adequate soil oxygen levels for healthy soil biota and vegetation,
4. Provide proper soil conditions for biodegradation and retention of pollutants, and
5. Prevent conditions supportive of mosquito breeding.

Construction and Maintenance

Bioretention facilities and rain gardens rely on water movement through the surface soils as infiltration and interflow to underlying soils. Therefore, it is important to always consider the pathway of interflow and ensure that the pathway is maintained in an unobstructed and uncompacted state both during and after construction.

Bioretention facilities, as with all types of infiltration facilities, should generally not be used as temporary sediment traps during construction. If a bioretention facility is to be used as a sediment trap, do not excavate to final grade until after the upgradient drainage area has been stabilized. Remove any accumulation of silt before putting the facility into service.

Minimizing compaction of the base and sidewalls of the bioretention or rain garden area is critical. Excavation, soil placement, or soil amendment shall not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the facility and no heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should be allowed on the bottom of the facility. If machinery must operate in the facility for excavation, light weight, low ground-contact pressure equipment should be used and the base shall be scarified at completion to refracture soil to a minimum of 12 inches.

On-site soil mixing or placement should not be performed if soil is saturated. The bioretention soil mixture should be placed and graded by excavators and/or backhoes operating adjacent to the facility. The soil mixture should be placed in horizontal layers not to exceed 12 inches per lift for the entire area of the bioretention facility.

The soil mixture will settle and proper compaction can be achieved by allowing time for natural compaction and settlement. To speed settling, each lift can be watered until saturated. Water for saturation should be applied by spraying or sprinkling.

Maintenance

Bioretention areas require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioretention maintenance requirements are typical landscape care procedures. See Appendix V-C for maintenance checklists.

Site Design Elements

Setbacks

Bioretention facilities shall meet the setback requirements for infiltration facilities of Appendix V-E.

Landscaping (Planting Considerations)

Plant roots aid in the physical and chemical bonding of soil particles that is necessary to form stable aggregates, improve soil structure and increase infiltration capacity.

The primary and significant benefits of small trees, shrubs, and ground cover in bioretention areas during the wet season are the presence of root activity and contribution of organic matter that aids in the development of soil structure and infiltration capacity.

Planting of bioretention areas should be designed by a landscape architect or landscaper. Appendix V-E includes a detailed bioretention plant list adapted from *Low Impact Development: Technical Guidance Manual for Puget Sound* (PSAT 2005).

Primary design considerations in plant selection include:

- *Soil moisture conditions*: Plants should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for the lengths of time anticipated by facility design.
- *Expected pollutant loadings*: Plants should tolerate pollutants and loadings from the surrounding land uses.
- *Above and below ground infrastructure in and near the facility:* Plant size and wind firmness should be considered within the context of the surrounding infrastructure. Rooting depths should be selected to not damage underground utilities if present. Perforated pipe should be more than 5 feet from tree locations.
- *Adjacent plant communities and potential invasive species control.*
- *Site distances and setbacks for roadway applications.*
- *Visual buffering:* Plants can be used to buffer structures from roads, enhance privacy among residences, and provide an aesthetic amenity for the site.
- *Aesthetics:* Visually pleasing plant design adds value to the property and encourages community and homeowner acceptance. Homeowner education and participation in plant selection and design for residential projects should be encouraged to promote greater involvement in long-term care.

Signage and Fencing

Bioretention facilities (Rain Gardens) are stormwater management facilities and shall be identified as such with signage and fencing. Signs shall be installed identifying the facility and its purpose and not to disturb. Fencing should be considered to reduce public access through the facility, especially if located within a parking area or other area easily accessible to the public.

2.2.6 LID.09 Alternative Paving Surfaces

Alternative paving surfaces are designed to accommodate pedestrian, bicycle, and auto traffic while allowing infiltration and storage of stormwater. Alternative paving surfaces include:

- Porous asphalt pavement
- Porous concrete
- Grid or lattice rigid plastic or paving blocks where the holes are filled with soil, sand, or gravel
- Cast-in-place paver systems.

Alternative paving systems may be designed with an underdrain to collect stormwater or without an underdrain as an infiltration facility.

Applicability

Appropriate applications for alternative paving surfaces include parking overflow areas, parking stalls, low volume residential roads, alleys, driveways, sidewalks/pathways, patios, emergency access, and facility maintenance roads.

Permeable paving surfaces can provide some attenuation and uptake of stormwater runoff even on cemented till soils while still providing the structural integrity required for a roadway surface to support heavy truck loads.

Permeable paving surfaces can be designed with aggregate storage to function as an infiltration facility with relatively low subgrade infiltration rates. Since the contributing flow is only the incident rainfall the hydraulic loading rate of the infiltration area is low.

Limitations

Thurston County will not currently approve porous pavement surfaces on County-maintained roads.

Porous pavement is not intended to receive “run-on” stormwater from other areas.

Porous paving surfaces are not appropriate for roads subject to high sediment loadings (such as roads that are sanded for deicing purposes in the winter). Application of sand and other gritty substances can clog the pavement, impeding the infiltration of stormwater and resulting in hazardous ponded water conditions.

Because of water quality concerns related to stormwater with high concentrations of oils or other contaminants infiltrating through the surface and contaminating groundwater, porous pavement surfaces shall not be allowed with land uses that generate heavy loadings of these pollutants. These include, but are not limited to, gas stations, commercial fueling stations, autobody shops, automobile repair services, and automobile wash services.

Sidewalk designs incorporate scoring, or truncated domes, near the curb ramp to indicate an approaching traffic area for the blind. The rougher surface of permeable paving may obscure this transition. Therefore standard concrete with scoring or truncated domes with pavers should be used for curb ramps.

The aggregate within the cells of permeable pavers can settle or be displaced from vehicle use. As a result, paver installations for disabled parking spaces and walkways should use solid pavers or standard concrete or asphalt.

Alternative pavement surfaces are suitable for use in Type A through C soils and are not recommended for Type D soils. However, with adequate accommodation of potential runoff from the porous paving surface over Type D soils, the application can be beneficial for encouraging infiltration.

Hydrologic and Hydraulic Design Considerations

Porous paving surfaces differ greatly in infiltration capacity. Base materials of porous pavement systems can be designed to infiltrate vertically into outwash soils.

Where cemented till layers of soil exist under a parking lot, a porous pavement system can still be effective to attenuate peak flows. In small area applications, the subgrade of the parking lot can be built up with porous base material and graded to direct runoff through this material to a controlled outfall, such as bioretention areas.

Flow Credit/Modeling of Alternative Paving Surfaces

Porous pavement surfaces designed in accordance with this section for infiltration should be modeled as indicated in Table 2.4. Note that alternative paving surfaces should not be receiving “run on” from other surfaces. Alternative paving surfaces are highly effective at infiltrating runoff, even with relatively low infiltration rates because the BMP surface area is the same as the contributing surface area. Installing an underdrain is typically unnecessary and greatly reduces the flow control benefit of this BMP.

Table 2.4. Continuous Modeling Assumptions for Alternative Paving Surfaces

Variable	Assumption
Computational Time Step	5-minutes
Inflows to Facility	Model pavement area as impervious basin routed to a gravel-filled trench with infiltration to underlying soil. Additional areas draining to the pavement (surface flow and interflow), if any, are also routed to the gravel trench.
Precipitation Applied to Facility	No (applied to basin before routing to trench)
Evaporation Applied to Facility	Yes. While evaporation is applied to the impervious basin before routing to the trench, additional evaporation occurs when water is stored in the storage reservoir
Storage Reservoir Depth	Average maximum subsurface water ponding depth in the storage reservoir (average across the facility) before berm overtopping or overflow. Note: The maximum ponding depth in the storage reservoir shall be a minimum of 6 inches below the surface of pavement.
Storage Reservoir Porosity	Assume maximum 20 percent unless test is provided showing higher porosity for aggregate compacted and in place
Native Soil Design Infiltration Rate	Measured infiltration rate with correction factor applied (see Volume III)
Infiltration Across Wetted Surface Area	No (bottom area only)
Underdrain (optional)	If underdrain is placed at bottom extent of the storage reservoir, all water which enters the facility must be routed through the underdrain. If there is no liner or impermeable layer and the underdrain is elevated within the storage reservoir, water stored in the reservoir below the underdrain may be allowed to infiltrate.
Outlet Structure	Overflow elevation set at average maximum subsurface ponding depth. May be modeled as weir flow over riser edge or notch. Note that freeboard must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge.

Design Criteria

Manufacturer’s recommendations on design, installation, and maintenance shall be followed for each application.

Drainage Conveyance

Design roads with adequate drainage conveyance facilities as if the road surface was impermeable.

Design drainage flow paths to safely move water away from the road prism and into the roadside drainage facility for roads with base courses that extend below the surrounding grade.

Runoff Treatment

The subgrade must have an infiltration rate of less than 2.4 inches per hour and a cation exchange capacity of 5 milliequivalents CEC/100 grams dry soil or greater to provide water quality treatment that satisfies Minimum Requirement #6 requirements. Runoff treatment does not apply to alternative paving surface facilities with an underdrain.

Geometry

Positive surface drainage shall be provided to eliminate risk of ponding on pavement surface (minimum surface slope of 1 percent).

- Unless approved in writing by the Administrator or designee maximum slopes for alternative paving surfaces are 5 percent (porous asphalt), 6 percent (porous concrete), 10 percent (interlocking pavers), and 5 to 6 percent (grid and lattice systems).

Materials

Figures 2.10 and 2.11 show examples of typical cross-sections of porous paving sections. They typically consist of a top layer (porous wearing course), an aggregate subbase, an optional leveling course and geo-textile fabric.

Porous Wearing Course

The wearing course or surface layer of the alternative paving surface may consist of permeable asphalt, permeable concrete, interlocking concrete pavers, or open-celled paving grid with vegetation or gravel. The wearing course must provide adequate porosity for stormwater infiltration.

Requirements for the wearing layer include the following:

- A minimum infiltration rate of 10 inches/hour is required though higher infiltration rates are desirable.

- For porous asphalt, products must have adequate voice space, commonly 12 to 20 percent.

- For porous concrete, products must have adequate void space, commonly 15 to 21 percent.

- For grid/lattice systems filled with gravel, sand or a soil of finer particles with or without grass, fill must be at least 2 inches. Fill shall be underlain with 6 inches or more of sand or gravel to provide an adequate base. Locate fill at or slightly below the top elevation of the grid/lattice structure. Modular grid openings must be at least 40 percent of the total surface area.

- For paving blocks, fill spaces between blocks with 6 inches of free draining sand or aggregate material. Provide a minimum of 12 inches of free draining surface area.

- For a vegetated open-celled paving grid, topsoil shall have a minimum 4 percent organic matter by dry weight.

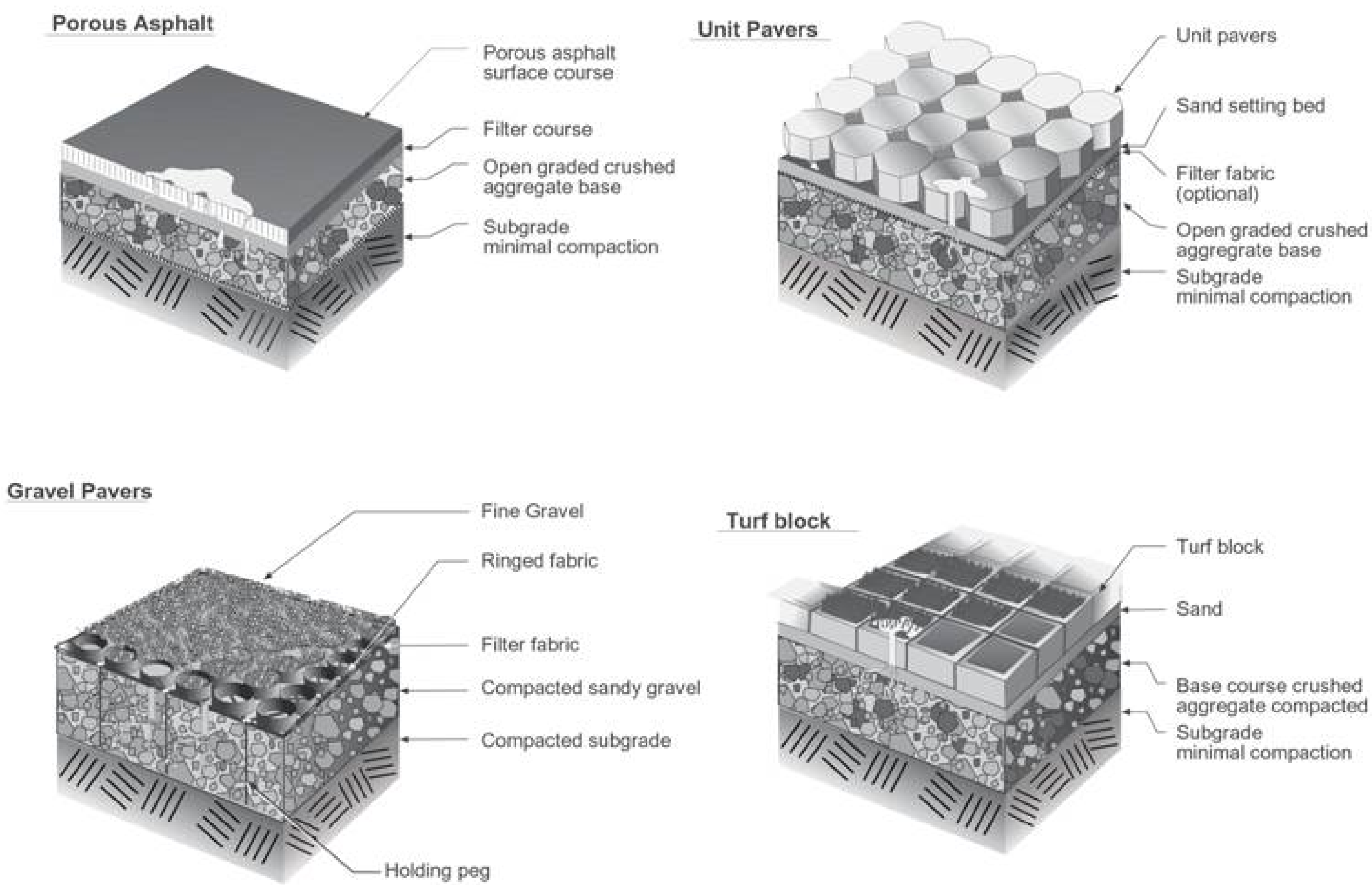


Figure 2.10. Alternative Paving Surfaces.

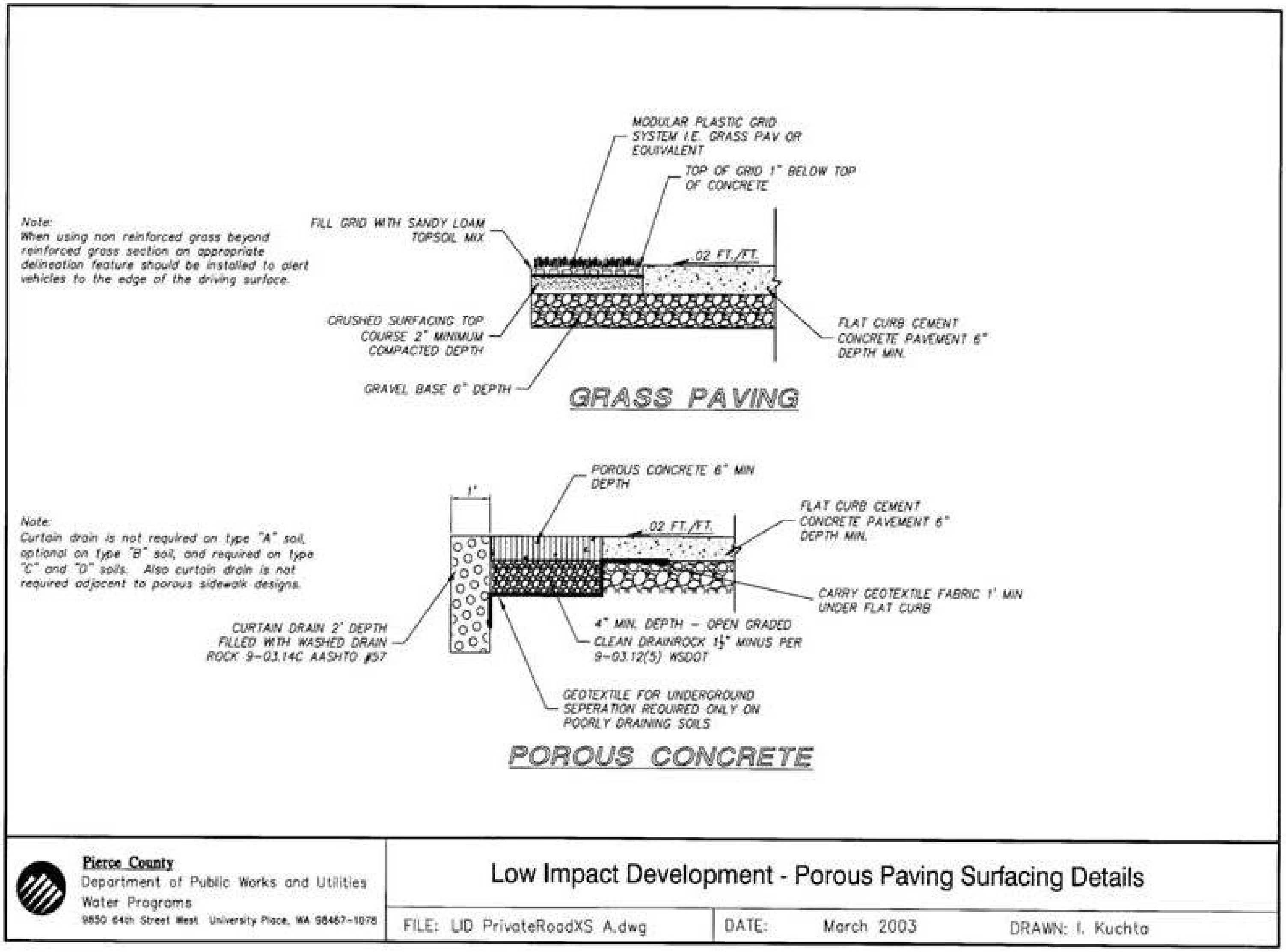


Figure 2.11. Porous Paving Surfacing Details.

Leveling Course

Depending upon the type of permeable pavement installation, a leveling course (also called a bedding or choker course) may be required (per manufacturer recommendations). A leveling course is often required for open-celled paving grids and interlocking concrete pavers. This course is a layer of aggregate that provides a more uniform surface for laying pavement or pavers and consists of crushed aggregate smaller in size than the underlying aggregate subbase. Course thickness will vary with permeable pavement type.

Aggregate Subbase

The aggregate subbase in an alternative paving surface serves as the support base and must be designed to support the expected loads and be free draining. The subbase shall meet the following criteria:

- Material must be free draining.
- A 4 to 6-inch depth of aggregate subbase is recommended under the porous wearing course and leveling course (if any)
- Aggregate subbase shall consist of larger rock at the bottom and smaller rock directly under the top surface (e.g., a gradient from 2 to 5/8 inch)
- Below are examples of possible base material specifications. See Chapter 6 of the "Low Impact Development: Technical Guidance Manual for Puget Sound" for more detailed information.
    - Driveway base material:
        - >4-inch layer of free-draining crushed rock, screened gravel, or washed sand.
        - <5 percent fines (material passing the #200 sieve) based on fraction passing the #4 sieve.
    - Roads and Parking Lots
        - Follow the standard material and quantities used for asphalt roads.

Geotextile Fabric

As part of the pavement section design, the designer should review the existing native soil or subbase characteristics and determine if a nonwoven geotextile is needed for separation of subbase from underlying soils.

Where necessary, the bottom and sides of the aggregate subbase should be contained by a nonwoven geotextile. The fabric should allow water to infiltrate but restrict movement of other particles into the gravel. See Appendix V-B for geotextile specifications.

Separation or Bottom Filter Layer (optional but recommended)

A layer of sand or crushed stone graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect the underlying soil from compaction, and serve as a transition between the base coarse and the underlying geotextile.

Subgrade

Compact the subgrade to the minimum necessary for structural stability. Use small static dual wheel mechanical rollers or plate vibration machines for compaction. Do not allow heavy compaction due to heavy equipment operation. The subgrade should not be subject to truck traffic.

Structural Design Considerations

Structural designs for porous surfaces shall be per the manufacturer's specifications. If any deviations are made from the manufacturer's recommendations or if the manufacturer's recommendations require engineering judgments, the design shall be stamped by a geotechnical engineer.

Porous systems that utilize pavers must be confined with a rigid edge system to prevent gradual movement of the paving stones.

ADA compliance should be requested from the manufacturer and is a consideration in determining where to use alternative paving surfaces.

Construction and Maintenance

Installation Criteria

Proper installation is key to the success of porous paving surfaces. As with any pavement system, porous pavement system requires careful preparation of the subgrade and base course to ensure success in terms of strength and permeability. The compressive strength of a permeable paver system relies mainly on the strength of the underlying soils, particularly when using modular or plastic units where the pavement itself lacks rigidity. Alternative paving surfaces shall be designed and installed according to manufacturer recommendations.

Install appropriate source and erosion control BMPs to prevent sediment transport from construction activities onto the base material or top course when the porous surface is applied prior to the completion of construction and stabilization of the entire site.

If possible, temporary roads should be used during construction and final construction of the base material, and porous surfacing completed after building construction is complete.

Acceptance Test

Test all permeable surfaces by throwing a bucket of water on the surface. If anything runs off the surface or puddles, additional testing is necessary prior to accepting the construction.

As directed by the Administrator or designee, test with a 6–inch ring Infiltrometer or sprinkle Infiltrometer. Wet the road surface continuously for 10 minutes. Test to determine compliance with the 10 inches per hour minimum infiltration rate.

For facilities designed to infiltrate, the bucket test shall be completed annually.

Test documentation shall be retained with maintenance records and submitted with the engineer's inspection report at project completion.

Maintenance Criteria

Appendix V-C has maintenance guidelines for alternative paving surfaces. Some general considerations are as follows:

- Clogging is the primary mechanism that degrades infiltration rates. However, as discussed above, the surface design can have a significant influence on clogging of void space.

- Studies have indicated that infiltration rates on moderately degraded porous asphalts and concrete can be partially restored by suctioning and sweeping of the surface. Highly degraded porous asphalts and concrete require high pressure washing with suction.

- Maintenance frequencies of suctioning and sweeping shall be specified in the Maintenance Plan.

- Porous pavement systems designed with pavers have advantages of ease of disassembly when repairs or utility work is necessary. However, it is important to note that the paver removal area should be no greater than the area that can be replaced at the end of the day. If an area of pavers is removed, leaving remaining edges unconfined, it is likely that loading in nearby areas will create movement of the remaining pavers thereby unraveling significantly more area than intended.

2.2.7 LID.10 Vegetated Roofs

Vegetated roofs are areas of living vegetation installed on top of buildings to provide flow control via detention, attenuation, and soil storage, and to control losses to interception, evaporation, and transpiration. Vegetated roofs are also known as ecoroofs, green roofs, and roof gardens. Vegetated roofs also provide habitat, enhance aesthetics, reduce temperature within urban centers, and last longer than traditional roofing materials (mainly due to lessened temperature fluctuation of roofing materials).

Vegetated roofs are categorized by their depth and the courses used in their construction. Deeper, or "intensive" roofs, have at least 8 inches of growth media and are planted with groundcovers, grasses, shrubs, and (sometimes) trees. Extensive vegetated roofs require regular landscape maintenance.

Shallower, or "extensive" roofs, have less than 8 inches of growth media and use drought-tolerant, low maintenance groundcovers.

Extensive systems are further classified as either "single-course" systems, consisting of a single media designed to be freely draining and support plant growth, and "multi-course" systems that include both a growth media layer and a separate, underlying drainage layer.

Applicability

Vegetated roofs are applicable in highly developed environments where other LID practices of forest retention or infiltration are not feasible. They are most appropriate for nearly flat roofs, those with a pitch of up to 2 percent. These are the easiest to install and generally provide the greatest stormwater storage capacity per inch of growth medium.

Limitations

Steeper slopes, such as those on single family residences, may result in reduced flow control performance and may trigger additional design requirements (e.g., underlying drainage layer and lateral support measures).

In addition, applications on slopes steeper than 15 percent (5H:1V) will not qualify for flow control credits.

Submittals and Approval

Vegetated roofs shall also require acceptance from the Thurston County Fire Marshal to demonstrate adequate ventilation or ability to ventilate in cases of a fire. Other building permit requirements should be investigated by the applicant.

Hydrologic and Hydraulic Design Considerations

Flow Credit for Vegetated Roofs

Extensive roofs with 3 to 8 inches of growing media can be represented as 50 percent till landscaped area and 50 percent impervious area in the stormwater hydrologic model.

Intensive roofs with soil/growing media depth of greater than 8 inches can be modeled as 50 percent till pasture and 50 percent impervious area.

Design Criteria

A vegetated roof consists of a system in which several materials are layered to achieve the desired vegetative cover and drainage characteristics (see Figure 2.12).

Materials

Design components vary depending on the vegetated roof type and site constraints, but typically include a waterproof membrane, a drain system, a drainage layer, a separation fabric, a growth medium (soil), and vegetation.

Waterproof Membrane

Waterproof membranes are made of various materials, including reinforced polyvinyl chloride (PVC), synthetic rubber (EPDM), thermoplastic polyolefins, high-density polyethylene (HDPE), modified asphalts (bitumens), and hypalon (CPSE). Some waterproofing materials come in sheets or rolls and some are available in liquid form. Each material has different strengths and functional characteristics.

Root Barrier

To discourage root damage to the waterproofing membrane, a physical root barrier may be required. The need for a root barrier depends primarily on the particular waterproof membrane selected. Some waterproofing membranes have root barrier capabilities intrinsic to the material. Modified asphalts usually require a root barrier, while EPDM and reinforced PVC typically do not. The manufacturer must be consulted to determine whether a root barrier is recommended for a particular product.

During installation, treatment to prevent root penetration should not be restricted to parts of the roof that will be covered with vegetation, as the roots will extend beyond the areas in which vegetation shows at the surface. Care should be taken to fully treat the areas at joints, borders, and seams.

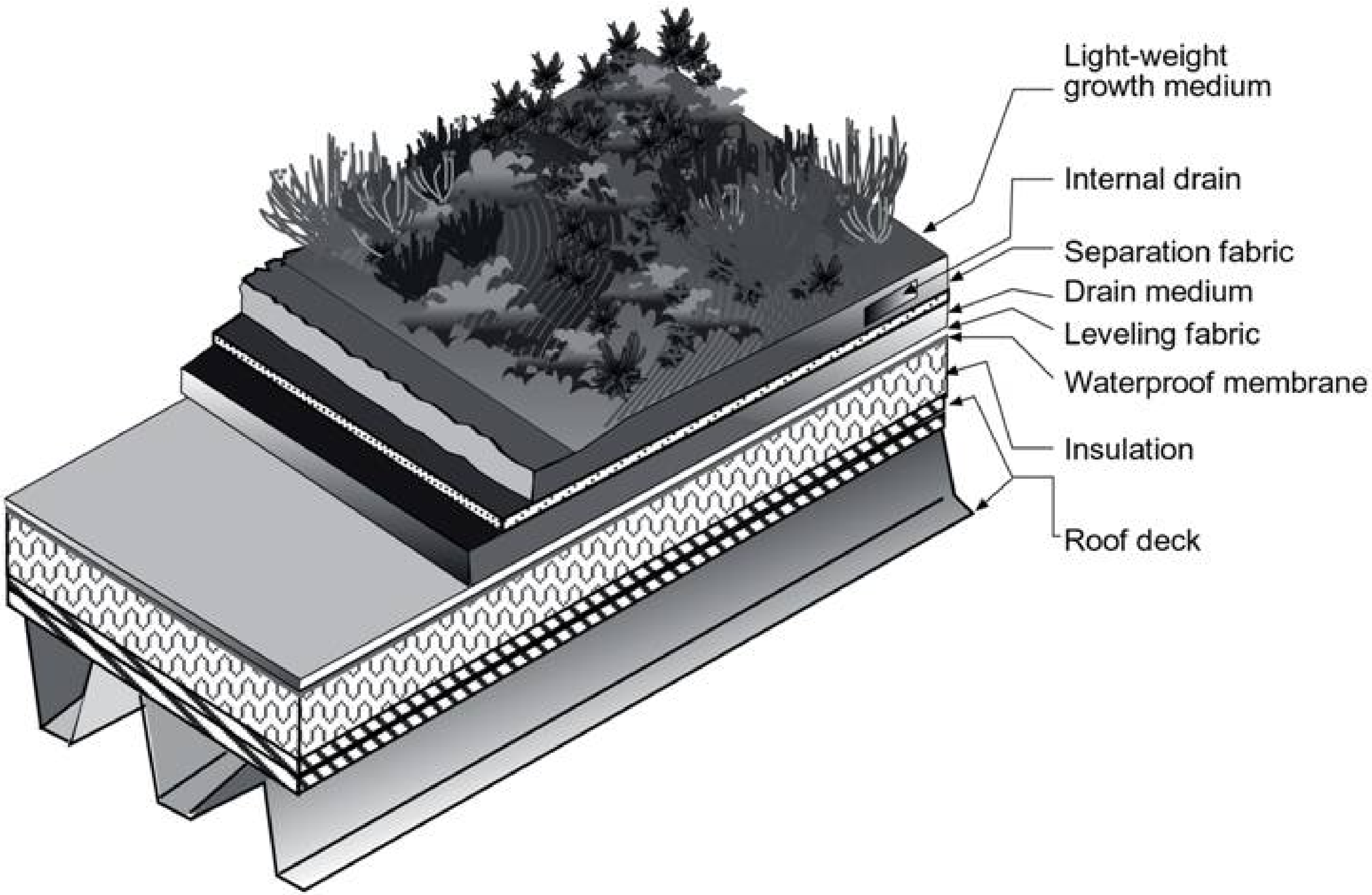


Figure 2.12. Vegetated Roof.

The root barrier shall not contain leachable water quality contaminants (e.g., herbicides, copper, and zinc), which have sometimes been used in the past to inhibit root growth. To demonstrate this, a material safety data sheet (MSDS) must be submitted.

Drainage Layer

For intensive and extensive multi-course vegetated roof systems, a drainage layer must underlie the growth medium. The drainage layer is a multipurpose layer designed to both provide void spaces to hold a portion of the water that passes through the growth medium, and to channel the water to the roof drain system.

The drainage layer can consist of a layer of aggregate or a manufactured mat or board that provides an open free-draining area. Many manufactured products include "egg carton"-shaped depressions that retain a portion of the water for eventual evapotranspiration. Some studies have shown that aggregate drainage layers may provide the better flow control.

For extensive single-course vegetated roofs larger than 1,000 square feet, hydraulic calculations shall be submitted showing that the transmissivity and permeability of the media are sufficient to convey the 25-year recurrence interval peak flow.

For aggregate drainage layers, the drainage media shall meet the following requirements:

- Minimum total pore volume of 25 percent by volume (per American Society for Testing and Materials [ASTM] E2399)
- Minimum saturated hydraulic conductivity of 0.3 centimeters per second, cm/s (per ASTM E2396-05)
- Maximum total organic matter of 1 percent by mass (per loss on ignition testing).

For optimal flow control, an aggregate drainage layer with a saturated hydraulic conductivity of less than 3.2 cm/s is recommended.

Separation Fabric

A nonwoven geotextile must be installed between the growth medium (soil) and the drainage layer to prevent fine soil and substrate components from being washed out of the growth medium into the drainage layer (note that this does not apply to single-course extensive vegetated roofs). The fabric must be pervious to allow water to percolate into the drainage layer.

If a manufactured drainage layer is used, the separation fabric is typically included.

The separation fabric shall be installed between the growth medium and the drainage layer and between the growth medium and all surrounding areas, roof edges, penetrations, and structures. The fabric also shall have average opening size sufficient to retain media.

Growth Medium

Vegetated roofs use a light-weight growth medium with adequate fertility and drainage capacity to support plants and allow infiltration and storage of water. Growth medium composition (fines content and water holding capacity) is the key to flow control performance.

The growth medium typically has a high ratio of mineral to organic material content and can be a mixture of various components including gravel, sand, compost, soil, or light weight aggregate material. Because of their excessive weight, particularly when wet, native soils are not acceptable substrates for vegetated roofs.

The growth medium must be a minimum of 4 inches deep, and shall have the following characteristics:

- Minimum total pore volume shall be 45 percent by volume for multi-course systems and 30 percent by volume for single-course systems (per ASTM E2399)

- Water capacity shall be no less than 25 percent for single-course systems, 35 percent for extensive (shallow) multi-course systems, and 45 percent for intensive (deep) multi-course systems (per ASTM E2399)

- Saturated hydraulic conductivity (permeability) should be between 0.01 and 0.85 cm/s for single-course systems and 0.002 and 0.02 cm/s for multi-course systems (per ASTM E2396-05)

- Minimum air content at maximum water capacity should be 5 percent by volume (per ASTM E2396-05), or 10 percent by volume (per FLL method)

- Maximum total maximum organic matter shall be 4 percent by mass for single-course systems, 6 percent by mass for extensive (shallow) multi-course systems, and 8 percent by mass for intensive (deep) multi-course systems (per loss on ignition testing).

Growth medium depth and characteristics must support growth for selected plant species.

Mulch, mat, or other measures to control erosion of growth media shall be maintained until 90 percent vegetation coverage is achieved.

Vegetation

Vegetation used on extensive vegetated roofs should be drought tolerant, self-sustaining, low maintenance, and perennial or self-sowing. Appropriate plants should also be able to withstand heat, cold, periodic inundation and high winds. Vegetation with these attributes typically includes succulents, grasses, herbs, and wildflowers that are adapted to harsh conditions.

Plants can be installed as vegetation mats, individual plugs, cuttings, or spread as seeds:

- *Vegetation mats* – vegetation mats are sod-like, pre-germinated mats that achieve immediate full plant coverage. They provide immediate erosion control, do not need mulch, provide the most rapid establishment for sedums, and minimize weed intrusion. They also need minimal maintenance during the establishment period and little ongoing watering and weeding.

- *Plugs or potted plants* – plugs or potted plants may provide more design flexibility than mats. However, they take longer to achieve full coverage, are more prone to erosion, need more watering during establishment, require mulching, and require more weeding. Birds sometimes pull out plugs, in which case netting may be needed until they are fully rooted.

- *Cuttings* – while cuttings may be used, they become established more slowly than mats and plugs and have a higher mortality rate.

- *Seeds* – seeds can be either hand broadcast or applied by hydroseeding. Seed plantings require more weeding, erosion control, and watering than mats and plugs.

In the long term, the generation of warm and cold air currents by rooftop heating and air-conditioning vents can cause frost and drought damage to plants. Exhaust gases such as sulfur dioxide or grease from chimneys and exhausts can result in direct damage to vegetation, depending on the species. Therefore, areas that are affected by warm air, variable air currents, and exhaust gasses need to be checked carefully to determine whether they are suitable areas for planting and to identify the type of vegetation that is best suited to the particular conditions. In addition, vegetation must be suitable for harsh (e.g., hot, cold, wet and windy) rooftop conditions.

An additional consideration is the effect of providing a vegetated roof habitat. Habitat may be enhanced by using diverse planting and including some larger plants. Some projects sites may not want to encourage wildlife (e.g., birds near air fields).

Plant spacing and plant size shall be designed by a certified landscape architect. Turf grasses are not recommended for vegetated roof application because of the dangers of longer grasses growth dying, drying out, and becoming a fire danger. Plants must not require fertilizer, pesticides, or herbicides after 2-year establishment period. Plans shall specify that vegetation coverage of selected plants shall achieve 90 percent coverage within 2 years or additional plantings shall be provided until this coverage requirement is met.

Drain System

Vegetated roof drainage facilities must be capable of collecting subsurface and surface drainage and conveying it safely to an approved discharge point. To facilitate subsurface drainage, interceptor drains are often installed at a 15 to 25 foot spacing to prevent excessive moisture build up in the media and convey water to the roof drain.

The roof outlets at vegetated roof sites must be protected from the invasion of plant growth and the entry of loose gravel, and they must be constructed and located so that they are permanently accessible.

Overflow grates tied into the roof downspouts shall be provided set at the height of the soil.

Structural Design Considerations

Extensive vegetated roofs have the lowest weight and are the most suitable for placement on existing structures.

Vegetated roofs must not be subject to any use that will significantly compact the growth medium. Unless designed for foot traffic, vegetated roof areas that are accessible to the public shall be protected (e.g., signs, railing, and fencing).

Construction and Maintenance

Irrigation Plan

Provisions must be made for supplemental irrigation during the first two dry seasons after installation to improve plant survival. Subsurface irrigation methods are preferred. If surface irrigation is the only method available, drip irrigation should be used to deliver water to the base of the plant. At a minimum, a water tap should be available on the roof for manual watering.

A permanent irrigation system using potable water may be used, but an alternative means of irrigation, such as air conditioning condensate or another readily available non-potable source should be considered to maximize efficient use of resources. Any non-potable sources must be analyzed to ensure that they do not contain chemicals that might harm or kill the vegetation. Any permanent irrigation system that relies on potable water shall be designed to apply no more than 0.2 inches of water every 14 days from June through September, after the 2-year establishment period. It is recommended that permanent irrigation systems have automatic controls, including a rain shutoff sensor.

Sufficient irrigation shall be provided to achieve and maintain 90 percent plant coverage after 2 years following installation.

Maintenance Criteria

Vegetated roofs are designed to need very little maintenance. They should also have a longer lifespan than traditional roofs because of the protective nature of the soil structure. Inspections still should be performed regularly to identify any leakage of the membrane system or blockages of the overflow system. A maintenance checklist is included in Appendix V-C and shall be included in the Maintenance Plan for the project.

2.2.8 LID.11 Full Dispersion

Purpose and Definition

This BMP allows for "fully dispersing" runoff from impervious surfaces and cleared areas of development sites that preserve the equivalent of at least 65 percent of the site (or a threshold discharge area on the site) in a forest or native condition.

Fully dispersed runoff from impervious surfaces means that the area is "ineffective." Ineffective impervious areas are included in the Total Impervious Area thresholds when determining applicable Minimum Requirements, but are not included in the thresholds specific to the applicability of Minimum Requirement #6 (Runoff Treatment), and Minimum Requirement #7 (Flow Control).

Applicability

Full dispersion differs from other LID BMPs described previously in that if minimum native area preservation is adhered to, the limitations on how impervious surfaces are modeled and how concentrated flow can be dispersed are less restrictive. Additionally, if the minimum native area preservation requirements are met, on-site landscape area soils are not required to meet the minimum requirements of BMP LID.02 (Post-Construction Soil Quality and Depth) except as noted in the table below for landscape area equaling or exceeding 50 percent of the site on till soils.

Full dispersion would be most applicable to developments that desire to or can retain large portions of the site in native conditions such as for critical area buffers, or that concentrate development in a smaller area of a larger site to obtain some benefit from zoning codes (PRRD, Cluster Development, PRD, etc.).

Full dispersion can be used as long as the developed areas draining to the native vegetation do not have effective impervious surfaces that exceed 10 percent of the entire site.

Rural single family residential developments should use this BMP wherever possible to minimize effective impervious surface to less than 10 percent of the development site.

Other types of development that retain 65 percent of the site (or a threshold discharge area on the site) in a forested or native condition may also use this BMP to avoid triggering the flow control facility requirement.

Full Dispersion for All or Part of the Development Site

Developments that cannot preserve 65 percent or more of the site in a forested or native condition may disperse runoff into a forested or native area in accordance with the elements of this BMP if:

- The effective impervious surface of the area draining into the native vegetation area is <10 percent; and
- The development maintains ratios proportional to the 65 percent forested or native condition and 10 percent effective impervious surface area. Examples of such ratios are:

% Native Vegetation Preserved (min. allowed)	% Effective Impervious (max allowed)	% Lawn/Landscape (max allowed)
65	10	35
60	9	40
55	8.5	45
50	8	50*
45	7	55*
40	6	60*
35	5.5	65*

* Where lawn/landscape areas are established on till soils, and exceed 50 percent of the total site, they shall be developed using BMP LID.02 (Post-Construction Soil Quality and Depth).

Within the context of full dispersion for all or part of the development site the only impervious surfaces that are ineffective are those that are routed into an appropriately sized dry well or into an infiltration basin that meets the flow control standard and does not overflow into the forested or native vegetation area.

Limitations

Runoff must be dispersed into native areas per the guidelines and limitations indicated in this BMP.

Additional impervious areas are allowed that exceed the 10 percent threshold, but should not drain to the native vegetation area and are subject to the thresholds, and treatment and flow control requirements of the stormwater manual.

Native vegetation areas must be protected from future development. Protection must be provided through legal documents on record with the local government. Examples of adequate documentation include a conservation easement, conservation parcel, and deed restriction.

All trees within the preserved area at the time of permit application shall be retained, aside from approved timber harvest activities and the removal of dangerous or diseased trees. Removal of dangerous or diseased trees will require acceptance of Thurston County and may require an arborist to make a written assessment of the trees condition.

The preserved area may be used for passive recreation and related facilities, including pedestrian and bicycle trails, nature viewing areas, fishing and camping areas, and other similar activities that do not require permanent structures, provided that cleared areas and areas of compacted soil associated with these areas and facilities do not exceed eight percent of the preserved area.

Design Guidelines

Roof Downspouts

- Roof surfaces that comply with the downspout infiltration requirements of BMP LID.04 are considered to be "fully dispersed" (i.e., 0 percent effective imperviousness).
- All other roof surfaces are considered to be "fully dispersed" only if they are within a threshold discharge area that is or will be more than 65 percent forested (or native vegetative cover) and less than 10 percent effective impervious surface, and if they comply with the downspout dispersion requirements of BMP LID.05, and have vegetated flow paths through native vegetation exceeding 100 feet.

Driveway Dispersion

- Driveway surfaces are considered to be "fully dispersed" if they are within a threshold discharge area that is or will be more than 65 percent forested (or native vegetative cover) and less than 10 percent effective impervious surface, and if they comply with the dispersion BMPs – BMP LID.06 and BMP LID.07 — and have flow paths through native vegetation exceeding 100 feet.
- This also holds true for any driveway surfaces that comply with the roadway dispersion BMPs described below.

Roadway Dispersion BMPs

Roadway surfaces are considered to be "fully dispersed" if they are within a threshold discharge area that is or will be more than 65 percent forested (or native vegetative cover) and less than 10 percent effective impervious surface, and if they comply with the following dispersion requirements:

- Roadway runoff dispersion is allowed only on rural neighborhood collectors and local access streets. To the extent feasible, disperse driveways to the same standards as roadways to ensure adequate water quality protection of downstream resources.

- Design the road section to minimize collection and concentration of roadway runoff. Use sheet flow over roadway fill slopes (i.e., where roadway subgrade is above adjacent right-of-way) wherever possible to avoid concentration.

- When it is necessary to collect and concentrate runoff from the roadway and adjacent upstream areas (e.g., in a ditch on a cut slope), concentrated flows shall be incrementally discharged from the ditch via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows shall not exceed 0.5 cfs at any one discharge point from a ditch for the 100-year runoff event (using approved continuous simulation model).

- Where flows at a particular ditch discharge point were already concentrated under existing site conditions (e.g., in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.

- Ditch discharge points with up to 0.2 cfs discharge for the peak 100-year flow shall use rock pads or dispersion trenches to disperse flows. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use only dispersion trenches to disperse flows.

- Dispersion trenches shall be designed to accept storm flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flow path, and shall be minimum 2’ x 2’ in section, 50 feet in length, filled with 3/4-inch to 1-1/2-inch washed rock, and provided with a level notched anchor plate flow spreader (see Figure A-12 in Appendix V-A). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to four trenches. Dispersion trenches shall have a minimum spacing of 50 feet.

- After being dispersed with rock pads or trenches, flows from ditch discharge points must traverse a minimum of 100 feet of undisturbed native vegetation before leaving the project site, or entering an existing onsite channel carrying existing concentrated flows across the road alignment.

- Flow paths from adjacent discharge points must not intersect within the 100-foot flow path lengths, and dispersed flow from a discharge point must not be intercepted by another discharge point. To enhance the flow control and water quality effects of dispersion, the flow path shall not exceed 15 percent slope, and shall be located within designated open space.

- Ditch discharge points shall be located a minimum of 100 feet upgradient of slopes steeper than 40 percent, wetlands, and streams.

- Where the County determines there is a potential for significant adverse impacts downstream (e.g., erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

Cleared Area Dispersion BMPs

The runoff from cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture is considered to be "fully dispersed" if it is dispersed through at least 25 feet of native vegetation in accordance with the following criteria:

- The contributing flow path of cleared area being dispersed must be no more than 150 feet.

- Slopes within the 25-foot minimum flow path through native vegetation shall be no steeper than 8 percent. If this criterion cannot be met due to site constraints, the 25-foot flow path length must be increased 1.5 feet for each percent increase in slope above 8 percent.

2.2.9 LID.12 Rural Road Natural Dispersion

Natural dispersion is related to sheet flow dispersion (BMP LID.06) and channelized dispersion (BMP LID.07), but only applies to linear projects such as roads, bicycle paths, etc. in rural areas that meet certain criteria. This BMP is derived from the WSDOT's *Highway Runoff Manual* and is principally for use outside of the NPDES Phase II permit boundary and Urban Growth Areas of Thurston County.

Rural road natural dispersion meets Minimum Requirement #5 (On-site Stormwater Management), basic and enhanced treatment targets of Minimum Requirement #6 (Runoff Treatment), and Minimum Requirement #7 (Flow Control).

Introduction

Natural dispersion uses existing vegetation, soils, and topography to effectively provide flow control and runoff treatment. In this way it differs from BMP LID.06 and LID.07 which allow dispersion to native vegetation areas for treatment, but may still require flow control facilities further downstream.

Natural dispersion generally requires little or no construction activity. Site selection is important to the success of this BMP. The pollutant-removal processes include infiltration into the existing soils and through vegetation root zones; evaporation; and uptake and transpiration by the vegetation.

The key to natural dispersion is that flows from the impervious area enter the natural dispersion area as sheet flow. Because stormwater enters the dispersion area as sheet flow, it only needs to traverse a narrow band of contiguous vegetation for effective attenuation and treatment. The goal is to have the flows dispersed into the surrounding landscape such that there is a low probability any surface runoff will reach a flowing body of water.

There are two types of natural dispersion: sheet flow dispersion and channelized dispersion. Sheet flow natural dispersion takes advantage of unconcentrated roadside discharge, while channelized natural dispersion requires dispersal BMPs to create sheet flow conditions.

Using natural dispersion on projects will result in benefits when determining applicable minimum requirements and thresholds. New impervious surfaces that drain to dispersion areas should be accounted for when determining the project's total new impervious surface area, but the area should be counted as noneffective impervious surface (and noneffective PGIS). When modeling the hydrology of the project site and threshold discharge area, the project engineer should treat natural dispersion areas and their tributary drainage areas as disconnected from the project site because they do not contribute flow to other flow control or runoff treatment BMPs.

Applicability

- Only allowed for roadway and linear projects such as bicycle paths, trails, utility projects in the rural areas of Thurston County (outside UGA's and NPDES Phase II permit boundary). Examples include large lot or short plat access roads through large lot subdivisions and short plats, County or private road widening projects and new construction.

- Existing topography, soils and vegetation must be conducive to dispersion (see Design Criteria below).

- Natural dispersion helps maintain the temperature norms of stormwater because it promotes infiltration, evaporation, and transpiration and should not have a surface discharge to a lake or stream.

Limitations

- The effectiveness of natural dispersion relies on maintaining sheet flow to the dispersion area, which maximizes soil and vegetation contact and prevents short-circuiting due to channelized flow. If sheet flow cannot be maintained, natural dispersion will not be effective.

- Natural dispersion areas must be protected from future development. For public projects, purchase of additional right-of-way or easements may be required to satisfy the criteria for natural dispersion areas. For private projects, dedicated tracts or easements are required to protect natural dispersion areas.

- Natural dispersion areas initially may cost as much as other constructed BMPs because rights-of-way or easements often need to be purchased, but long-term maintenance costs are lower. These natural areas will also contribute to the preservation of native habitat and provide visual buffering of the roadway.

- Floodplains are not suitable areas for natural dispersion.

The following area additional limitations for site where runoff is channelized upstream of the dispersion area:

- The channelized flow must be redispersed before entering the natural dispersion area. Flow dispersal trenches (see Section 3.2 of Volume III) must be used to create sheet flow conditions.

- Energy dissipaters in conjunction with flow dispersal trench may be needed to prevent high velocities through the natural dispersion areas.
- Channelized flows are limited to on-site flows. Parallel conveyance systems may be needed to separate off-site flows.

Submittals and Approvals

Include in the submittals required in Volume I the following:

- Calculations demonstrating the flows for the 100-year storm meet the criteria of this BMP
- Documentation of easements, tracts or other protective mechanisms for the dispersion area
- Identify the location of signage and fencing required to protect the dispersion area from future disturbance/development
- Details of dispersion pads, energy dissipators, level spreaders, etc. necessary to construction the project
- Identify on a site plan the contributing areas, point of dispersion and dispersion areas
- Geotechnical information documenting the underlying soils type and infiltration rate for the dispersion area
- Show the location of wells, drainfields, steep slopes and how the design meets the setback criteria for this BMP
- Include in the Soils Management Plan prepared per BMP LID.02 the location of the dispersion area and any planting or soils enhancement required.

Hydrologic and Hydraulic Design Considerations

Those pollution and non-pollution generating impervious surfaces that are dispersed according to this BMP are considered non-effective impervious surface. They are counted in the total impervious area when applying minimum requirements (Volume I, Section 2.3), but not towards the individual thresholds of Minimum Requirement #6 (Runoff Treatment) or Minimum Requirement #7 (Flow Control).

The size of the natural dispersion area depends on the flow contributing area and the predicted rates of water loss through the dispersion system.

The designer should ensure the dispersion area is sufficient to dispose the runoff through infiltration, evaporation, transpiration, and soil absorption.

Design Criteria

Sheet Flow

Sheet flow dispersion criteria for natural dispersion areas are as follows:

- The sheet flow path leading to the natural dispersion area shall not be longer than 150 feet. The sheet flow path is measured in the direction of flow and generally represents the width of the pavement area.
- Pervious shoulders and side slopes are not counted in determining the sheet flow path.
- The longitudinal length of the dispersion area should be equivalent to the longitudinal length of roadway that is contributing sheet flow.
- The longitudinal pavement slope (i.e., centerline grade) contributing flow to a dispersion area shall be less than 5 percent. The lateral pavement slope (i.e., crown or superelevation) shall be less than 8 percent.
- Roadway side slopes leading to natural dispersion areas should be 25 percent (4H:1V) or flatter. Slopes steeper than 25 percent are allowed if the existing side slopes are well vegetated and show no signs of erosion problems.
- For any existing slope that will lead to a natural dispersion area, if evidence of channelized flow (rills or gullies) is present, a flow spreading device should be used before those flows are allowed to enter the dispersion area.

Sheet flow dispersion areas are sized based on soil characteristics of the dispersion area as follows:

For sheet flow dispersion on all Type A and some Type B soils (depending on saturated hydraulic conductivity rates):

- For short-term infiltration rates (as determined in Volume III) of 4 inches per hour or greater and for the first 20 feet (along the sheet flow path) of impervious surface that drains to the dispersion area, there must be 10 lateral feet of dispersion area width. For each additional foot of impervious surface (along the sheet flow path) that drains to the dispersion area, 0.25 lateral feet of dispersion area shall be provided.

- For dispersion areas that receive sheet flow from only disturbed pervious areas (bare soil and non-native landscaping), for every 6 feet (along the sheet flow path) of disturbed pervious area, 1 lateral foot width of dispersion area is required.

The following criteria are specific to sheet flow dispersion on all Type C and D soils and some Type B soils with short-term infiltration rates of 4 inches per hour or less:

- For every 1 foot of contributing pavement width, a dispersion area width of 6.5 feet is needed.

- The dispersion area shall have a minimum width of native vegetation of 100 feet (measured in the direction of the flow path).

Figure 2.13 illustrates the configuration of a typical natural dispersion area relative to the roadway.

Channelized Flow

Channelized flow dispersion criteria for Type A, B, C, and D soils are as follows:

- Concentrated runoff from the roadway and adjacent upstream areas (such as in a ditch or cut slope) must be incrementally discharged from the conveyance system (such as a ditch, gutter, or storm sewer) via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows must not exceed 0.5 cubic feet per second (cfs) at any single discharge point from the conveyance system for the 100-year runoff event (determined by an approved continuous flow model). Where flows at a particular discharge point are already concentrated under existing site conditions (for example, in a natural channel that cross the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.

- Discharge points with up to 0.2 cfs discharge for the peak 100-year flow may use rock pads or dispersion trenches to disperse flows. Discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow must use only dispersion trenches to disperse flows.

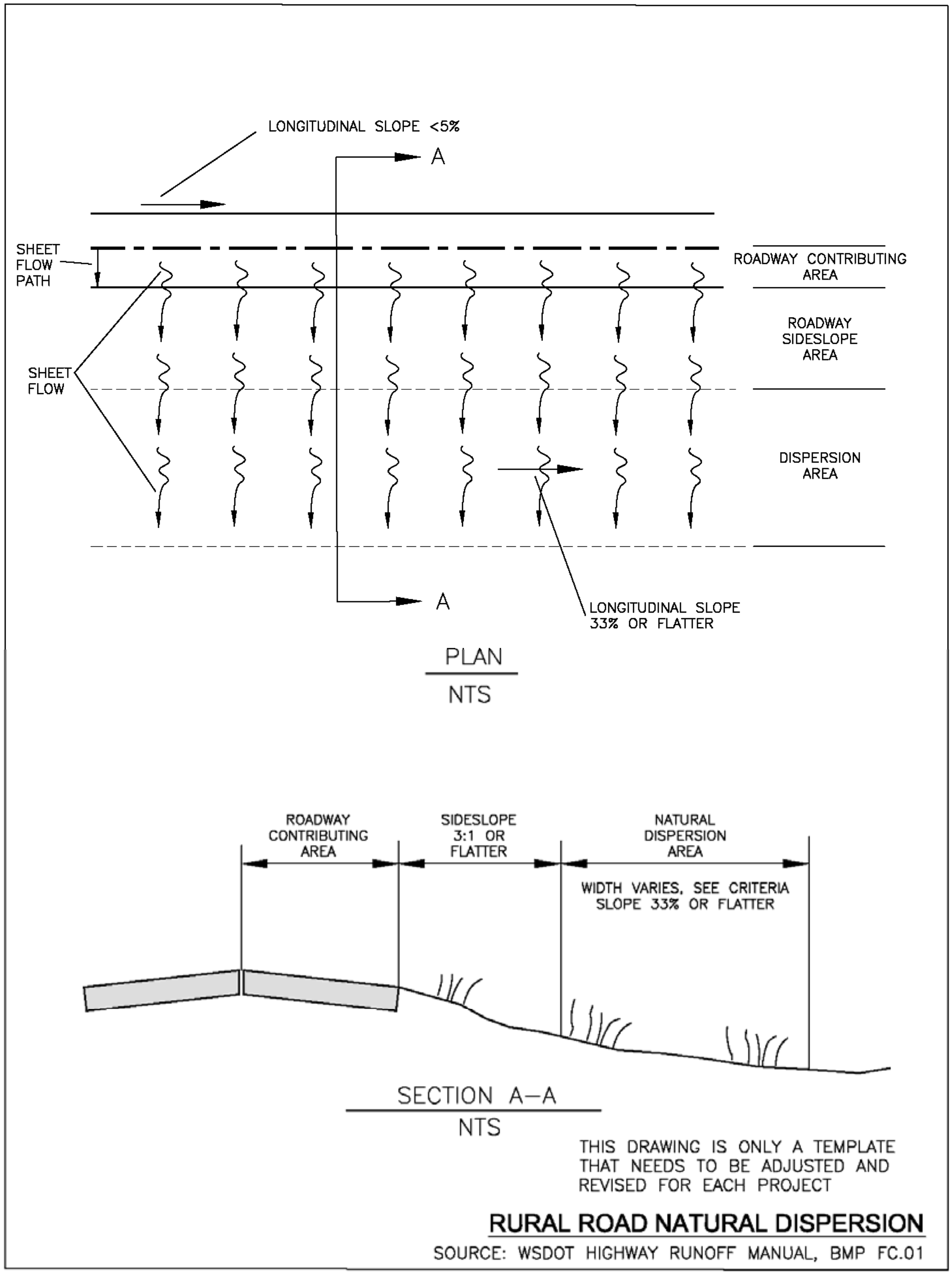


Figure 2.13. Natural Dispersion.

- Dispersion trenches must be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end; aligned perpendicular to the flow path; a minimum of 2' x 2' in section; 50 feet in length; filled with 3/4 to 1-1/2 inch washed rock; and provided with a level notched grade board (see Figure 3.4, Flow Dispersal Trench, in Volume III). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between four trenches (maximum). Dispersion trenches must have a minimum spacing of 50 feet.

- After being dispersed with rock pads or trenches, flows from discharge points must traverse the required flow path length of the dispersion area before entering an existing on-site channel carrying existing concentrated flows away from the roadway alignment.

  Note: to provide the required flow path length to an existing channel, some roadway runoff may unavoidably enter the channel undispersed.

- Flow paths from adjacent discharge points must not intersection within the required flow path lengths, and dispersed flow from a discharge point must not be intercepted by another discharge point.

- Ditch discharge points must be located a minimum of 100 feet upgradient of slopes steeper than 40 percent within a vertical change of at least 10 feet, wetlands, and streams.

- Where the County determines that there is a potential for significant adverse impacts downstream (such as erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

The following criterion is specific to channelized flow dispersion on all Type A and some Type B soils, depending on infiltration rates.

- For short-term infiltration rates (as determined in Volume III) of 4 inches per hour or greater, the dispersion area should be at least 50 percent of the tributary drainage area.

The following criteria are specific to channelized dispersion on all Type C and D soils and on Type B soils with short-term infiltration rates less than 4 inches per hour:

- For every 1 foot of contributing pavement width, a dispersion area width of 6.5 feet is needed.

- The dispersion area shall have a minimum width of native vegetation of 100 feet, measured in the direction of the flow path.

Pipe or Ditch Conveyance System

Flows collected in a pipe or ditch conveyance system require energy dissipation and dispersal at the end of the conveyance system before entering the dispersion area. For flow dispersal and energy dissipation BMPs and techniques, see Section 3.8 of Volume III.

Site Design Elements

The key to natural dispersion is having vegetative land cover with a good established root zone where the roots, organic matter, and soil macroorganisms provide macropores to reduce surface compaction and prevent soil pore sealing. The vegetative cover also provides filtration and maintains sheet flow, reducing the chance for erosion. The following areas are considered appropriate candidates for natural dispersion because they are likely to retain these vegetative conditions over the long term:

- County right-of-way (for County projects only)
- Protected natural areas (critical area buffers, green belts, etc.)
- Dedicated tracts in plats for native vegetation protection
- Agricultural areas
- Parks and nature areas
- Commercial or government-owned forest lands
- Rural areas with zoned densities of less than one dwelling unit per 5 acres.

While these are generally appropriate areas for natural dispersion, the dispersion area shall still be protected from future development by an easement or dedicated tract. **Note:** Though natural dispersion areas should be adjacent to the project site, they do not have to be immediately adjacent to the length of the roadway.

Natural dispersion area shall have the following attributes:

- Be well vegetated with established root zones
- Have an average longitudinal slopes of 6H:1V or flatter

- Have an average lateral slope of 6H:1V or flatter for both the roadway side slopes and natural area to be part of the natural dispersion area
- Have infiltrative soil properties that are verified by a soils professional per Volume III methods.

Natural dispersion areas that have impervious areas (for example, abandoned roads with compacted subgrades) within them shall have those areas tilled and restored using the soil amendments and plantings per BMP LID.01 (Restoring Natural Vegetation).

Natural dispersion areas that are within a landslide hazard area must be evaluated by a geotechnical engineer or qualified geologist.

Natural dispersion areas shall have a separation of at least2 feet between the existing ground elevation and the average annual maximum groundwater elevation. This separation depth requirement applies to the entire limits of the dispersion area. There should be no discernible continuous surface flow paths through the dispersion area.

Intent: Natural dispersion areas are not likely to have a uniform slope across their entire area. As a result, there are ponding areas and uneven terrain. Minor channelization of flow within the dispersion area is expected. However, a continuous flow path through the entire dispersion area disqualifies its use as a BMP because channelized flow promotes erosion of the channel that carries the flow and greatly reduces the potential for effective pollutant removal and peak flow attenuation.

When selecting natural dispersion areas, determine whether there are groundwater management plans for the area and contact the local water purveyors to determine whether the project lies within a designated wellhead protection area or groundwater protection zone, septic drain fields, or aquifer recharge area. There may be additional restrictions within these areas.

Setback Requirements

- Natural dispersion areas can extend beyond the right-of-way provided that documentation ensures (via easements or dedicated tracts) the dispersion area is not developed in the future. Occasionally for public roadway projects, limited right-of-way prevents the securing of the required easements on adjacent properties and limits the ability to construct flow control facilities. In this particular case, the dispersion area can be considered protected if the adjacent land is zoned agricultural, forestry, or rural residential (5-acre parcels or greater). An attempt to obtain a drainage easement for this circumstance should still be made.

- Natural dispersion areas shall be setback at least 100 feet from drinking water wells and springs used for public drinking water supplies. Natural dispersion areas upgradient of drinking water supplies and within the 1-, 5-, and 10-year time of travel zones for a public water system must comply with the Washington State Department of Health (DOH) requirements.

- Natural dispersion areas shall be setback at least 100 feet from septic drainfields. The 100-foot setback is in addition to the required dispersion area. For example if there is a 100-foot width dispersion area, there would be an additional 100-foot setback making a total of 200 feet from the point of discharge of water to the dispersion area to the drainfield area. If the applicant can demonstrate that the dispersion flow path will not intercept the drainfield, this setback requirement may be relaxed.

- If the project significantly increases flows to off-site properties, a drainage easement may be required or additional right-of-way purchased.

Signage

- The limits of natural dispersion area shall be marked as a stormwater management facility and also shall be physically marked in the field during and after construction. Signage ensures the natural dispersion area is protected from construction activity disturbance and is adequately protected by measures shown in the temporary erosion and sedimentation control (TESC) plan.

- Signage helps ensure the natural dispersion area is not cleared or disturbed after the construction project.

- Signage shall be posted at a minimum on all four sides of the dispersion area and at intervals not exceeding 75 feet.

- See Appendix V-E for sign specifications.

Construction Considerations

- For installation of dispersal BMPs and conveyance systems near dispersion areas, the area that needs to be cleared or grubbed should be minimized. Maintaining plant root systems is important for dispersion areas.

- The area around dispersion areas should not be compacted.

- To the maximum extent practicable, low-ground-pressure vehicles and equipment should be used during construction.

Maintenance

- Maintenance of natural dispersion areas includes maintaining natural vegetation or restoring natural vegetation disturbed after construction.
- Signage and fencing shall be inspected and restored /replaced as required.
- Ensure that sheet flow paths are maintained to the dispersion areas, perform hand maintenance to ensure sheet flow.
- Maintain energy dissipators and level spreaders. Cleanout any structures associated with these devices and inspect spreaders to ensure they are functioning correctly. Remove buildup of soil/debris over the surface of level spreader as required to maintain its function.

2.2.10 LID.13 Rural Road Engineered Dispersion

Engineered dispersion is related to Sheet Flow Dispersion (BMP LID.06) and Concentrated Flow Dispersion (BMP LID.07) but only applies to linear projects such as roads, bicycle paths, etc. in rural areas that meet certain criteria. This BMP is derived from the WSDOT's Highway Runoff Manual and is principally for use outside of the NPDES Phase II Permit boundary and Urban Growth Areas of Thurston County.

Engineered dispersion is similar to natural dispersion (BMP LID.13). The distinction between these BMPs is that natural dispersion can take advantage of an existing vegetated area for dispersion, while this dispersion area must be at least partially constructed. This BMP can be used for impervious surfaces that are graded to drain via sheet flow or are graded to collect and convey stormwater to engineered dispersion areas after going through a flow spreading or energy dissipater device. Engineered dispersion uses the existing vegetation or landscaped areas, existing soils or engineered compost-amended soils, and topography to effectively provide flow control and runoff treatment. This type of dispersion may require major or minor construction activity depending on the existing site conditions. Site selection is very important to the success of this BMP. The pollutant-removal processes include infiltration to the existing or engineered soils and through vegetation root zones; evaporation; and uptake and transpiration by the existing vegetation or landscaped areas.

The key to effective engineered dispersion is that flows from the impervious area enter the dispersion area as sheet flow. Because stormwater enters as sheet flows to the dispersion area, it need only traverse a band of contiguous vegetation and compost-amended soils for effective attenuation and treatment. Absorption capacity can be gained by using compost-amended soils to disperse and absorb contributing flows to the dispersion area. The goal is to have the flows dispersed into the surrounding landscape such that there is a low probability that surface runoff will reach a flowing body of water.

Rural road engineered dispersion meets Minimum Requirement #5 (On-site Stormwater Management), basic and enhanced treatment targets of Minimum Requirement #6 (Runoff Treatment), and Minimum Requirement #7 (Flow Control).

Applicability

- Engineered dispersion is ideal for roadway and other linear projects that collect and convey stormwater to discrete discharge points along the project.

- Engineered dispersion maintains temperature norms of stormwater because it promotes infiltration, evaporation, and transpiration and should not have a surface discharge to a lake or stream.

Limitations

- The effectiveness of engineered dispersion relies on maintaining sheet flow to the dispersion area, which maximizes soil and vegetation contact and prevents short-circuiting due to channelized flow. If sheet flow cannot be maintained, engineered dispersion will not be effective.

- Dispersion areas must be protected from future development. For Public projects, purchase of additional right-of-way or easements may be required. For private projects, dedicated tracts or easements are required to protect engineered dispersion areas.

- Engineered dispersion areas may cost as much as other BMPs because right of way or easements often need to be purchased and compost-amended soils may need to be added. But long-term maintenance costs are lower.

- Floodplains are not suitable areas for engineered dispersion.

Submittals and Approvals

Include in the submittals required in Volume I the following:

- Calculations demonstrating the flows for the 100-year storm meet the criteria of this BMP

- Documentation of easements, tracts or other protective mechanisms for the dispersion area.

- Identify the location of signage and fencing required to protect the dispersion area from future disturbance/development

- Details of dispersion pads, energy dissipators, level spreaders, etc. necessary to construction the project

- Identify on a site plan the contributing areas, point of dispersion and dispersion areas

- Geotechnical information documenting the underlying soils type and infiltration rate for the dispersion area

- Show the location of wells, drainfields, steep slopes and how the design meets the setback criteria for this BMP

- Show areas of engineered dispersion on the Soil Management Plan required as part of BMP LID.02. Include specifications for the soil mix and a planting plan.

Hydrologic and Hydraulic Design Considerations

The required size of the engineered dispersion area depends on the area contributing flow and the predicted rates of water loss through the dispersion system. The designer should ensure the dispersion area is able to dispose of (through infiltration, evaporation, transpiration, and soil absorption) stormwater flows predicted by an approved continuous runoff model.

Because a water balance model has not be developed for designing engineered dispersion areas, a set of conservative guidelines similar to those given for natural dispersion have been agreed upon with Ecology (WSDOT 2008). Updates to the engineered dispersion criteria may occur and the project engineer should check with the Administrator to determine if additional criteria have been implemented.

Design Criteria

Geometry

- The average longitudinal slope of the dispersion area shall not exceed 6H:1V.
- The average lateral slope of the dispersion area shall not exceed 6H:1V.
- There should be no discernible flow paths through the dispersion area. A channel or flow path may short circuit the flows and reduce treatment and infiltration ability.
- There should be no surface water discharge from the dispersion area to a conveyance system or Category I or II wetlands (as defined by Ecology's Wetland Rating Systems for western Washington).

Sizing Criteria

Figure 2.14 illustrates a typical engineered dispersion area relative to the adjacent roadway.

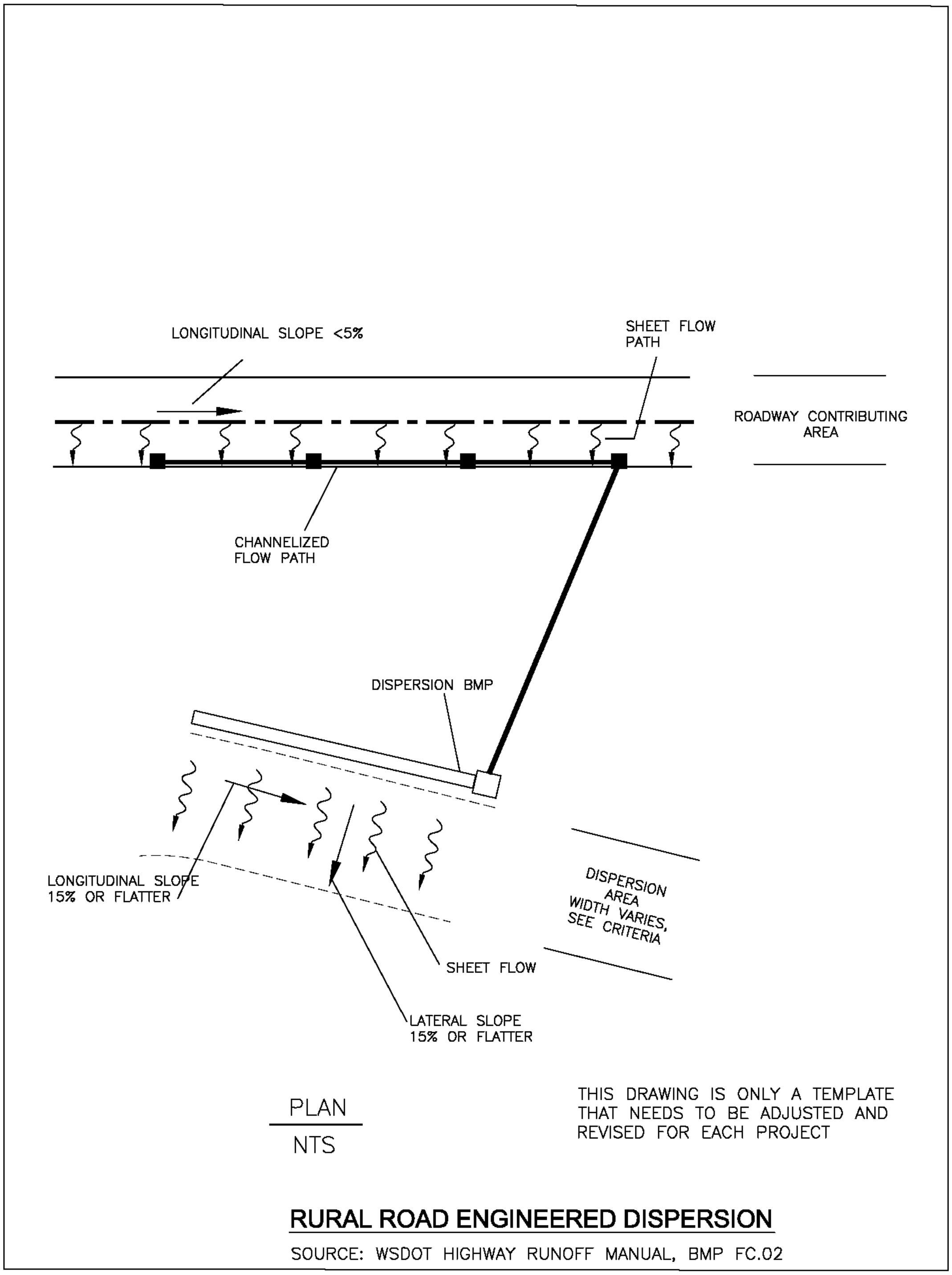


Figure 2.14. Engineered Dispersion.

Sheet Flow Dispersion

Sheet flow dispersion criteria for Type A, B, C, and D soils are as follows:

- The sheet flow path leading to the engineered dispersion area shall not be longer than 150 feet. The sheet flow path is measured in the direction of flow and generally represents the width of the pavement area.
- Pervious shoulders and side slopes are not counted in determining the sheet flow path.
- The longitudinal length of the dispersion area shall be equivalent to the longitudinal length of the roadway that is contributing sheet flow.
- Roadway side slopes leading to engineered dispersion areas should be 25 percent (4H:1V) or flatter. Roadway side slopes that are 25 percent to 15 percent (7H:1V) should not be considered part of the dispersion area. Slopes steeper than 25 percent are allowed if the existing side slopes are well vegetated and show no signs of erosion problems. For any existing slope that will lead to an engineered dispersion area, if evidence of channelized flow (rills or gullies) is present, a flow-spreading device should be used before those flows are allowed to enter the dispersion area.
- Roadway side slopes that are 15 percent or flatter are considered part of the dispersion area if engineered dispersion practices are applied to the slope (6.5 feet of compost amended side slope width mitigates for 1 foot of impervious surface). The use of natural or engineered dispersion concepts within one threshold discharge area is acceptable.

The following criteria are specific to sheet flow dispersion on all Type A and some Type B soils, depending on infiltration rates:

- For short-term infiltration rates of 4 inches per hour or greater, and for the first 20 feet (along the sheet flow path) of impervious surface that drains to the dispersion area, there must be 10 lateral feet of dispersion area width. For each additional foot of impervious surface (along the sheet flow path) that drains to the dispersion area, 0.25 lateral feet of dispersion area shall be provided.
- For dispersion areas that receive sheet flow only from disturbed pervious areas (bare soil and non-native landscaping), for every

6 feet (along the sheet flow path) of disturbed pervious area, 1 lateral food width of dispersion area is required.

The following criteria are specific to sheet flow dispersion on all Type C and D soils and Type B soils with a short-term infiltration rate less than 4 inches per hour:

- For every 1 foot of contributing pavement width, a dispersion area width of 6.5 feet is needed.
- The dispersion area shall have a minimum width of 100 feet, measured in the direction of the flow path.

Channelized Flow Dispersion

Channelized flow dispersion criteria for Type A, B, C, and D soils are as follows:

- Concentrated runoff from the roadway and adjacent upstream areas (such as in a ditch or cut slope) must be incrementally discharged from the conveyance system (such as a ditch, gutter, or storm sewer) via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows must not exceed 0.5 cubic feet per second (cfs) at any single discharge point from the conveyance system for the 100-year runoff event (determined by an approved continuous flow model). Where flows at a particular discharge point are already concentrated under existing site conditions (for example, in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.
- Discharge points with up to 0.2 cfs discharge for the peak 100-year flow may use rock pads or dispersion trenches to disperse flows. Discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow must use only dispersion trenches to disperse flows.
- Dispersion trenches must be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end; aligned perpendicular to the flow path; a minimum of 2' x 2' in section; 50 feet in length; filled with 3/4 to 1-1/2 inch washed rock; and provided with a level notched grade board (see Figure 3.4, Flow Dispersal Trench, in Volume III). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between four trenches (maximum). Dispersion trenches must have a minimum spacing of 50 feet.

- After being dispersed with rock pads or trenches, flows from discharge points must traverse the required flow path length of the dispersion area before entering an existing on-site channel carrying existing concentrated flows away from the roadway alignment.

  Note: To provide the required flow path length to an existing channel, some roadway runoff may unavoidably enter the channel undispersed.

- Flow paths from adjacent discharge points must not intersection within the required flow path lengths, and dispersed flow from a discharge point must not be intercepted by another discharge point.

- Discharge points must be located a minimum of 100 feet upgradient of slopes steeper than 40 percent within a vertical change of at least 10 feet, wetlands, and streams.

- Where the County determines that there is a potential for significant adverse impacts downstream (such as erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

The following criterion is specific to channelized flow dispersion on all Type A and some Type B soils, depending on infiltration rates.

- For short-term infiltration rates (as determined in Volume III) of 4 inches per hour or greater, and for the first 20 feet (along the sheet flow path) of impervious surface that drains to the dispersion area, there must be 10 lateral feet of dispersion area width. For each additional foot of impervious surface (along the sheet flow path) that drains to the dispersion area, 0.25 lateral feet of dispersion area shall be provided.

The following criteria are specific to channelized flow dispersion on all Type C and D soils and Type B soils with a short-term infiltration rate less than 4 inches per hour:

- For every 1 foot of contributing pavement width, a dispersion area width of 6.5 feet is needed.

- The dispersion area shall have a minimum width of native vegetation of 100 feet, measured in the direction of the flow path.

Pipe or Ditch Conveyance System

Flows collected in a pipe or ditch conveyance system require energy dissipation and dispersal at the end of the conveyance system before entering the dispersion area. For flow dispersal BMPs, see Section 3.8 of Volume III.

Materials

Soils in engineered dispersion areas must meet the requirements of BMP LID.02 (Post-Construction Soil Quality and Depth).

Site Design Elements

The following areas are appropriate engineered dispersion areas because they are likely to remain in their existing condition over the long term:

- County right-of-way (for County projects only).
- Protected beautification areas and landscape areas.
- Agricultural areas.
- Parks and nature areas.
- Commercial or government-owned forest lands.
- Rural areas with zoned densities of less than one dwelling unit per 5 acres.

Engineered dispersion areas shall have infiltrative soil properties that are verified by the geotechnical professional using the methods described in Volume III.

Engineered dispersion areas that have impervious areas (for example, abandoned roads with compacted subgrades) within them shall have those areas tilled and reverted using the soil amendments per BMP LID.02 (Post-Construction Soil Quality and Depth).

Engineered dispersion areas that are within a landslide hazard area must be evaluated by a geotechnical engineer or qualified geologist. Engineered dispersion areas should not be sited above slopes greater than 20 percent or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and acceptance by Thurston County.

Engineered dispersion areas shall have a separation of at least 2 feet between the existing ground elevation and the average annual maximum groundwater elevation. This separation depth requirement applies to the entire limits of the dispersion area.

When selecting engineered dispersion areas, determine whether there are groundwater management plans for the area and contact the local water purveyors to determine whether the project lies within a wellhead or groundwater protection zone, septic drain fields, or aquifer recharge area. There may be additional restrictions within these areas.

Setback Requirements

- Engineered dispersion areas can extend beyond the right-of-way provided that documentation ensures (via easements or dedicated tracts) the dispersion area is not developed in the future.

- Engineered dispersion areas shall be setback at least 100 feet from drinking water wells and springs used for public drinking water supplies. Engineered dispersion areas upgradient of drinking water supplies and within the 1-, 5-, and 10-year time of travel zones must comply with the Washington State Department of Health (DOH) requirements.

- Engineered dispersion areas shall be setback at least 100 feet from septic drainfields. The 100-foot setback is in addition to the required dispersion area. For example if there is a 100-foot width dispersion area, there would be an additional 100-foot setback making a total of 200 feet from the point of discharge of water to the dispersion area to the drainfield area. If the applicant can demonstrate that the dispersion flow path will not intercept the drainfield, this setback requirement may be relaxed.

- If the project significantly increases flows to off-site properties, a drainage easement may be required or additional right-of-way purchased.

Signage

- The limits of engineered dispersion area shall be marked as a stormwater management facility and also shall be physically marked in the field during and after construction. Signage ensures the dispersion area is protected from construction activity disturbance and is adequately protected by measures shown in the temporary erosion and sedimentation control (TESC) plan.

- Signage helps ensure the engineered dispersion area is not cleared or disturbed after the construction project.

- Signage shall be posted at a minimum on all four sides of the dispersion area and at intervals not exceeding 75 feet.

- See Appendix V-E for sign specifications.

Construction Considerations

- For installation of dispersal BMPs and conveyance systems near dispersion areas, the area that needs to be cleared or grubbed should be minimized. Maintaining plant root systems is important for dispersion areas.

- The area around dispersion areas should not be compacted.

- To the maximum extent practicable, low-ground-pressure vehicles and equipment should be used during construction.

Maintenance

- Use the maintenance checklist for vegetated filter strips and energy dissipators for maintenance requirements (Appendix V-C).

- Signage and fencing shall be inspected and restored /replaced as required.

- Ensure that sheet flow paths are maintained to the dispersion areas, perform hand maintenance to ensure sheet flow.

- Maintain energy dissipators and level spreaders. Cleanout any structures associated with these devices and inspect spreaders to ensure they are functioning correctly. Remove buildup of soil/debris over the surface of level spreader as required to maintain its function.

Chapter 3 - Infiltration BMPs

Infiltration BMPs discharge stormwater into the ground, rather than through a surface or piped outflow. Infiltration can aid in pollutant removal, peak flow control, groundwater recharge, and flood control.

However, to avoid contaminating drinking water sources, infiltration facilities must be sited properly (see site suitability criteria in Volume III) and stormwater runoff must often be pretreated before infiltration. See the individual BMP design guidelines in this chapter for pretreatment requirements.

3.1 General Considerations

3.1.1 Runoff Treatment and Flow Control

Infiltration can be used for both runoff treatment and flow control.

To adequately address groundwater protection when evaluating infiltration, it is important to understand the difference between soils suitable for runoff treatment and soils suitable only for flow control.

Infiltration for runoff treatment treats stormwater by using the filtration, adsorption, and biological decomposition properties of soils. To be used for runoff treatment, soils must include sufficient organic content and sorption capacity to remove pollutants. Examples are silty and sandy loams.

Coarser soils, such as gravelly sands, can provide flow control through rapid infiltration to groundwater, but are not suitable for treating runoff. The use of coarser soils to provide flow control for runoff from pollution generating surfaces must be preceded by treatment in some cases to protect groundwater quality. Thus, there will be instances when soils are suitable for treatment but not flow control, and vice versa.

The hydraulic design goal should be to mimic the natural hydrologic balance between surface and ground water, as needed to protect water uses. Frequently infiltration will be used in combination with detention and release to meet Minimum Requirement #7 (Flow Control). Detention may be provided after infiltration or in combination with infiltration by installing a control structure for controlled release of stormwater for events that exceed the infiltration capacity of the facility.

3.1.2 Site Suitability

Because infiltration facilities release stormwater to groundwater, they must be located and designed to ensure that stormwater discharge will not contaminate drinking water sources or downstream surface waters. Site characterization and suitability criteria are described in Volume III and includes characterization of the soils; locational restrictions and siting criteria; calculating a design infiltration rate; characterization of the infiltration receptor (vadose zone), and underlying aquifer; and mounding analysis requirements.

3.1.3 Underground Injection Control

Infiltration is regulated by the Washington State Department of Ecology (Ecology) and the Underground Injection Control (UIC) Program (Washington Administrative Code [WAC] 173-218).

The following information on Underground Injection Control (UIC) is excerpted from the 2006 Department of Ecology document *Guidance for UIC Wells that Manage Stormwater*. This document is available online at: <http://www.ecy.wa.gov/biblio/0510067.html>.

The UIC program in the state of Washington is administered by the Department of Ecology. In 1984, the Department of Ecology adopted Chapter 173-218 WAC – Underground Injection Control to implement the program. A UIC well is a manmade subsurface fluid distribution system designed to discharge fluids into the ground and consists of an assemblage of perforated pipes, drain tiles, or other similar mechanisms, or a dug hole that is deeper than the largest surface dimension (WAC 173-218-030).

UIC systems include drywells, pipe or French drains, drain fields, and other similar devices that are used to discharge stormwater directly into the ground. Infiltration trenches with perforated pipe used to disperse and inject flows (as opposed to collect and route to surface drainage, as in an underdrain) are considered to be UIC wells. All stormwater UICs must be registered with Ecology, except residential UICs used for roof runoff control.

The following are not UIC wells; therefore, this guidance does not apply in these situations:

- Buried pipe and/or tile networks that serve to collect water and discharge that water to a conveyance system or to surface water.
- Surface infiltration basins and flow dispersion stormwater infiltration facilities, unless they contain additional infiltration structures at the bottom of the basin/system such as perforated pipe, or additional bored, drilled, or dug shafts meant to inject water further into the subsurface greater than 20 feet deeper than

the bottom of the pond (or deeper than the largest surface dimension per above).

- Infiltration trenches designed without perforated pipe or a similar mechanism
- A system receiving roof runoff from a single family home.

The two basic requirements of the UIC Program are:

- Register UIC wells with the Washington State Department of Ecology unless the wells are located on tribal land. (Those wells should be registered with the Environmental Protection Agency.)
- Make sure that current and future underground sources of ground water are not endangered by pollutants in the discharge (non-endangerment standard).

UIC wells must either be rule-authorized or covered by a state waste discharge permit to operate. If a UIC well is rule-authorized, a permit is not required. Rule-authorization can be rescinded if a UIC well no longer meets the non-endangerment standard. Ecology can also require corrective action or closure of a UIC well that is not in compliance. Additional information on UIC systems can be found online at: <http://www.ecy.wa.gov/biblio/0510067.html>.

In order to find adequate infiltration rates, an engineer may propose to excavate through a till layer or low permeability layer when designing a stormwater facility. Since excavating through this low permeability layer creates a new condition, more extensive geotechnical reports, runoff treatment BMPs, and monitoring may be required including but not limited to groundwater monitoring through a wet season (December 1st through April 30th).

3.1.4 Groundwater Protection Areas

The applicant must check the Critical Aquifer Recharge (CARA) map, sole source aquifer designations, and wellhead protection areas mapped by the Washington State Department of Health and Thurston County to determine if the project lies within a groundwater protection area. A site is not suitable if the infiltration facility will cause a violation of Washington State Ground Water Quality Standards. At a minimum, projects located within groundwater protection areas may be required to meet one of the soil requirements for infiltration for water quality treatment outlined in Volume 3, Section 2.3.1. If an infiltration facility is proposed within a designated well head protection area for a public water system serving over 1,000 connections the enhanced treatment is required prior to infiltration.

3.1.5 Verification of Performance

Verification testing of the completed full-scale infiltration facility (BMPs IN.01, IN.02, or IN.03) is required during the first 1 to 2 years of operation and prior to release of any financial assurance instruments (bonds, letters of credit, assignment of funds). Verification testing is required to ensure that the completed full-scale infiltration facility operates as designed including confirmation of estimated design infiltration rates.

The applicant shall submit a facility monitoring and evaluation report to document the results of the verification testing. A licensed civil engineer shall prepare and seal the report. The report shall document work and assess stormwater infiltration facility performance versus design.

All field work shall be done under the engineer's direction and supervision. Testing shall consist of automated continuous water level monitoring over a sufficient number of storms to provide an accurate "long-term" infiltration rate. Testing shall either have a minimum of 30 days' test results with two or more events exceeding 30 percent of facility volume, or one full wet season's data (November 1 to March 30). An alternative, with Administrator or designee acceptance, is to simulate storm events using hydrant or trucked water. The report shall specify any actions needed to restore performance, such as sediment removal or facility expansion.

A program for monitoring of groundwater quality may be required and if so it shall be prepared by the site professional. Instances in which groundwater monitoring may be required include shallow groundwater, infiltration facilities at commercial or industrial sites, and infiltration facilities located within critical, sensitive or sole-source aquifer areas as designated by Thurston County. For those facilities required to conduct groundwater monitoring, the ground water monitoring wells installed during site characterization may be used for this purpose. At a minimum at least one up-gradient and one down-gradient groundwater sample will be collected per year and analyzed for pollutants such as metals, nitrogen, phosphorous and dissolved solids.

Long-term (more than 2 years) in-situ drawdown and confirmatory monitoring of the infiltration facility is also strongly recommended, along with a maintenance program that results in achieving expected performance levels. Long term monitoring and groundwater monitoring shall be included in the Maintenance plan for the facility including methods of testing, frequency and reporting requirements.

3.1.6 Contingency Planning

The methods used to estimate infiltration rates described in Volume III are expected to yield relatively accurate estimates of ultimate infiltration rates. However, soils, shallow geology, and groundwater conditions can be extremely complex and highly variable, which may cause inaccuracies. Therefore, it is necessary to have a plan for fixing under performance discovered after facilities are installed (see Section 3.1.2, Verification of Performance).

All projects using infiltration facilities shall provide a contingency plan for under performance. The plan shall include a reasonable “worst-case” project of long-term infiltration performance and describe methods and costs for improving/restoring performance and/or expanding facility size. These costs shall provide one basis for required performance/operation and maintenance bonding (see Volume I).

3.2 Infiltration BMPs

This section includes the following BMPs:

- IN.01 Infiltration Basin
- IN.02 Infiltration Trench
- IN.03 Infiltration Vault
- IN.04 Bio-Infiltration Swale.

3.2.1 IN.01 Infiltration Basins

Infiltration basins are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff.

This section describes design and maintenance criteria for infiltration basins (see schematic in Figure 3.1).

Applicability

Infiltration basins for flow control are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Infiltration basins designed to meet runoff treatment criteria of Minimum Requirement #6 rely on the soil profile or an engineered soil layer to provide pollutant removal. Runoff in excess of the infiltration capacity of the basin must be managed to comply with the flow control requirements in Volume I, Minimum Requirement #7, if applicable.

Infiltration basins are a good option (and may be required) for flow control where soils have adequate infiltration rates and the site meets the site suitability criteria for infiltration facilities described in Volume III.

Infiltration basins for water quality treatment are capable of achieving performance objectives for water quality treatment. In general, this treatment method can capture and remove or reduce target pollutants to levels that:

- Will not adversely affect public health or beneficial uses of surface and ground water resources, and
- Will not cause a violation of ground water quality standards

Infiltration treatment systems are typically installed:

- As off-line systems, or on-line for small drainages
- As a polishing treatment for street/highway runoff after pretreatment for solids and oil.
- As part of a treatment train
- As retrofits at sites with limited land areas, such as residential lots, commercial areas, parking lots, and open space areas
- With appropriate pretreatment for oil and silt control to prevent clogging. Appropriate pretreatment devices include a pre-settling basin or a basic treatment BMP such as wet pond/vault, biofilter, constructed wetland, media filter, and oil/water separator.

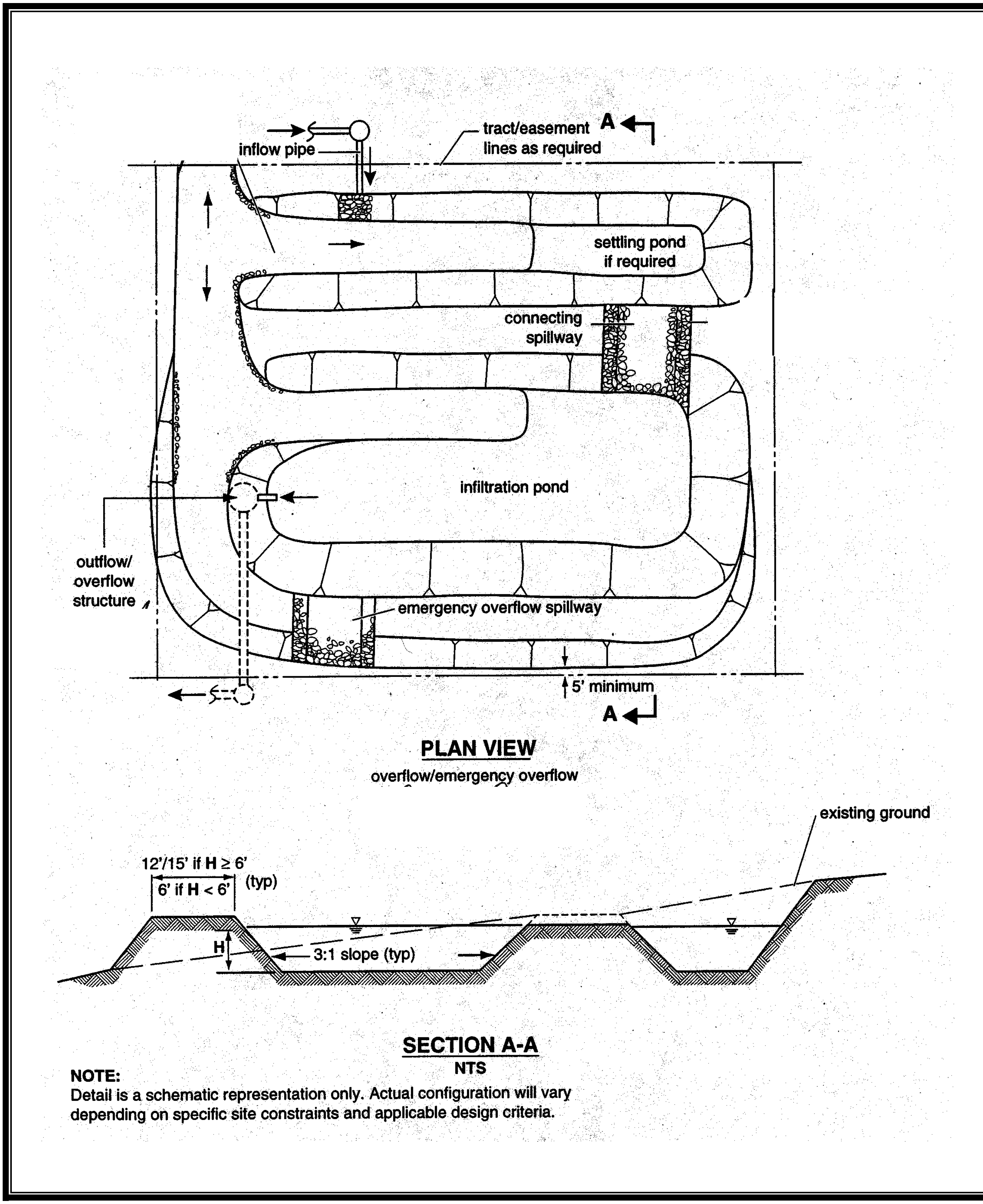


Figure 3.1. Typical Infiltration Pond/Basin.

Infiltration basins are preferred over infiltration trenches (BMP IN.02), infiltration vaults (BMP IN.03), and bio-infiltration swales (BMP IN.04). This is primarily because basins are easier and less expensive to construct and maintain.

Limitations

See Volume III for soil testing and site suitability criteria.

Submittals and Approval

Prepare submittals required by Volume I and include the following information in the submittal:

- Hydrologic modeling results showing the how the facility meets the flow control minimum requirements
- Show details of all structures and material and construction specifications
- Planting plan showing plant species, quantity, location and any special planting requirements
- Provide at least one cross section of the pond through the control structure
- Provide design calculations for the overflow structures
- Show how the facility location meets setback requirements
- Required contingency planning and performance verification testing information
- Geotechnical report and infiltration rate calculations required by Volume III.

Pretreatment

With the exception of clean runoff water from roofs or other non-pollution generating pervious or impervious surfaces, all stormwater shall pass through a designed biofiltration system (BMPs BF.01, BF.03, BF.04, or BF.05) or presettling basin (BMP WP.05) for water quality treatment prior to discharge to an infiltration facility. The pretreatment facility must safely convey or bypass the developed 100-year peak flow per conveyance design standards of Volume III.

Hydrologic and Hydraulic Design Considerations

See Volume III for detailed guidance on modeling infiltration basins.

100-Year Overflow Conveyance

An overflow route must be identified for stormwater flows that overtop the facility when infiltration capacity is exceeded or when the facility becomes plugged and fails. The overflow route must be able to convey the 100-year developed peak flow to the downstream conveyance system or other acceptable discharge point without posing a health or safety risk or causing property damage. The emergency overflow spillway shall be designed in accordance with the requirements for detention pond overflow spillway design criteria (BMP D.01).

Spill Control Device

All infiltration facilities must have a spill control device upstream of the facility to capture oil or other floatable contaminants before they enter the infiltration facility. If a "tee" section is used for spill control, the top of the spill control riser must be set above the infiltration facility's 100-year overflow elevation to prevent oils from entering the infiltration facility.

Soil Physical and Chemical Suitability for Treatment

(Applies to infiltration facilities used as treatment facilities not to facilities used for flow control only).

The soil texture and design infiltration rates should be considered along with the physical and chemical characteristics specified below to determine if the soil is adequate for removing the target pollutants. Section 2.3.1 of Volume III discusses the soil properties needed to meet runoff treatment requirements.

Engineered soils may be used to meet infiltration BMP design criteria in Volume V and the performance goals in Minimum Requirement #6 (Runoff Treatment; Volume I). BMP LID.08 Bioretention provides an acceptable engineered soil specification for runoff treatment. Use of alternate engineered soils must be approved by the County, and requires field performance evaluation(s), using acceptable protocols, to determine effectiveness, feasibility, and acceptability.

Design Criteria

Geometry

- The slope of the basin bottom shall not exceed 3 percent in any direction.

- A minimum of 1 foot of freeboard is required when establishing the design ponded water depth. Freeboard is measured either from the rim of the infiltration facility to the maximum ponding level, or from the rim down to the overflow point if overflow or a spillway is included.

Materials

- **Lining material**: Basins can be open or covered with a 6- to 12-inch layer of filter material such as coarse sand, or a suitable filter fabric, to help prevent the buildup of impervious deposits on the soil surface. A nonwoven geotextile shall be selected that will function sufficiently without plugging (see geotextile specifications in Appendix V-A). The filter layer can be replaced or cleaned when/if it becomes clogged.

- **Vegetation**: The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas shall be stabilized and planted—preferably with grass—in accordance with the *Drainage Design and Erosion Control Plan* (see Minimum Requirement #1 of Volume I).

- Treatment infiltration basins must have sufficient vegetation established on the basin floor and side slopes to prevent erosion and sloughing and to provide additional pollutant removal. Erosion protection of inflow points to the basin must also be provided (e.g., riprap, flow spreaders, energy dissipators. Select suitable vegetative materials for the basin floor and side slopes to be stabilized.

- Seed mixtures shall be the same as those recommended in Table E-2 in Appendix V-E. The use of slow-growing, stoloniferous grasses will permit long intervals between mowing (twice a year is usually satisfactory). Fertilizers shall be applied only as necessary and in limited amounts, to avoid contributing to ground water pollution. Consult the local extension agency for appropriate fertilizer types and application rates.

Site Design Elements

Access must be provided for vehicles to easily maintain the forebay (presettling basin) area, while not disturbing vegetation or resuspending sediment any more than absolutely necessary.

Access Road

An access road to the control structure and at least one access point per cell are needed, and may be designed and constructed as specified in Appendix V-D.

Construction Criteria

- Initial basin excavation must be conducted to within 2 feet of the final elevation of the basin floor. Excavate infiltration trenches and basins to final grade only after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation must remove all silt accumulated in the infiltration facility before putting it into service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying runoff water through an appropriate pretreatment system such as a presettling basin, wet pond, or sand filter.

- Infiltration basins should not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any silt accumulation in the basin must be removed before putting it into service.

- Light-tracked equipment is recommended to avoid compaction of the basin floor. The use of draglines and trackhoes should be considered for constructing infiltration basins. The infiltration area must be flagged or marked to keep heavy equipment away.

- The infiltration basin area shall be clearly identified and protected prior to construction to prevent compaction of underlying soils by vehicle traffic.

- Infiltration basins shall not begin operation until all erosion-causing project improvements are completed, and all exposed ground surfaces are stabilized by revegetation or landscaping.

Maintenance Criteria

Provision shall be made for regular and perpetual maintenance and access (tract, easement, etc., see Volume III) to the infiltration basin/trench. Adequate access, including measures to prevent encroachment into tracts/easements for purposes of inspection, operation and maintenance must be part of infiltration basin and trench design. Provisions must be made for regular and perpetual maintenance of the infiltration basin or trench, including replacement or reconstruction of any media used for treatment purposes. The Operation and Maintenance Plan shall be submitted to and approved by the County to ensure maintenance of the desired infiltration rate.

Debris/sediment accumulation – Removal of accumulated debris/sediment in the basin/trench should be conducted every 6 months or as needed to prevent clogging, or when the measured infiltration rate is significantly less than the design rate.

Vegetation growth should not be allowed to exceed 18 inches in height. Mow the slopes periodically and check for clogging, and erosion.

See Appendix V-C for additional information on maintenance requirements.

3.2.2 IN.02 Infiltration Trenches

This section describes design, construction, and maintenance criteria for infiltration trenches. For trenches associated with roof downspout infiltration, see BMP LID.04.

Figures 3.2 through 3.7 provide different configurations for infiltration trenches. Infiltration trenches are rectangular trenches generally at least 24 inches wide backfilled with a coarse stone aggregate that temporarily stores stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil.

Applicability

Infiltration trenches are more appropriate for small contributing areas or the risk of clogging and flooding increases. They are also suited to retrofit situations where limited area is available for infiltration basins.

Limitations

See Volume III for soil testing and site suitability criteria.

Submittals and Approval

In addition to submittal requirements of Volume I, complete geotechnical investigations and prepare a site suitability analysis per Volume III. If an infiltration trench includes a perforated distribution pipe, the BMP is subject to the requirements of the Underground Injection Control (UIC) regulations (see Section 3.1.3).

Pretreatment

With the exception of clean runoff water from roofs or other non-pollution generating pervious or impervious surfaces, all stormwater shall pass through a designed biofiltration swale system, basic filter strip or presettling basin for water quality treatment (see BMP BF.01, BMP BF.04 and BMP WP.05) prior to discharge to an infiltration trench. The pretreatment facility must safely convey or bypass the developed 100-year peak flow per conveyance design standards of Volume III.

Hydrologic and Hydraulic Design Considerations

See Volume III for guidance on determining a design infiltration rate and hydrologic modeling requirements.

- **Overflow Channel**: Because an infiltration trench is normally used for small drainage areas, an emergency spillway is not necessary. However, a non-erosive overflow channel leading to a stabilized watercourse shall be provided.

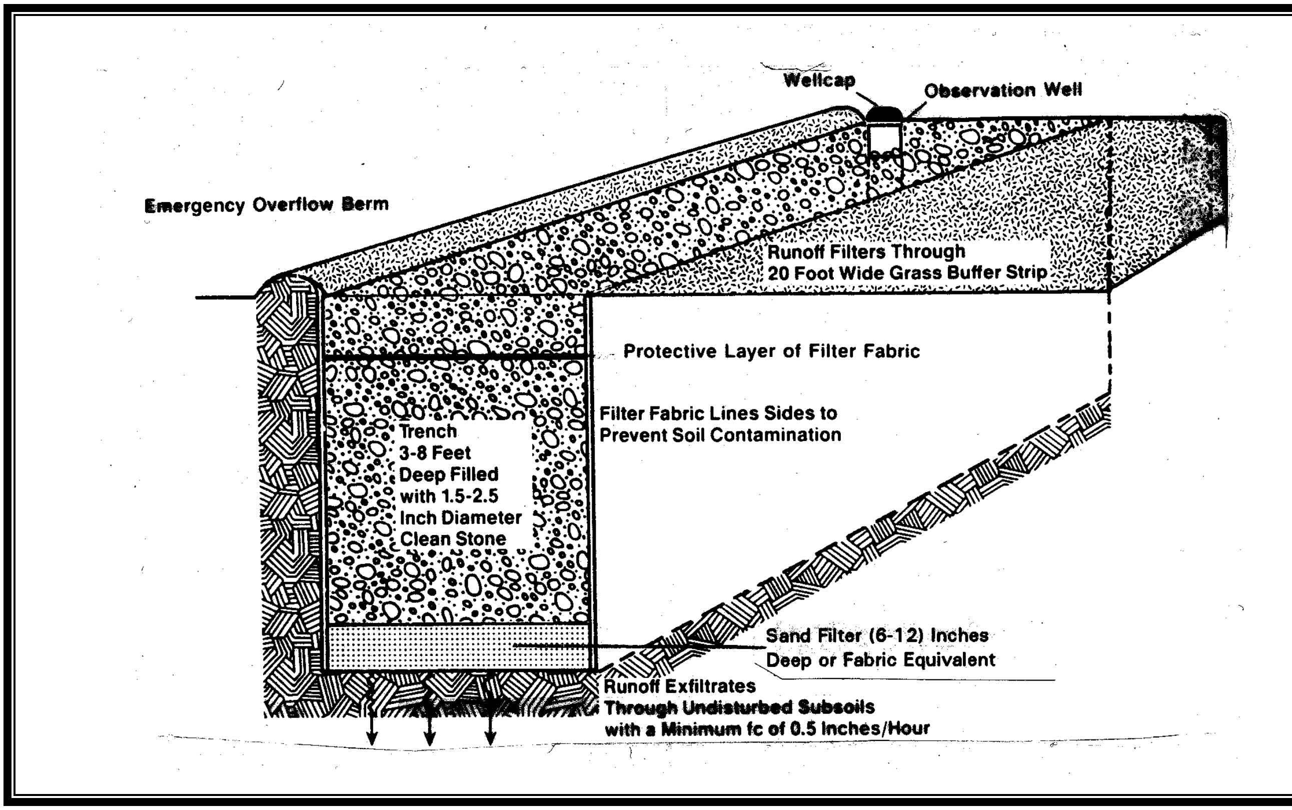


Figure 3.2. Schematic of an Infiltration Trench.

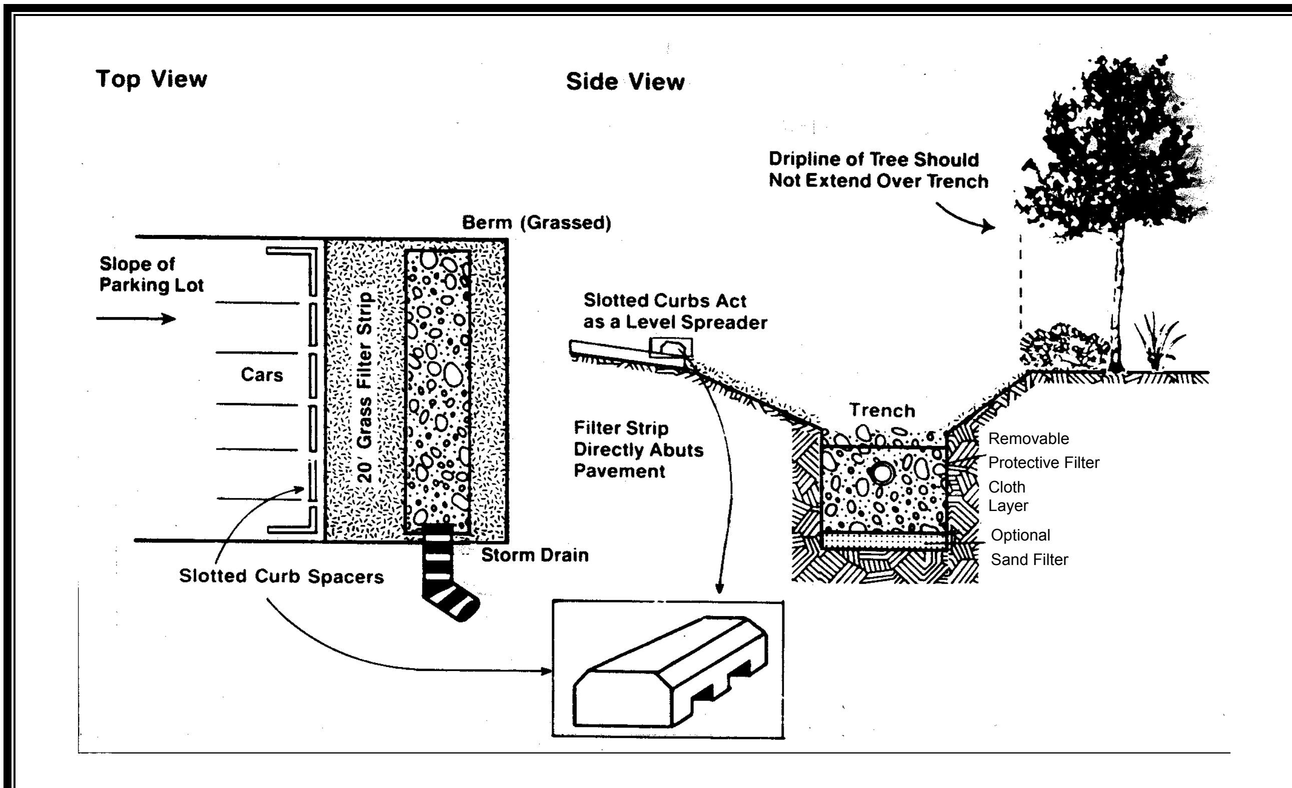
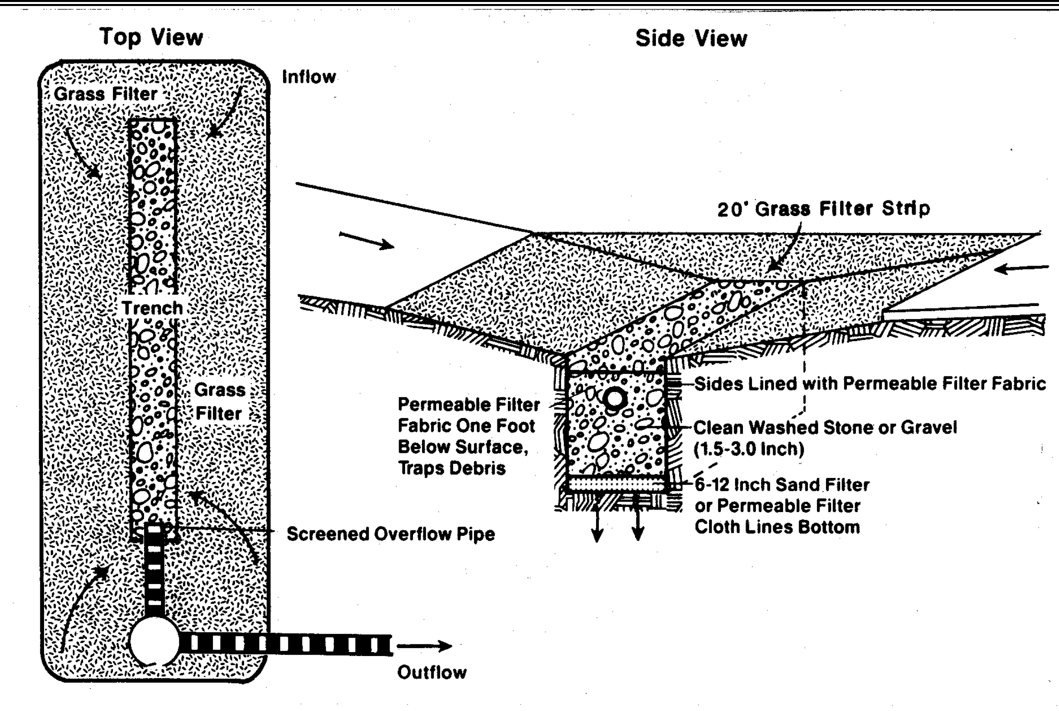
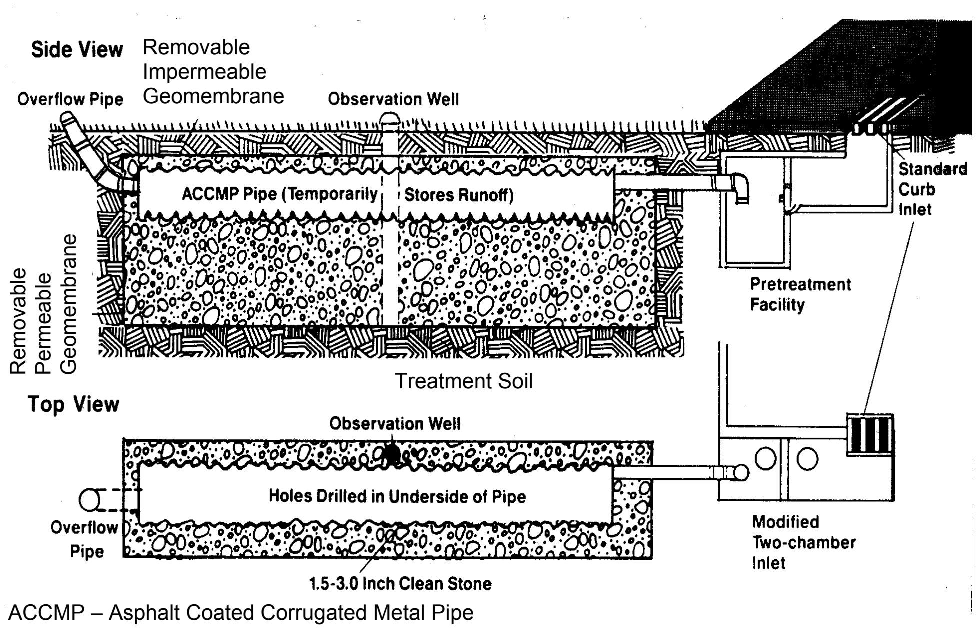


Figure 3.3. Parking Lot Perimeter Trench Design.



Source: Schueler (reproduced with permission)

Figure 3.4. Median Strip Trench Design.



Source: Schueler (reproduced with permission)

Figure 3.5. Oversized Pipe Trench Design.

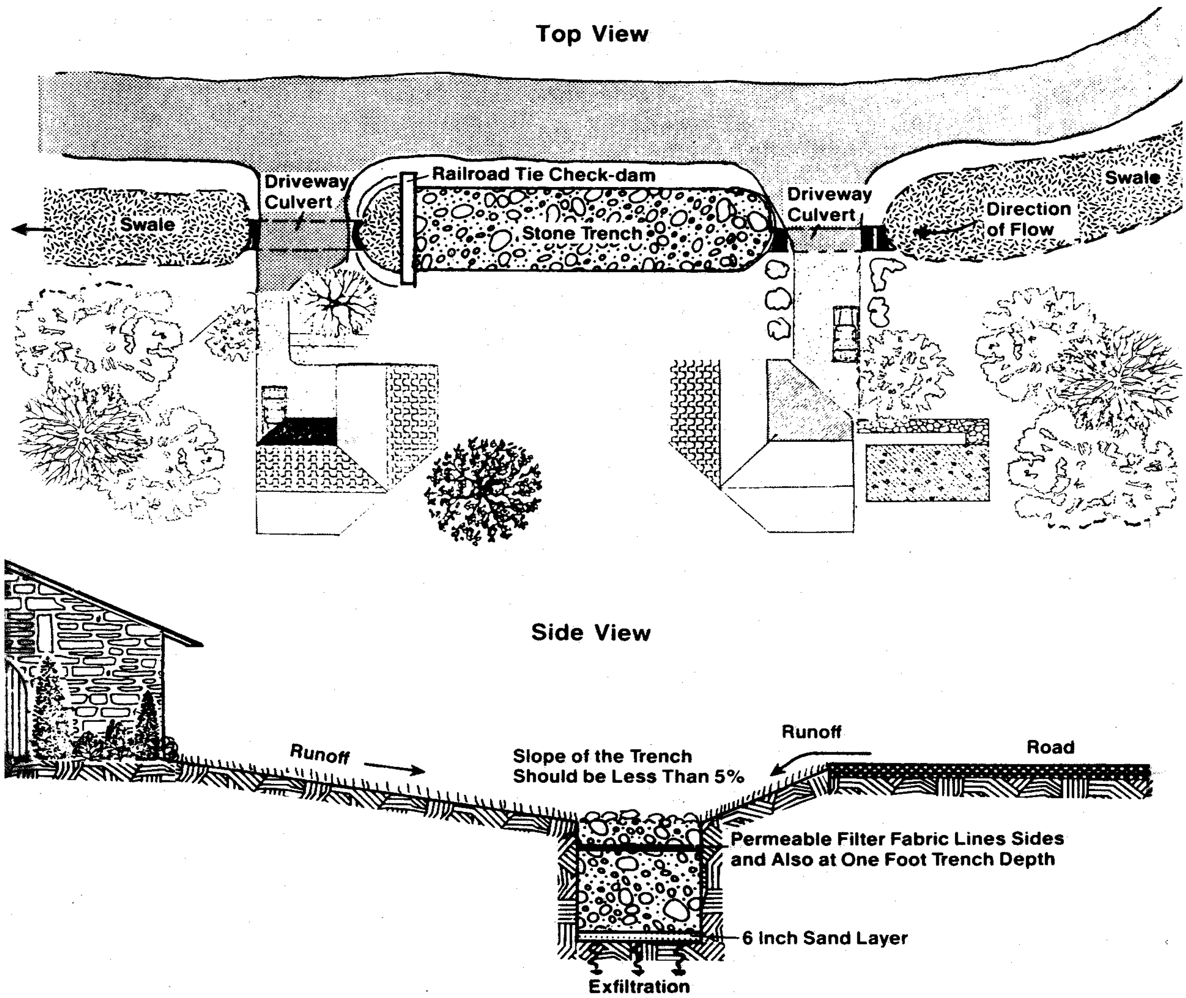


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Figure 3.6. Swale/Trench Design.

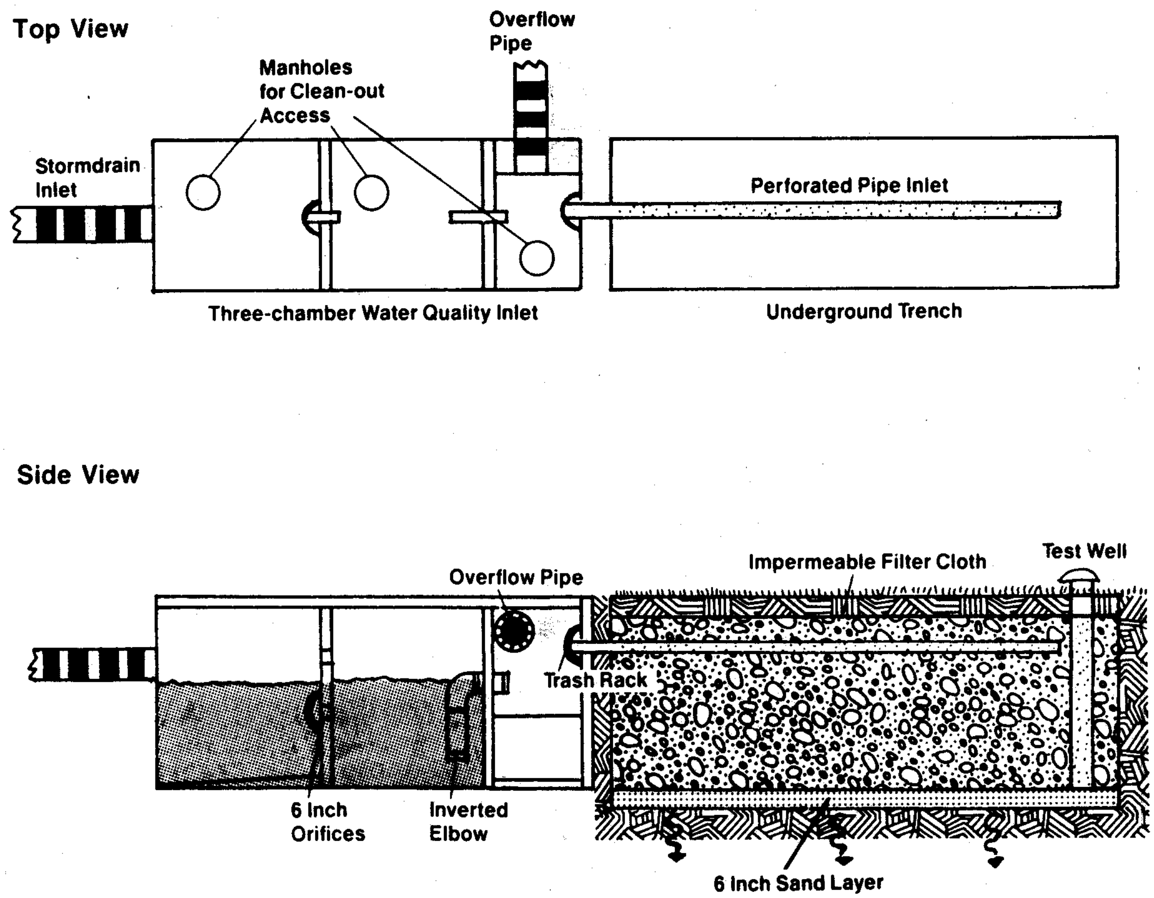

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Figure 3.7. Underground Trench with Oil/Grit Chamber.

- **Surface Cover**: A stone-filled trench can be placed under a porous or impervious surface cover to conserve space. If located under an off-street parking lot the following are required:
  - Observation wells must be placed no further than 100 feet apart.
  - The Maintenance Plan must clearly state that the pavement may have to be removed for maintenance.
  - No infiltration facilities shall be allowed under streets or roads, public or private (if more than one parcel is served).
- **Observation Well**: An observation well shall be installed at the lower end of the infiltration trench to check water levels, drawdown time, and sediment accumulation, and to conduct water quality monitoring. Figure 3.2 illustrates observation well details. The well should consist of a perforated PVC pipe 4 to 6 inches in diameter, and be constructed flush with the ground elevation. For larger trenches, a 12- to 36-inch-diameter well can be installed to facilitate maintenance operations (e.g., pumping out sediment). The top of the well shall be capped to discourage vandalism and tampering.

Design Criteria

Trench Cover

The surface of the trench can be covered with grating, or consist of stone, gabion, sand, or a grassed covered area with a surface inlet.

Distribution Pipe

Perforated rigid pipe at least 8 inches in diameter can also be used to distribute stormwater in the infiltration trench. However, an infiltration trench with distribution pipe is subject to the requirements of the Underground Injection Control (UIC) program (see Section 3.1.3).

Geometry

Infiltration trenches are generally at least 24 inches wide. However, narrower or wider trenches are allowed if they meet the requirements of this section.

Parallel trenches shall be spaced no closer than 10 feet or based on recommendations of the geotechnical engineer.

Trenches should generally follow a contour line.

Materials

- **Backfill Material**: The aggregate material for the infiltration trench must consist of a clean washed aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Void space for these aggregates must be in the range of 30 to 40 percent.

- **Geotextile fabric liner**: The aggregate fill material shall be completely encased in an engineering geotextile material. Geotextile must surround all of the aggregate fill material except for the top 1 foot, which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging (see Appendix V-A of Volume V).

- The sand filter shown at the base of the infiltration trenches in the attached figures is optional.

Spill Control

All infiltration trenches must have a spill control device upstream of the facility to capture oil or other floatable contaminants before they enter the infiltration facility. If a "tee" section is used for spill control, the top of the spill control riser must be set above the infiltration facility's 100-year overflow elevation to prevent oils from entering the infiltration facility.

Construction and Maintenance

- Initial trench excavation shall be conducted to within no less than 2 feet of the final elevation of the basin floor. Excavate infiltration trenches to final grade only after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation must remove all silt accumulation in the infiltration trench before putting it into service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a presettling basin, biofiltration swale or filter strip, wet pond, or sand filter.

- Infiltration facilities should not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any asilt accumulation in the basin must be removed before putting it into service.

- The infiltration facility area shall be clearly identified and protected prior to construction to prevent compaction of underlying soils by vehicle traffic.

- Infiltration facilities shall not begin operation until all erosion-causing project improvements are completed and all exposed ground surfaces are stabilized by revegetation or landscaping.

- **Trench Preparation**: Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care must also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic (see erosion and sediment control criteria in Volume II).

- **Stone Aggregate Placement and Compaction**: The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.

- **Potential Contamination**: Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.

- **Overlapping and Covering**: Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll must overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

- **Voids behind Geotextile**: Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. Soil piping, geotextile clogging, and possible surface subsidence will be avoided by this remedial process.

- **Unstable Excavation Sites**: Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

See Appendix V-C for information on maintenance requirements.

3.2.3 IN.03 Infiltration Vault

This section describes design, construction, and maintenance criteria for infiltration vaults.

Infiltration vaults are typically bottomless underground structures used for temporary storage and infiltration of stormwater runoff to groundwater. Infiltration tanks are large-diameter cylindrical structures with perforations in the base. These types of underground infiltration facilities can be a useful alternative for sites with constraints that make siting an infiltration pond difficult.

Applicability

Infiltration of runoff is the preferred method of flow control following appropriate runoff treatment. Runoff in excess of the infiltration capacity must be detained and released in compliance with the flow control requirement described in Minimum Requirement 6.

Limitations

Because infiltration vaults are difficult to maintain, County acceptance must be gained prior to implementation of this BMP.

Infiltration vaults shall not be located under the travel way in public rights-of-way. For all residential subdivisions and mixed use developments the infiltration vault shall be located in a separate tract with access from a public right-of-way. See Section 3.6 of Volume III for additional requirements.

Submittals and Approval

In addition to submittal requirements of Volume I, complete geotechnical investigations and prepare a site suitability analysis per Volume III.

Pretreatment

With the exception of clean runoff water from roofs or other non-pollution generating pervious or impervious surfaces, all stormwater shall pass through a designed biofiltration swale system, basic filter strip or presettling basin for water quality treatment (see BMP BF.01, BMP BF.04 and BMP WP.05) prior to discharge to an infiltration trench. The pretreatment facility must safely convey or bypass the developed 100-year peak flow per conveyance design standards of Volume III.

Hydrologic and Hydraulic Design Considerations

See Volume III for guidance on determining a design infiltration rate and hydrologic modeling requirements.

- **Overflow**: A primary overflow must be provided to bypass flows over the 100-year postdeveloped peak flow to the infiltration vault.

Design Criteria

Geometry

- The maximum depth from finished grade to the vault invert shall be 20 feet
- The minimum internal height shall be 7 feet, measured from the highest point of the vault floor (not sump), and the minimum width shall be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. The minimum internal height requirement may not be needed for any areas covered by removable panels.

Spill Control

All infiltration vaults must have a spill control device upstream of the facility to capture oil or other floatable contaminants before they enter the infiltration facility. If a "tee" section is used for spill control, the top of the spill control riser must be set above the infiltration facility's 100-year overflow elevation to prevent oils from entering the infiltration facility.

Structural Design Considerations

Materials

Minimum 3,000 psi structural reinforced concrete shall be used for infiltration vaults. All construction joints must be provided with water stops. Pre-cast vaults or vaults made of materials other than concrete may be allowed subject to meeting the requirements of this section and with prior acceptance of the Administrator or designee.

Infiltration vaults may be constructed using material other than reinforced concrete, such as large, perforated, corrugated metal pipe (see Figure 3.8), provided that the following additional criteria are met:

- Bedding and backfill material for the structure must be washed drain rock extending at least 1 foot below the bottom of the structure, at least 2 feet beyond the sides, and up to the top of the structure.
- Drain rock must be completely covered with construction geotextile for separation (per the *Standard Specifications*) prior to backfilling. If the drain rock becomes mixed with soil, the affected rock material must be removed and replaced with washed drain rock to provide maximum infiltration effectiveness.

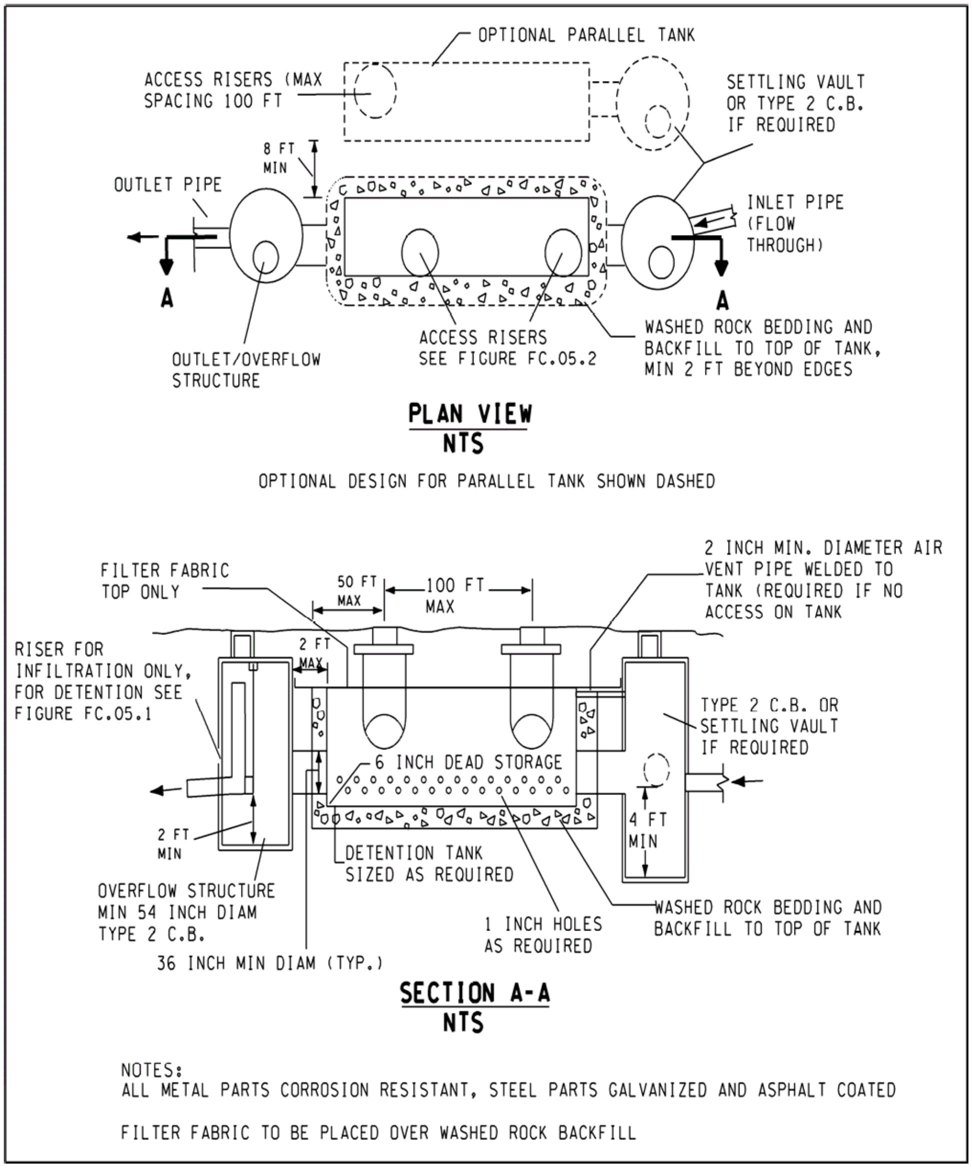


Figure 3.8. Infiltration Vault.

- The perforations (holes) in the bottom half of the pipe must be 1 inch in diameter and start at an elevation of 6 inches above the invert. The nonperforated portion of the pipe in the lower 6 inches is intended for sediment storage to protect clogging of the native soil beneath the structure.

- The number and spacing of the perforations should be sufficient to allow complete infiltration of the soils with a safety factor of 2.0 without jeopardizing the structural integrity of the pipe.

Structural Stability

All vaults must meet structural requirements for overburden support and H-20 vehicle loading. Vaults located under roadways must meet the live load requirements of the Standard Specifications. Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed structural civil engineer. Bottomless vaults must be provided with footings placed on stable, well consolidated native material and sized considering overburden support, traffic loading (assume maintenance traffic, if vault is placed outside right of way), and lateral soil pressures when the vault is dry. Infiltration vaults are not allowed in fill slopes unless a geotechnical analysis approves fill stability. The infiltration medium at the bottom of the vault must be native soil.

Access

Access must be provided over the inlet pipe and outlet structure. The following guidelines for access shall be used:

- Access openings must be positioned a maximum of 50 feet from any location within the tank. Additional access points may be needed on large vaults. If more than one “v” is provided in the vault floor, access to each “v” must be provided.

- For vaults with greater than 1,250 square feet of floor area, a 5' by 10' removable panel shall be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided as shown in Figure 3.8.

- Ladders and hand-holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified below.

- All access openings, except those covered by removable panels, shall have round, solid locking lids, or 3-foot square, locking diamond plate covers.

- Vaults with widths 10 feet or less shall have removable lids.

- Any vault requiring internal structural walls shall provide wall openings sufficient for maintenance access between cells. The openings shall be sized and situated to allow access to the maintenance "v" in the vault floor.

- Vaults must comply with the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

- Ventilation pipes (minimum 12-inch diameter or equivalent) shall be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively removable panels over the entire vault may be provided.

Construction and Maintenance

Initial excavation should be conducted to within 1 foot of the final elevation of the infiltration vault base. Final excavation to the finished grade should be deferred until all disturbed areas in the upgradient drainage area have been stabilized or protected. The final phase of excavation should remove all accumulated sediment.

Infiltration vaults, as with all types of infiltration facilities, should generally not be used as temporary sediment traps during construction. If an infiltration vault is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any accumulation of silt in the vault must be removed before the vault is put into service.

Relatively light-tracked equipment is recommended for excavation to avoid compacting the soil beneath the base of the infiltration vault. The use of draglines and trackhoes should be considered. The infiltration area should be flagged or marked to keep equipment away.

See Appendix V-C for information on maintenance requirements.

3.2.4 IN.04 Bio-Infiltration Swales

Bio-infiltration swales, also known as Grass Percolation Areas, combine grassy vegetation and soils to remove stormwater pollutants by percolation into the ground. Their pollutant removal mechanisms include filtration soil sorption, and uptake by vegetative root zones.

Applicability

In general, bio-infiltration swales are used for treating stormwater runoff from roofs, roads and parking lots. Runoff volumes greater than water quality design volume are typically overflowed to the subsurface through an appropriate conveyance facility such as a dry well, or an overflow channel to surface water. Overflows that are directed to a surface water must meet Minimum Requirement #7 or #8 (as applicable) unless the discharge is to a marine water, or qualifies for a flow control exemption in accordance with the criteria in Minimum Requirement #7.

Limitations

See Volume III for soil testing and site suitability criteria.

Submittals and Approval

The applicant should consult with Thurston County at the pre-submittal meeting and stormwater scoping report/meeting for the project to discuss the suitability of and requirements for a bio-infiltration swale if one is proposed for the project.

Project submittal shall include the following in addition to the requirements of other sections:

- Source of treatment soil and testing results of treatment soil
- Description of method used and results of infiltration testing of base soils
- Description of method used and results of infiltration testing for treatment soil
- Hydrologic modeling results for the bio-infiltration swale demonstrating that the water quality treatment design storm is handled by the facility and how volumes greater than the water quality design flow are managed
- Project drawings shall include a typical cross-section of the swale and specifications for installation of treatment soils, seeding, sodding and other construction requirements

- Maintenance Plan shall include a discussion of maintenance requirements for the bio-infiltration swale.

Pretreatment

Pretreatment should be provided for removal of debris, gross TSS, and oil & grease to prevent the clogging of the treatment soil and/or growth of the vegetation, where necessary. Use of a pre-settling basin or other approved pre-treatment structure may be required depending on the specific location, contributing stormwater flows and other site specific factors.

Hydrologic and Hydraulic Design Considerations

The space available for ponding water within a bio-infiltration swale can be sized by either:

- Completely retaining the water quality design volume, i.e., the 91st percentile, 24-hour runoff volume indicated by an approved continuous runoff model (or, the runoff volume from a 6-month, 24-hour storm). No reduction in volume is taken for any infiltration. Under this option, the overflow to a dry well or to a surface water must be above the elevation corresponding to the water quality design volume.

- Using the same design sizing procedures for infiltration facilities designed as treatment facilities.

Drawdown time for the water quality design volume: 48 hours max.

The treatment soil infiltration rate should not exceed 1-inch per hour for a treatment zone depth of 6 inches relying on the root zone to enhance pollutant removal. The Site Suitability Criteria in Volume III must also be applied; if a design soil depth of 18 inches is used, then a maximum infiltration rate of 2.4 inches per hour is applicable.

The maximum ponded level is 6 inches.

Design Criteria

Swale Bottom

The swale bottom should be flat with a longitudinal slope less than 1 percent.

Treatment Soil

Treatment soil shall be at least 18 inches thick with a CEC of at least 5 meq/100 gm dry soil, organic content of 8 to 10 percent, and sufficient target pollutant loading capacity. The design soil thickness may be reduced to as low as 6 inches if appropriate performance data demonstrates that the vegetated root zone and the natural soil can be expected to provide adequate removal and loading capacities for the target pollutants. The design professional should calculate the pollutant loading capacity of the treatment soil to estimate if there is sufficient treatment soil volume for an acceptable design period.

Other combinations of treatment soil thickness, CEC, and organic content design factors can be considered if it is demonstrated that the soil and vegetation will provide a target pollutant loading capacity and performance level acceptable to the local jurisdiction.

The treatment zone depth of 6 inches or more should contain sufficient organics and texture to ensure good growth of the vegetation.

Use native or adapted grass for vegetating the swale. The swale bottom shall be sodded to a height of at least 6 inches above the swale bottom the remaining sidewalls can be seeded.

Identify pollutants, particularly in industrial and commercial area runoff that could cause a violation of Ecology's ground water quality Standards (Chapter 173-200 WAC). Include appropriate mitigation measures (pretreatment, source control, etc.) for those pollutants.

Construction and Maintenance

See construction and maintenance requirements for biofiltration swale (BMP BF.01) and Appendix V-C.

Chapter 4 - Detention BMPs

4.1 Detention Facility BMPs

Detention facilities temporarily store increased surface runoff from development, meeting performance standards described in Minimum Requirement #7 for flow control (Volume I). The following types of detention facilities are described in this chapter:

- D.01 Detention Ponds
- D.02 Detention Tanks
- D.03 Detention Vaults
- D.04 Use of Parking Lots for Detention.

4.1.1 D.01 Detention Ponds

Drainage facilities, including detention ponds, should be made attractive features of the urban environment. Pond designers are encouraged to be creative in shaping and landscaping detention ponds and to consider aesthetics as an important design criterion.

Applicability

Detention ponds are appropriate for sites large enough for them. Detention ponds are not designed for habitat, in part because they usually drain completely between storms. If a detention facility is needed that provides habitat, flow control and runoff treatment, consider constructed wetlands designed with detention storage (BMP WP.04). Combined constructed wetland and detention ponds occupy a comparable amount of surface area as detention ponds while providing habitat, runoff treatment and a more aesthetically pleasing facility.

For projects located within a designated Well Head Protection Area (WHPA) for a public water system with over 1,000 connections the bottom of the detention pond shall be above the seasonal high groundwater elevation. Where less than 3-feet of separation exists to seasonal high groundwater, the detention pond shall be lined. Pond liners may not be used to place detention facilities below the seasonally high groundwater elevation.

Limitations

Detention ponds occupy a large amount of surface area, and so are typically not used for sites with a high land cost or dense development.

Submittals and Approval

The following information shall be included in required submittals (see Volume I, Chapter 3):

- Hydrologic modeling results showing the how the facility meets the flow control standards (Minimum Requirement #7 – see Volume I, Chapter 2).
- Details of all structures and material and construction specifications.
- Planting plan showing plant species, quantity, location and any special planting requirements.
- Cross section of the pond through the control structure (additional sections and details may be needed depending on the complexity of the grading).

- Design calculations for the overflow structures.
- Demonstration of how the facility location meets setback requirements.

Pretreatment

Pretreatment is not required.

Hydrologic and Hydraulic Design Considerations

General Hydraulic Design Considerations

Detention ponds must be designed as flow-through systems, and a design that maximizes the flow path between inlet and outlet is recommended to promote sedimentation.

Flows must enter the detention pond through a conveyance system separate from the control structure and outflow conveyance system.

Detention Volume and Outflow

The volume and outflow design for detention ponds must comply with both Minimum Requirement #7 in Volume I, and hydrologic analysis and design methods described in Volume III. See Appendix V-A for design guidelines for restrictor orifice structures.

Infiltration Considerations

Detention ponds may be sited on soils that are sufficiently permeable for a properly functioning infiltration system (see Section 3.2). These detention ponds have a surface discharge, and may also use infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements in Section 3.2 for infiltration ponds and Volume III for a soils report, testing, groundwater protection, presettling, and construction techniques.

Primary Overflow

The detention pond must have a primary overflow (usually a riser pipe within the control structure – see Appendix V-A) to bypass the 100-year developed peak flow over or around the restrictor system. This assumes the facility will be full due to plugged orifices or high inflows. The primary overflow is intended to protect against breaching of a pond embankment. The design must provide controlled discharge directly into the downstream conveyance system or other acceptable discharge point.

Secondary Inlet to Control Structure

A secondary inlet to the control structure must be provided in ponds as additional protection against overtopping if the control structure inlet becomes plugged. A grated opening in the control structure manhole functions as a weir when used as a secondary inlet (see Appendix V-A).

Note: The maximum circumference of this opening must not exceed one-half the control structure circumference. The "birdcage" overflow structure shown in Appendix V-A may also be used as a secondary inlet.

Emergency Overflow Spillway

Ponds must have an emergency overflow spillway (except as noted in the next paragraph). For impoundments of 10 acre-feet or greater, the emergency overflow spillway must meet the state's dam safety requirements. For impoundments under 10 acre-feet, ponds must have an emergency overflow spillway sized to pass the 100-year developed peak flow in the event of total control structure failure (e.g., blockage of the control structure outlet pipe) or extreme inflows. Emergency overflow spillways are intended to control the location of pond overtopping and direct overflows back into the downstream conveyance system or other acceptable discharge point.

As an alternative to an emergency overflow spillway for ponds with constructed berms over 2 feet in height, or for ponds located on grades in excess of 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a Type II manhole fitted with a birdcage as shown in Appendix V-A. The emergency overflow structure must be designed to pass the 100-year developed peak flow, with a minimum 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point.

Where an emergency overflow spillway would discharge toward a steep slope, consideration shall be given to providing an emergency overflow structure in addition to the spillway.

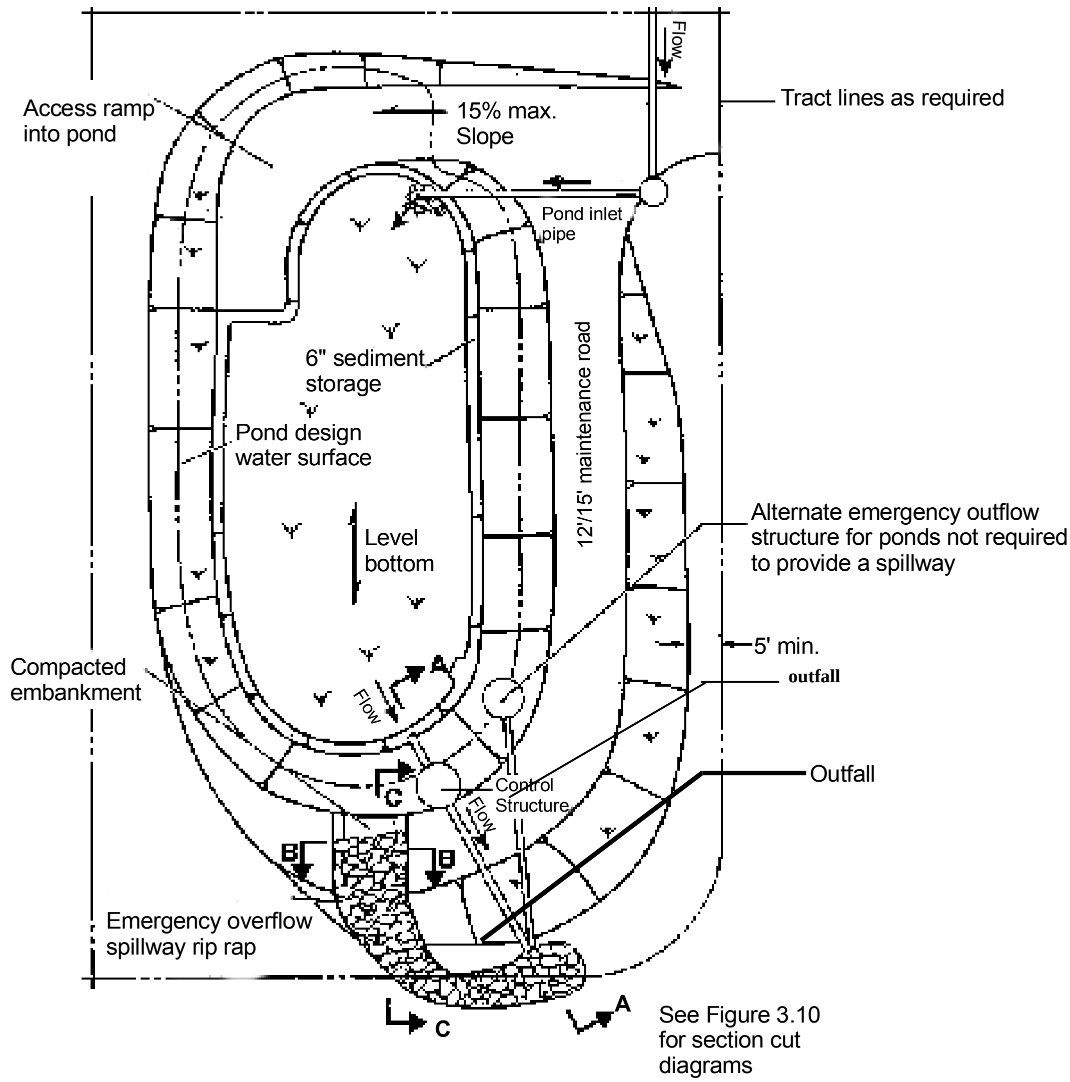
The emergency overflow spillway must be armored with riprap in conformance with the Outlet Protection BMP in Volume II. The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows reenter the conveyance system (see Figure 4.2).

Emergency Overflow Spillway Capacity

For impoundments under 10 acre-feet, the emergency overflow spillway weir section must be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir (see Appendix V-A).

Design Criteria

See Figures 4.1 and 4.2 for typical detention pond layout.



Note:
This detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 4.1. Typical Detention Pond.

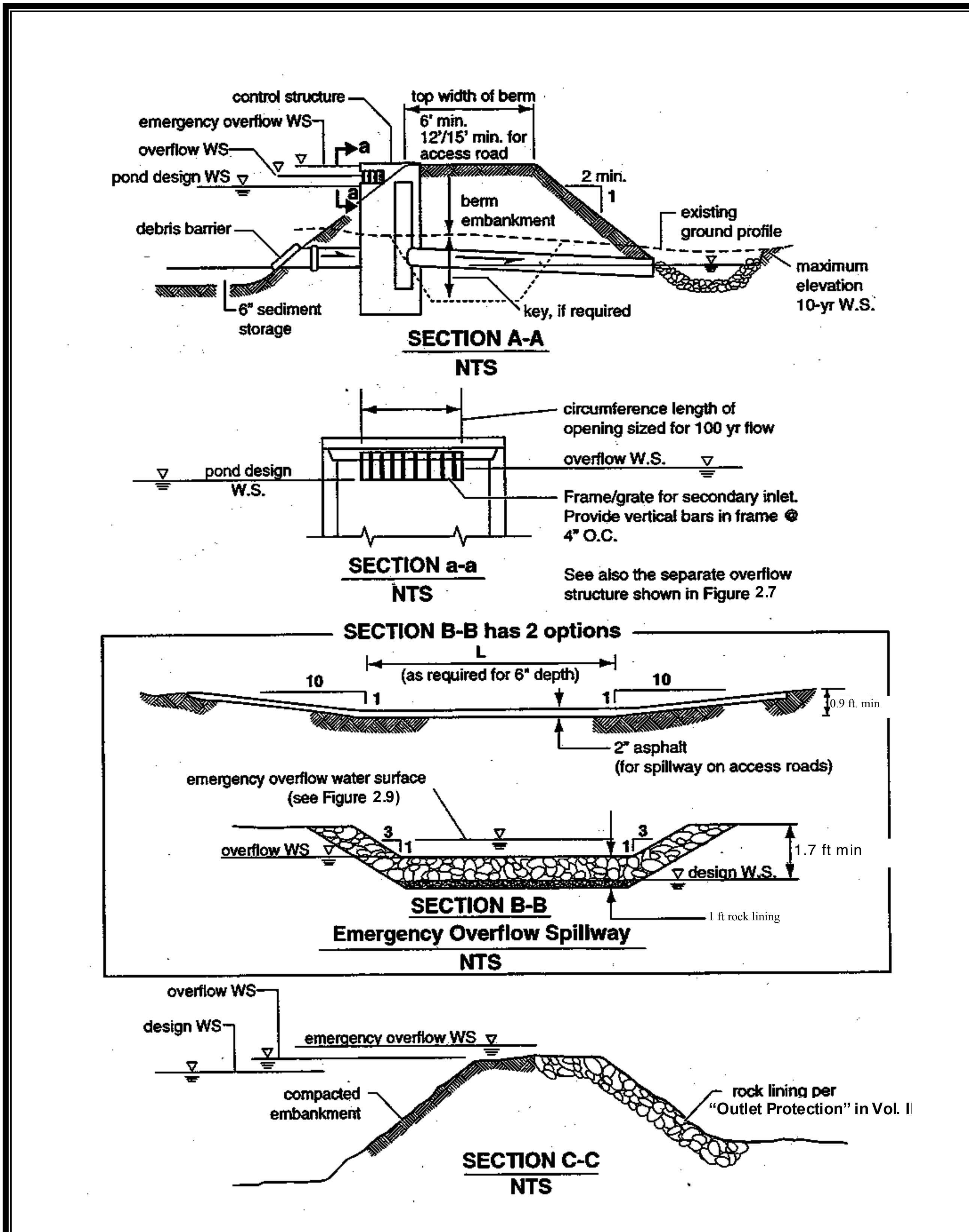


Figure 4.2. Typical Detention Pond Sections.

Geometry

- Pond bottoms must be level and be located a minimum of 0.5 foot (preferably 1 foot) below the inlet and outlet to provide sediment storage.
- Interior side slopes up to the emergency overflow water surface shall not be steeper than 3H:1V unless a fence is provided (see Appendix V-E, Fencing).
- Exterior side slopes must not be steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.

Structural Design Considerations

Ponds Located near Steep Slopes or Landslide Hazard Areas

A geotechnical analysis and report must be prepared for work located within 300 feet of the top of a slope designated a landslide hazard area (as defined in Thurston County Code Title 17.15.600, typically 50 percent, or lesser slopes if seeps are present). The scope of the geotechnical report shall include the assessment of impoundment seepage on the stability of natural slopes where the facility will be located within the setback limits of steep slopes (greater than 15 percent and 10 foot height).

The Administrator or designee may require a geotechnical report to evaluate whether a slope exceeding 15 percent is a landslide hazard area. Increased setbacks or other prohibitions may result from this report. The geotechnical analysis and report shall address the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

Vertical Side Slopes

Vertical retaining walls including rockeries, concrete, masonry unit walls, and keystone type walls may be used to contain the pond, provided:

- They are designed by a licensed geotechnical engineer or civil engineer with structural experience and account for the saturated conditions of the base and retained soils. Structural calculations are stamped by the professional engineer.
- A fence is provided along the top of the wall (see Appendix V-E)
- The entire pond perimeter may be retaining walls, however, it is recommended that at least 25 percent of the pond perimeter be a vegetated soil slope not steeper than 3H:1V
- An access ramp to the bottom of the pond is provided.

Embankments

Pond berm embankments must meet the following requirements:

- Constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report), which is free of loose surface soil materials, roots and other organic debris

- Constructed by excavating a "key" equal to 50 percent of the berm embankment cross-sectional height and width (except on till soils where the "key" minimum depth can be reduced to 1 foot of excavation into the till)

- Constructed of compacted soil (a minimum of 95 percent of the maximum dry density, standard proctor method per ASTM D1557) placed in 6 inch lifts, with the following soil characteristics per the United States Department of Agriculture's Textural Triangle: a minimum of 30 percent clay, a maximum of 60 percent sand, a maximum of 60 percent silt, with nominal gravel and cobble content or as recommended by a geotechnical engineer. (Note: glacial till is normally well-suited for berm embankment material) The core shall be adequate to make the embankment impervious.

- Anti-seepage collars shall be placed on outflow pipes in berm embankments impounding water greater than 8 feet in depth at the design water surface.

- Exposed earth on the pond side slopes shall be sodded or seeded with appropriate seed mixture (see Volume II, Erosion and Sedimentation Control BMPs). Establishment of protective vegetative cover shall be ensured with appropriate surface protection BMPs and reseeded as necessary.

- Where maintenance access is provided along the top of the berm, the minimum width of the top of the berm shall be 15 feet.

- Pond berm embankments greater than 6 feet in height shall require a design by a qualified Professional Engineer licensed in the State of Washington. Berm embankment width shall otherwise vary as recommended by the Professional Engineer.

- Embankments less than 6 feet in height shall have a minimum 6 foot top width and slopes not to exceed 2H:1V. However, maintenance access for mowing and pond access must still be provided.

- Embankments adjacent to a stream or other body of water shall be sufficiently protected with riprap or bio-engineering methods to prevent erosion of the pond embankment. Other control measures may be necessary to protect the embankment.

- Exterior and interior side slopes of retention and detention ponds that are steeper than 2H:1V, must be analyzed for stability by a qualified civil or geotechnical engineer.

- Anti-seepage filter-drain diaphragms must be placed on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Part IV, Section 3.3.B (pages 3-27 to 3-30) of the Dam Safety Guidelines (Ecology 2004). An electronic version of the Dam Safety Guidelines is available in PDF format at <http://www.ecy.wa.gov/programs/wr/dams/GuidanceDocs.html>.

Dam Safety for Detention BMPs

Stormwater facilities that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more with the water level *at the embankment crest* are subject to the state's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled release of the pond contents. Peak flows from dam failures are typically much larger than the 100-year flows which these ponds are typically designed to accommodate.

Electronic versions of dam safety guidance documents in PDF format are available on the Department of Ecology Web site at: <http://www.ecy.wa.gov/programs/wr/dams/dss.html>.

Site Design Elements

For planting recommendations, setbacks, signage and fencing, see Appendix V-E.

Construction and Maintenance

For access road design information, see Appendix V-D.

Maintenance

Maintenance can help ensure that detention ponds continue to function as originally designed. Hence, provisions to facilitate maintenance operations must be built into the project when it is installed. Thurston County, a designated group (such as a homeowner's association) or some individual must accept responsibility for maintaining the structures and the impoundment area. It is Thurston County policy not to accept maintenance responsibility for facilities constructed by a private applicant even if they serve runoff from the public right-of-way.

A maintenance plan must be formulated that outlines the schedule and scope of maintenance operations. See Appendix V-C for information on maintenance requirements for detention ponds.

Any standing water removed during the maintenance operation must be disposed of at an approved discharge location. Any discharge to a sanitary sewer system requires approval of the sewer service provider and is generally not allowed. Pretreatment may be necessary if standing water is not free of pollutants. Residuals must be disposed in accordance with state and local solid waste regulations (see Minimum Functional Standards for Solid Waste Handling, Chapter 173-304 WAC).

4.1.2 D.02 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Standard detention tank details are shown in Figure 4.3 and Figure 4.4.

Applicability

Detention tanks are appropriate for highly developed sites with limited land available for surface facilities.

Limitations

Detention tanks are typically laid flat or at a very low slope, so they are not likely appropriate for steep sections of roadway, due to the large amount of excavation required.

Tanks shall not be located under the travel way in public rights-of-way.

Hydrologic and Hydraulic Design Considerations

General Hydraulic Design Considerations

Tanks may either be designed as flow-through or back-up systems (see Figure 4.3).

Detention Volume

The volume and outflow design for detention tanks must comply with both Minimum Requirement #7-Flow Control in Volume I and hydrologic analysis and design methods described in Volume III.

Control Structures

Details of outflow control structures are given in Appendix V-A.

Tanks may be designed as flow-through systems or may be designed as backup systems if preceded by water quality facilities, since little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank.

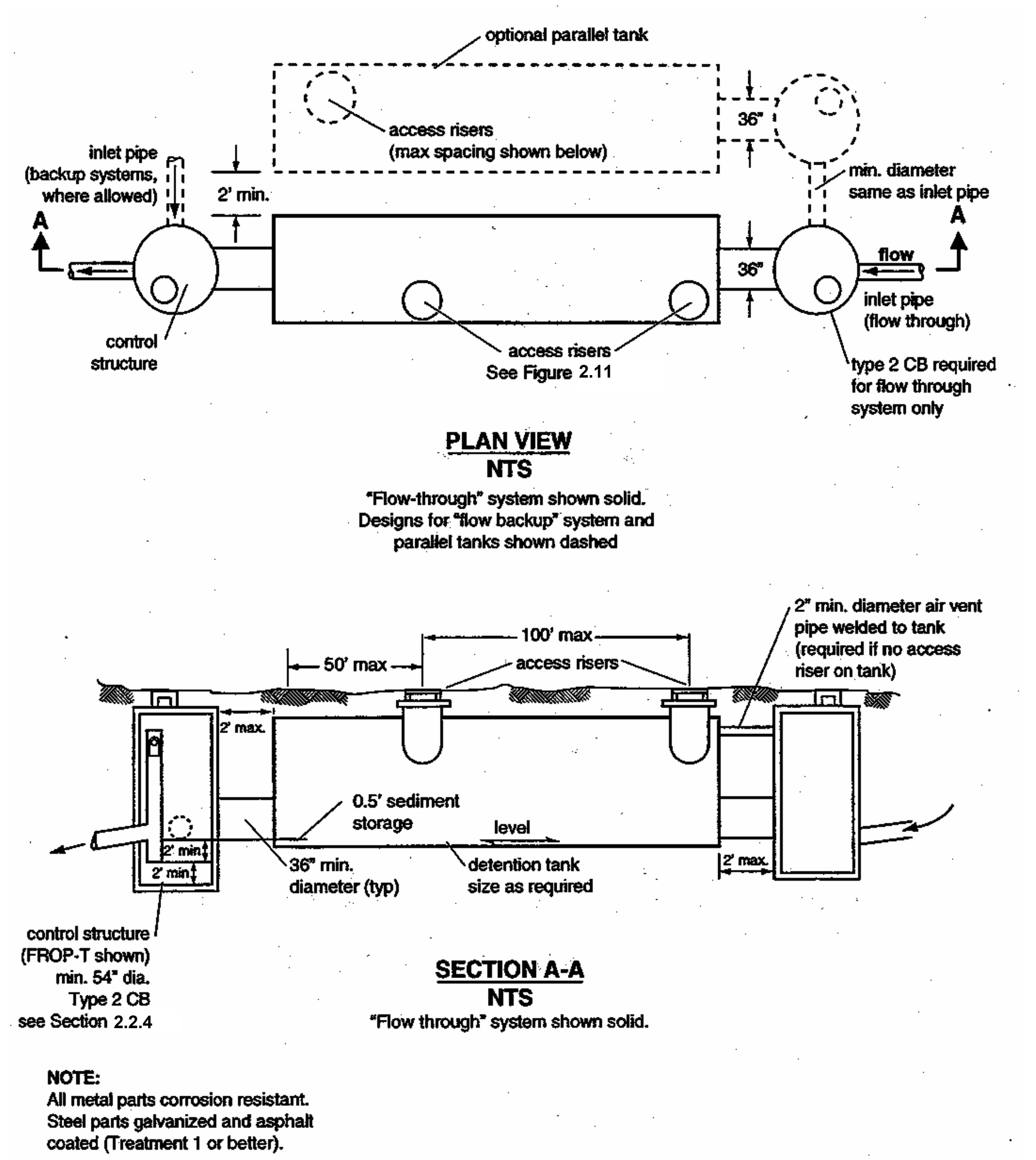
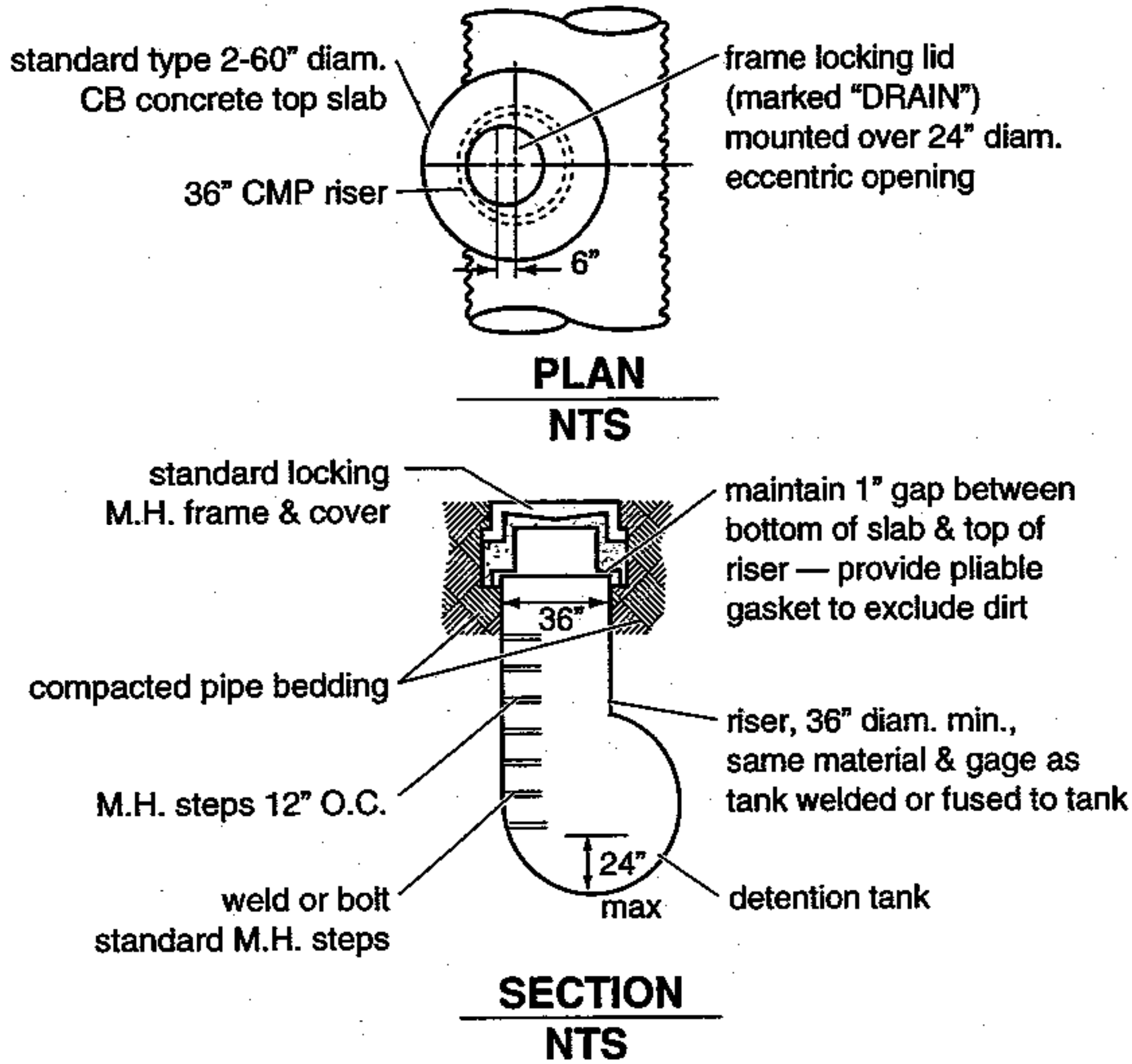


Figure 4.3. Typical Detention Tank.



Notes:
1. Use adjusting blocks as required to bring frame to grade.
2. All materials to be aluminum or galvanized and asphalt coated (Treatment 1 or better).
3. Must be located for access by maintenance vehicles.
4. May substitute WSDOT special Type IV manhole (RCP only).

Figure 4.4 Detention Tank Access Detail.

Design Criteria

Geometry

- The detention tank bottom shall be located 0.5 feet below the inlet and outlet to provide dead storage for sediment.
- The minimum pipe diameter for a detention tank is 36 inches.
- Tanks larger than 36 inches shall be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe. These sections will not be considered as access when determining required access points.
- The maximum depth to a detention tank invert shall be 20 feet.

Materials

Materials for underground detention tanks shall conform to requirements for conveyance systems described in Volume III. Materials for pipe shall be limited to:

- Aluminum spiral rib pipe (12-gauge minimum)
- Corrugated aluminum pipe and pipe arch (12-gauge minimum)
- Reinforced concrete pipe
- Corrugated high density polyethylene pipe (CPEP) – Smooth interior

No corrugated iron or steel pipe (galvanized or aluminized) will be allowed. Galvanized metals leach zinc into the environment, especially in standing water situations. This can result in zinc concentrations that are toxic to aquatic life. Therefore, use of galvanized materials in stormwater facilities and conveyance systems is prohibited.

Pipe material, joints, and protective treatment for tanks shall be in accordance with Section 9.05 of the *WSDOT Standard Specifications for Road, Bridge, and Municipal Construction*.

Detention tanks are not to be perforated so as to provide infiltration of stormwater.

Structural Design Considerations

Structural Stability

Tanks must meet structural requirements for overburden support and traffic loading (if appropriate). H-20 live loads shall be accommodated for tanks lying under parking areas and access roads. Metal tank end plates shall be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gauge material than the pipe, and may require reinforcing ribs. Tanks shall be placed on stable, well-consolidated native material with a suitable bedding. Tanks shall not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Buoyancy

Buoyancy calculations shall be required where groundwater may induce flotation. Buoyancy must be balanced by ballasting with backfill or concrete backfill, providing concrete anchors, increasing total weight, or providing subsurface drains to permanently lower the groundwater table. Calculations that demonstrate stability must be documented by the project engineer.

Access

Access requirements for detention tanks are as follows:

- Access must be provided to the upstream terminus of the tank if the tank is designed with a common inlet/outlet (e.g., a backup system rather than a flow through system).
- All tank openings must be easily accessible by maintenance vehicles.
- The maximum depth from finished grade to tank invert shall be 20 feet.
- Access points must support expected wheel loads.
- Access openings shall be positioned a maximum of 50 feet from any location within the tank.
- All tank access openings shall have round, solid locking lids (usually 1/2- to 5/8-inch diameter Allen-head cap screws).
- Thirty six-inch minimum diameter CMP riser-type manholes (Figure 4.4) of the same gage as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch

minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.

- Tanks must comply with the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Site Design Elements

Detention tanks shall not be located under the travel way in public rights-of-way. For all residential subdivisions and mixed use developments the detention tank shall be located in a separate tract with access from a public right-of-way. See Section 3.6 of Volume III for additional requirements.

Setbacks

All stormwater vaults and tanks shall be setback from any structure or property line at least a distance equal to the depth of the ground disturbed in setting the structure. Additional setbacks are listed under BMP D.01 – Detention Pond and Appendix V-E. Vaults and tanks shall also be within tracts or easements with widths equivalent to those listed for conveyance systems in Section 3.6 of Volume III.

All facilities must be a minimum of 50 feet from top of slopes steeper than 15 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

Construction and Maintenance

Maintenance

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix V-C for specific maintenance requirements.

Access Roads

Access roads are needed to all detention tank control structures and risers. The access roads shall be designed and constructed as specified in Appendix V-D. Access shall be provided through a tract or easement connecting to a public right-of-way. See additional access requirements in Volume III.

4.1.3 D.03 Detention Vaults

Applicability

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. Detention vaults are appropriate for highly developed sites with limited land available for surface facilities.

Hydrologic and Hydraulic Design Considerations

Detention Volume and Outflow

Volume and outflow design for detention vaults must comply with both Minimum Requirement #7 in Volume I, and the hydrologic analysis and design methods described in Volume III.

Restrictor and orifice design are given in Appendix V-A.

Details of outflow control structures are given in Appendix V-A.

Design Criteria

A standard detention vault detail is shown in Figure 4.5. Control structure details are shown in Appendix V-A.

Typical design guidelines are as follows:

- Detention vaults may be designed either as flow through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized where feasible.

- The detention vault bottom may slope at least 5 percent from each side towards the center, forming a broad “v” to facilitate sediment removal. More than one “v” may be used to minimize vault depth. Alternatively, the vault bottom may be flat with 0.5 to 1 foot of sediment storage if removable panels are provided over the entire vault. It is recommended that the removable panels be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.

- The invert elevation of the outlet shall be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet shall also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.

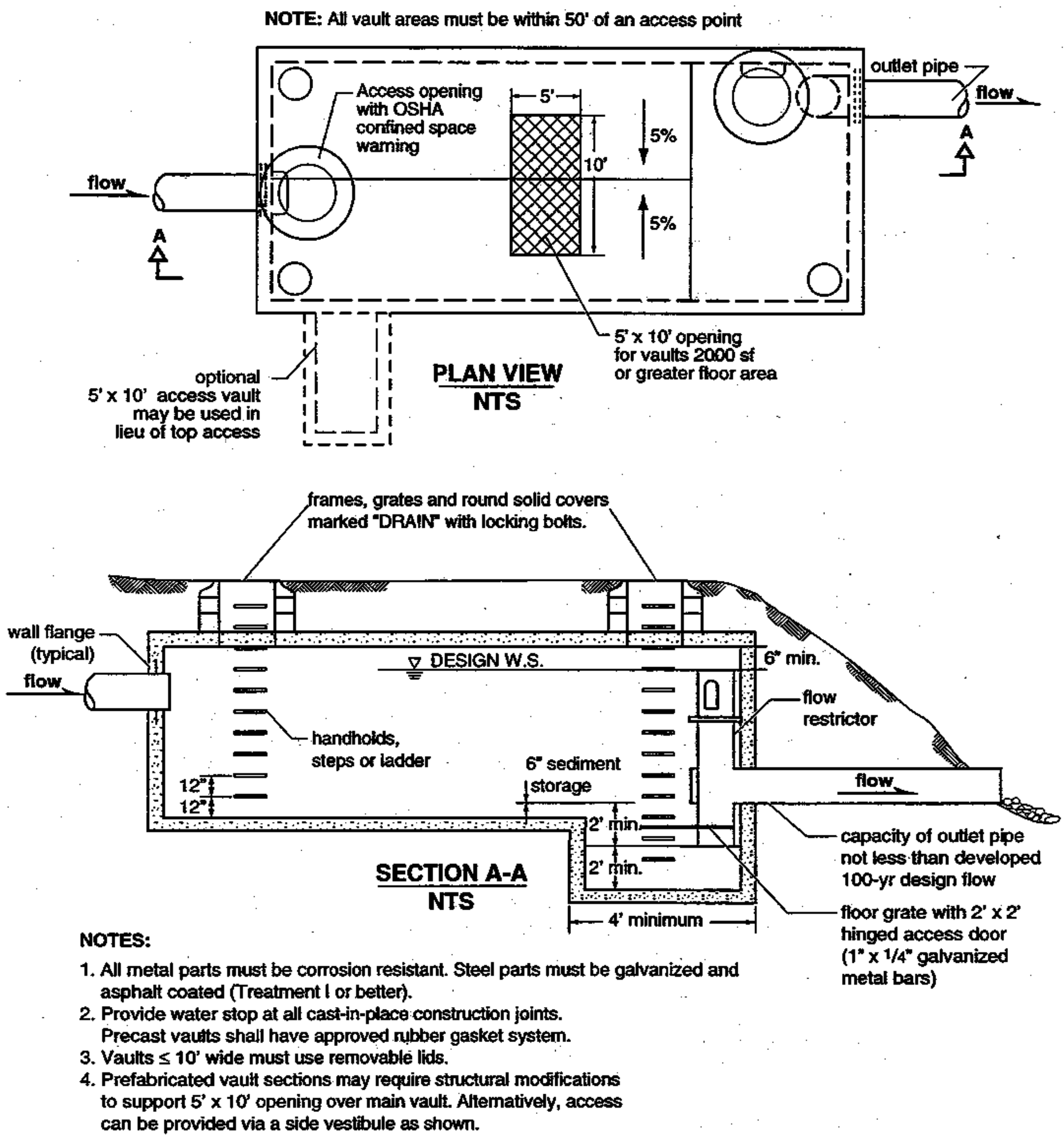


Figure 4.5. Typical Detention Vault.

Geometry

- The maximum depth from finished grade to the vault invert shall be 20 feet
- The minimum internal height shall be 7 feet, measured from the highest point of the vault floor (not sump), and the minimum width shall be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. The minimum internal height requirement may not be needed for any areas covered by removable panels.

Structural Design Considerations

Materials

Minimum 3,000 psi structural reinforced concrete shall be used for detention vaults. All construction joints must be provided with water stops. Pre-cast vaults or vaults made of materials other than concrete may be allowed subject to meeting the requirements of this section and with prior acceptance of the Administrator or designee.

Structural Stability

All vaults shall meet structural requirements for overburden support and H-20 traffic loading (See Standard Specifications for Highway Bridges, 1998 Interim Revisions, American Association of State Highway and Transportation Officials). Cast-in-place wall sections shall be designed as retaining walls. Structural designs for cast-in-place vaults shall be stamped by a licensed civil engineer with structural expertise. Vaults shall be placed on stable, well-consolidated native material with suitable bedding. Vaults shall not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Access

Access must be provided over the inlet pipe and outlet structure. The following guidelines for access shall be used:

- Access openings must be positioned a maximum of 50 feet from any location within the tank. Additional access points may be needed on large vaults. If more than one “v” is provided in the vault floor, access to each “v” must be provided.
- For vaults with greater than 1,250 square feet of floor area, a 5' by 10' removable panel shall be provided over the inlet pipe (instead

of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided as shown in Figure 3.16.

- Ladders and hand-holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified below.
- All access openings, except those covered by removable panels, shall have round, solid locking lids, or 3-foot square, locking diamond plate covers.
- Vaults with widths 10 feet or less shall have removable lids.
- Any vault requiring internal structural walls shall provided wall openings sufficient for maintenance access between cells. The openings shall be sized and situated to allow access to the maintenance "v" in the vault floor.
- Vaults must comply with the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.
- Ventilation pipes (minimum 12-inch diameter or equivalent) shall be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively removable panels over the entire vault may be provided.

Site Design Elements

Detention vaults shall not be located under the travel way in public rights-of-way. For all residential subdivisions and mixed use developments the detention vault shall be located in a separate tract with access from a public right-of-way. See Section 3.6 of Volume III for additional requirements.

Setbacks

All stormwater vaults shall be setback from any structure or property line at least a distance equal to the depth of the ground disturbed in setting the structure. Additional setbacks are listed under BMP D.01 – Detention Pond and in Appendix V-E. Vaults shall also be within tracts or easements with widths equivalent to those listed for conveyance systems in Section 3.6 of Volume III.

All facilities must be a minimum of 50 feet from top of slopes steeper than 15 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

Construction and Maintenance

Maintenance

Maintenance must be a basic consideration in design and in determination of first cost. Provisions to facilitate maintenance operations must be built into the vault, including panels, access openings, and openings between structural interior walls as applicable, as specified under *structural design considerations*, above.

See Appendix V-C for additional information on maintenance requirements.

Access

An access road must be provided to the control structure, panels, and other maintenance openings. See Appendix V-D for design and construction requirements.

4.1.4 D.04 Use of Parking Lots for Additional Detention

Private parking lots may be used to provide additional detention volume for runoff events greater than the 2-year runoff event if the following requirements are met:

- The depth of water detained does not exceed 1 foot at any location in the parking lot for runoff events up to and including the 100-year event.
- The gradient of the parking lot area subject to ponding is 1 percent or greater.
- The emergency overflow path is identified and noted on the engineering plan. The overflow must not create a significant adverse impact to downhill properties or drainage system.
- Fire lanes used for emergency equipment are free of ponding water for all runoff events up to and including the 100-year event.
- No overflow to a public right-of-way occurs.

Chapter 5 - Biofiltration BMPs

5.1 Biofiltration BMPs

Biofiltration provides runoff treatment by combining vegetation with slow and shallow-depth flow. As runoff passes through the vegetation, pollutants are removed by filtration, infiltration, and settling. These effects are aided by the reduction in velocity of stormwater as it passes through the biofilter. Biofiltration facilities include *swales*, designed to convey and treat concentrated runoff at shallow depths and slow velocities, and *filter strips*, broad areas of vegetation for treating sheet flow runoff.

A biofilter can be used as a basic treatment BMP for stormwater runoff from roadways, driveways, parking lots, and other pollution generating pervious and impervious surfaces. It can also be used as the first stage of a treatment train, multiple BMPs in a series for treating contaminated stormwater runoff. Placement of the biofilter "off-line" is preferred to on-line applications to avoid flattening of the vegetation and the erosive effects of high flows.

Generally biofiltration BMPs are suitable for sites that have the following characteristics:

- Accessibility for operation and maintenance
- Suitable growth environment (soil, exposure to sunlight, etc.) for the vegetation
- Adequate change in grade to allow inflow to the biofilter and conveyance to additional treatment/detention facilities located downstream.

The following biofiltration BMPs are described in this section:

- BF.01 Basic Biofiltration Swale
- BF.02 Wet Biofiltration Swale
- BF.03 Continuous Inflow Biofiltration Swale
- BF.04 Basic Filter Strip
- BF.05 Narrow Area Filter Strip
- BF.06 Compost Amended Vegetated Filter Strip.

5.1.1 BF.01 Basic Biofiltration Swale

Biofiltration swale with check dams at Ecology headquarters

Applicability

Biofiltration swales are a low-cost, easy to construct and maintain BMP that provides basic treatment or provides pretreatment for an infiltration facility or for another enhanced BMP.

Limitations

Basic biofiltration swales require a substantial amount of open space and flat, longitudinal slopes, and so will not work on every site. A site suitable for biofiltration swales should have the following:

- Adequate space to accommodate the swale (a minimum of 100 feet long with a bottom width of 2 feet; may be larger depending on flows)
- A longitudinal slope between 1.5 percent and 2.5 percent. Shallower slopes would require an underdrain and steeper slopes would require check dams at vertical drops of 12 to15 inches.
- Maintenance access.

Submittals and Approval

Biofiltration swale calculations as outlined in this section shall be provided for each biofiltration swale included in the project. Include calculations in the submittal completed in accordance with the requirements of Volume I, Chapter 3.

Project drawings shall show the location, slope, and bottom width of each biofiltration swale. Detail sheets shall include a biofiltration swale cross-section and specifications for seeding, amending soils, sodding and other design criteria as described in this section.

Pretreatment

Pretreatment is not required.

Hydrologic and Hydraulic Design Considerations

Table 5.1. Sizing Criteria Biofiltration Swale

Design Parameter	Requirement
Longitudinal Slope	0.015 – 0.025 (unless underdrain or check dams are included in the design - see note 1.)
Maximum Velocity	1 ft/sec
Maximum velocity for channel stability[2]	3 ft/sec
Maximum water depth	2” – if mowed frequently; 4” if mowed infrequently
Manning coefficient	0.2-0.3 (0.24 if mowed infrequently
Bed width (bottom)	2-10 ft (unless dividing berm and flow spreader are incorporated into the design – see note 3.)
Freeboard height	0.5 ft
Minimum hydraulic residence time at K multiplied by WQ Design Flow Rate	9 minutes (18 minutes for continuous inflow)
Minimum length	100 ft
Maximum sideslope	3H:1V 4H:1V preferred (backslope of 2H:1V allowed for limited right-of-way areas)

Notes:

1. For swales, if the slope is less than 1.5% install an underdrain using a perforated pipe, or equivalent. Amend the soil if necessary to allow effective percolation of water to the underdrain. Install the low-flow drain 6 inches deep in the soil. Slopes greater than 2.5% need check dams (riprap) at vertical drops of 12-15 inches. Underdrains can be made of 5 inch Schedule 40 PVC perforated pipe or equivalent with 6 inches of drain gravel on the pipe. The gravel and pipe must be enclosed by geotextile fabric.
2. Maximum flowrate for channel stability shall be the 100-year, 24-hour discharge calculated with WWHM using a 15-minute time step, or alternatively the 100-year, 24-hour event using a single event hydrologic model (SBUH or SCS).
3. For swale widths up to 16 feet the cross-section can be divided with a berm (concrete, plastic, compacted earthfill) using a flow spreader at the inlet.

Design Process Overview

To design a biofiltration swale for a project, perform the following per the detailed design guidance included in this section:

- Identify the location on the site, available slope constraints, and contributing area to the swale. Determine if swale will be upstream or downstream of detention and whether on-line or off-line. Note: if swale is downstream of detention a "wet biofiltration swale" swale design is required, see BMP BF.02.
- If slope is less than 1.5 percent, an underdrain will be required. If slope greater than 2.5 percent check dams will be required.
- Perform hydrologic modeling to establish design flows using either a single-event model (SBUH or SCS) or continuous simulation model.
- Size the swale to treat the water quality design event. Minimum length is 100 feet.
- Check the hydraulic capacity/stability of the swale under the 100-year flow condition (for on-line swale only).
- Select vegetation cover suitable for the swale.
- Determine need for level spreader and establish spacing/design.

Design Flow

Biofiltration swales shall be designed to treat the water quality design storm, as calculated using the Santa Barbara Urban Hydrograph (SBUH) method for a 6-month, 24-hour storm with a Type 1A rainfall distribution (Volume III). If hydrologic calculations are being performed using a continuous hydrologic model, the water quality design flow rate predicted by an approved continuous runoff model may be multiplied by the ratio from Figure 5.1a or 5.1b (for online or off-line swales, respectively) to obtain the design flow rate. This modified design flow rate is an estimate of the design flow rate determined by using SBUH procedures. Recent biofiltration sizing recommendations (9 minutes detention at the peak design flow rate estimated by SBUH for a 6-month, 24-hour storm with a Type 1A rainfall distribution) will be maintained until more definitive information on bioswale performance is collected.

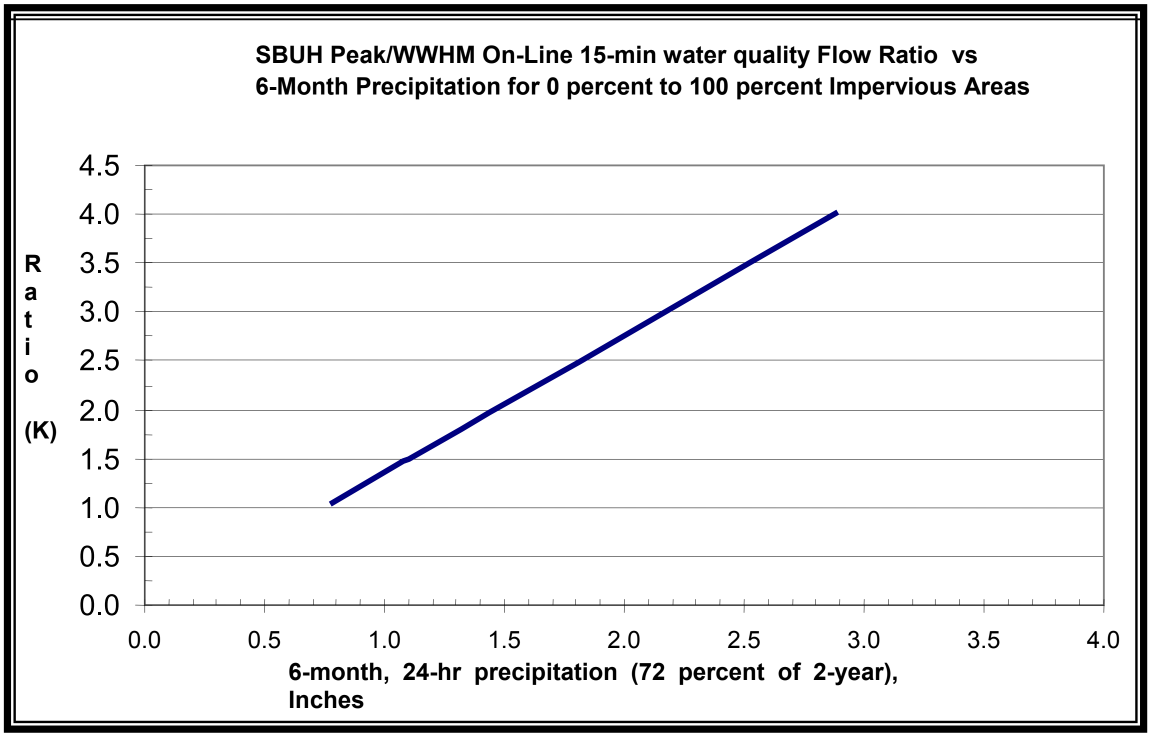


Figure 5.1.a. Ratio of SBUH Peak/Water Quality Flow.

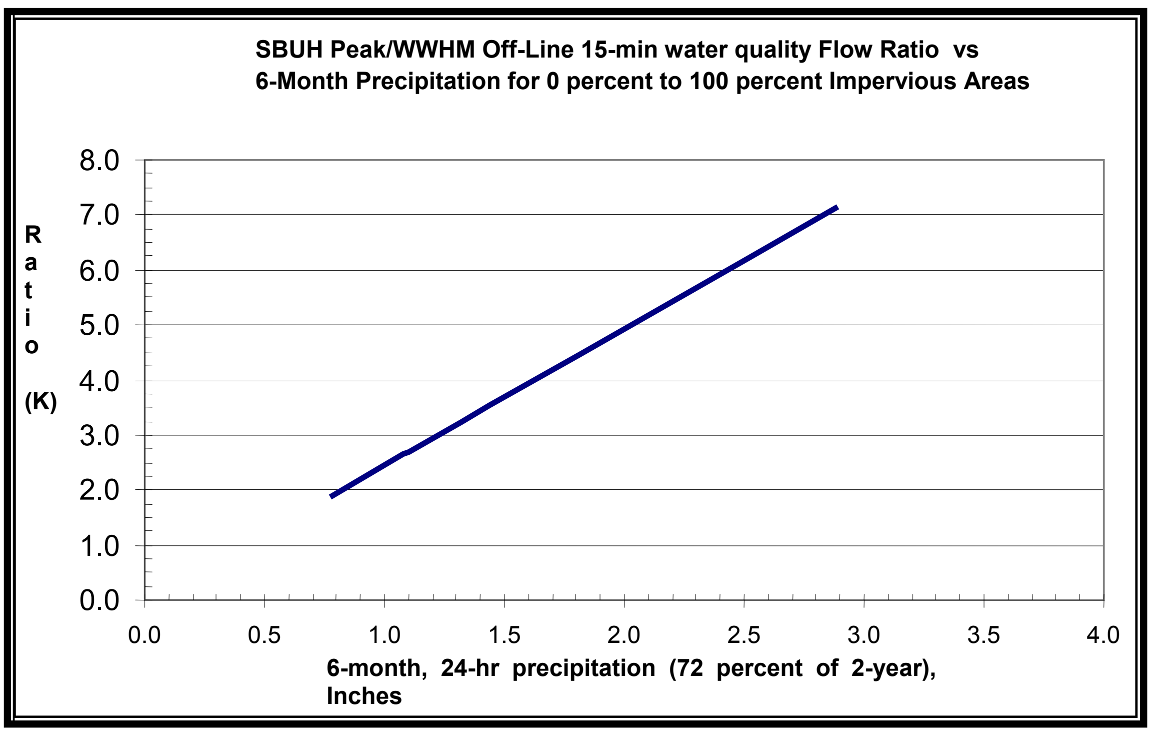


Figure 5.1.b. Ratio of SBUH Peak/Water Quality Flow.

Guidance for Bypassing Off-line Facilities

Biofiltration swales should be designed as off-line facilities, which receive only the water quality design flow rate, where feasible. For online systems, designers must evaluate the hydraulic capacity/stability for inflows greater than design flows. When designing a swale to be off-line, the stability check described under *Sizing Procedure for Biofiltration Swales* is not required.

Swales designed in an off-line mode shall not engage a bypass until the flow rate exceeds the water quality design flow rate.

Hydraulic Residence Time

The swale length must be a minimum of 100 feet. Swale length is determined by selecting swale slope and sectional properties that keep velocity below 1.0 feet per second for the water quality design flow rate and provide a minimum 9-minute hydraulic residence time (see Step D-7).

Velocity

The maximum velocity under the design flow rate is 1.0 feet per second. A velocity greater than 1.0 feet/sec has been found to flatten grasses, thus reducing filtration.

Sizing Procedure for Biofiltration Swales

This guide provides biofilter swale design procedures in full detail, along with examples.

Preliminary Steps (P)

P-1 Determine the Water Quality design flow rate (Q) in 15-minute time-steps using an approved continuous runoff model. Use the correct flow rate, off-line or online, for your design situation. Alternatively, use SBUH (Volume III) to calculate water quality design flow rate (6-month, 24-hour storm), in which case the correction factor, K, will not be required.

P-2 Establish preliminary geometry for your swale depending on your site. For initial calculations, assume the following (note that some of these design criteria may be modified if needed by adding underdrains or check dams but these are good initial assumptions):

- Longitudinal slope of 1.5 to 2.5 percent
- Minimum length 100 feet
- Width of 2 to 10 feet
- Side slopes of 3H:1V or flatter. (2H:1V Allows for backslope only in limited right-of-way applications).

Design Calculations for Biofiltration Swale

D-1. Select the design depth of flow:

- 2” if mowed frequently; 4” if mowed infrequently

D-2. Select a value of Manning's n.

- The manning coefficient will depend on the vegetation selected and the frequency of mowing. It should be in the range of 0.2 – 0.3. A manning coefficient of no less than 0.24 should be used if the swale will be mowed infrequently.

D-3. Select swale shape-typically trapezoidal.

D-4. Set up a table or spreadsheet relating flow depth to hydraulic radius, flow area, and wetted perimeter. For a trapezoidal channel, the relations will be as follows:

$A = by + (Z_1y^2 + Z_2y^2)/2$

Wetted perimeter, $P = b + d(\sqrt{1+Z_1{}^2} + \sqrt{1+Z_2^2})$

Hydraulic Radius, R = A/P

Where:

A = cross-sectional area of flow (square feet)

b = bottom width of trapezoid (feet)

y = flow depth (feet)

Z_1 = side slope on one side of trapezoid ([ft of horizontal distance]/[ft of vertical distance])*;

Z_2 = side slope on other side of trapezoid ([ft of horizontal distance]/[ft of vertical distance])*

*For example, if a swale has side slopes of 3 (horizontal): 1 (vertical), $Z_1 = Z_2 = 3$.

D-5. Use Chezy-Manning equation (which yields velocity), multiplied by the area to calculate conveyance capacity and determine whether swale has adequate capacity to convey water quality design flow within maximum flow depth and velocity constraints.

$$v = \frac{1.49}{n} R^{2/3} \sqrt{s}\text{, and}$$

$$Q = vA$$

- $Y \leq 0.17$ feet if mowed frequently; $y \leq 0.33$ feet if mowed infrequently.
- $V \leq 1$ foot per second.

If the velocity exceeds 1.0 feet/sec, adjust the swale geometry (wider swale bottom, flatter side slopes, and/or flatter longitudinal slope) and repeat steps D-4 and D-5 until the condition is met.

D-7. Compute the swale length (L, feet)

$$L = Vt$$

Where: t = hydraulic residence time (seconds), or 540 seconds (9 minutes).

If a biofilter length is greater than the space permits, investigate how Q can be reduced (e.g., use of LID BMPs). Alternatively, reduce velocity by adjusting the swale geometry (wider swale bottom, flatter side slopes, and/or flatter longitudinal slope) and repeat the analysis.

D-8. If there is still not sufficient space for the biofilter, consider the following solutions:

- Divide the site drainage to flow to multiple biofilters
- Use infiltration to provide lower discharge rates to the biofilter (only if the infiltration requirements in Volume III are met)
- Reduce the developed surface area to gain space for biofiltration
- Nest the biofilter within or around another BMP.

Check for Stability (Minimizing Erosion)

The stability check must be performed for the combination of highest expected flow and least vegetation coverage and height. A check is not required for biofiltration swales that are located "off-line" from the primary conveyance/detention system. Maintain the same units as in the biofiltration capacity analysis.

The maximum permissible velocity for erosion prevention (Vmax) is 3 feet per second.

SC-1. Calculate 100-year recurrence interval flow using 15-minute time steps using an approved continuous runoff model or the 100-year recurrence interval, 24-hour flow from a single event model (SBUH, SCS). If 15-minute time steps are not available in the continuous simulation runoff model, the designer can use the100-year hourly peak flows times an adjustment factor of 1.6 to approximate peak flows in 15-minute time steps.

SC-2. Estimate the vegetation coverage ("good" or "fair") and height when the biofilter will receive flow, or whenever the coverage and height will be least. Avoid flow introduction during the vegetation establishment period by timing planting or bypassing.

SC-3. Estimate the degree of retardance from Table 5.2. When uncertain, be conservative by selecting a relatively low degree.

Table 5.2. Guide for Selecting Degree of Retardance [(a)]

Coverage	Average Grass Height (inches)	Degree of Retardance
Good	<2	E. Very Low
	2-6	D. Low
	6-10	C. Moderate
	11-24	B. High
	>30	A. Very High
Fair	<2	E. Very Low
	2-6	D. Low
	6-10	D. Low
	11-24	C. Moderate
	>30	B. High

[a] See Chow (1959). In addition, Chow recommended selection of retardance C for a grass-legume mixture 6-8 inches high and D for a mixture 4-5 inches high. No retardance recommendations have appeared for emergent wetland species. Therefore, judgment must be used. Since these species generally grow less densely than grasses, using a "fair" coverage would be a reasonable approach.

SC-4. Select a trial Manning's *n* for the high flow condition. The minimum value for poor vegetation cover and low height (possibly, knocked from the vertical by high flow) is 0.033. A good initial choice under these conditions is 0.04.

SC-5. See Figure 5.2 to obtain a first approximation for VR, VR_{approx}.

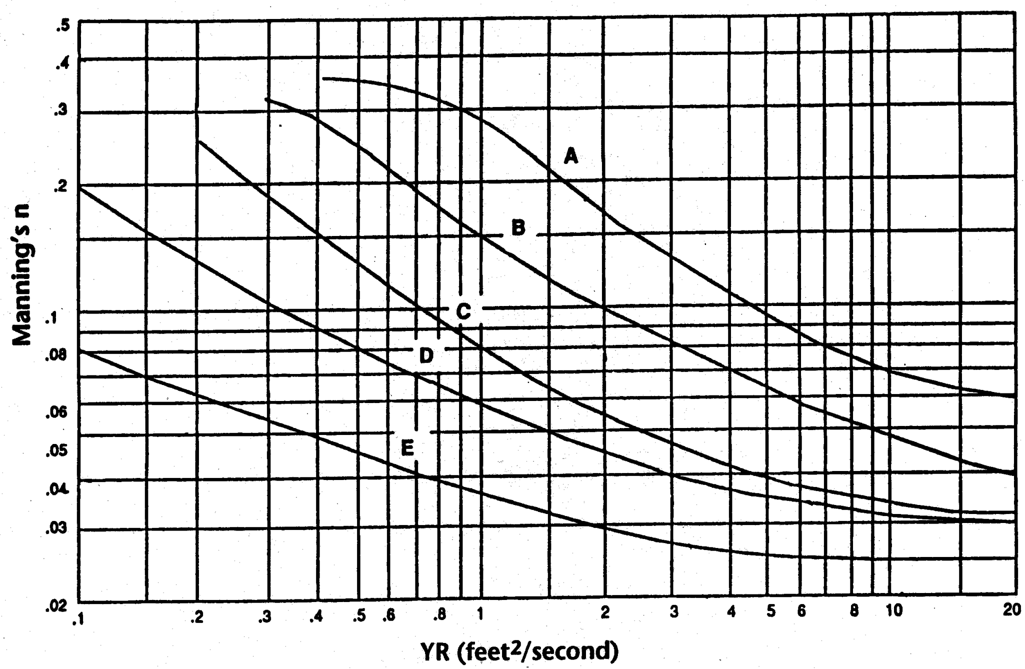
SC-6. Compute hydraulic radius, R_{100}, from VR in Figure 5.2 and a Vmax of 3 ft/second,

$R_{100} = VR_{approx} / V_{max,}$ where VR_{approx} is from Figure 5.2 (step SC-5).

SC-7. Use Chezy-Manning equation multiplied by R to solve for the actual VR:

$$vR = \frac{1.49}{n_{100}} R_{100}^{\ 5/3} \sqrt{s}\ ,$$

Where n_{100} is as selected in step SC-4; and R_{100} is the hydraulic radius calculated in step SC-6.



VR (ft ^{2}/second)

Note: VR is the product of velocity and hydraulic radius

Source: Livingston, et al., 1984

Figure 5.2. The Relationship of Manning's n with VR for Various Degrees of Flow Retardance (A-E).

SC-8. Compare the actual VR from Step SC-7 and first approximation from Step SC-5. If they do not agree within 5 percent, repeat Steps SC-4 to SC-8 until acceptable agreement is reached. If $n<0.033$ is needed to get agreement, set $n = 0.033$, repeat Step SC-7, and then proceed to Step SC-9.

SC-9. Compute the actual V for the final design conditions:

Check to be sure $V < V_{max}$ of 3 ft/second.

SC-10. Compute the required swale cross-sectional area, A, for stability:

SC-11. Compare the A, computed in Step SC-10 of the stability analysis, with the A from the biofiltration capacity analysis (Step D-5).

If less area is required for stability than is provided for capacity, the capacity design is acceptable. If not, use A from Step SC-10 of the stability analysis and recalculate channel dimensions.

SC-12. Calculate the depth of flow at the stability check design flow rate condition for the final dimensions and use A from Step SC-10.

SC-13. Compare the depth from Step SC-12 to the depth used in the biofiltration capacity design (Step D-1). Use the larger of the two and add 0.5 feet of freeboard to obtain the total depth (y_t) of the swale. Calculate the top width for the full depth using the appropriate equation.

SC-14. Recalculate the hydraulic radius: (use b from Step D-4 calculated previously for biofiltration capacity, or Step SC-11, as appropriate, and y_t = total depth from Step SC-13).

SC-15. Make a final check for capacity based on the stability check design storm (this check will ensure that capacity is adequate if the largest expected event coincides with the greatest retardance). Use Equation 1, a Manning's n selected in Step D-2, and the calculated channel dimensions, including freeboard, to compute the flow capacity of the channel under these conditions. Use R from Step SC-14, above, and $A = b(y_t) + Z(y_t)^2$ using b from Step D-4, D-15, or SC-11 as appropriate.

If the flow capacity is less than the stability check design storm flow rate, increase the channel cross-sectional area as needed for this conveyance. Specify the new channel dimensions.

Completion Step (CO)

CO. Review all of the criteria and guidelines for biofilter planning, design, installation, and operation above and specify all of the appropriate features for the application.

Design Criteria

Figures 5.3 through 5.6 provide details of biofiltration swales.

Geometry

Length

Biofiltration swales shall have a minimum length of 100 feet but 200 feet is preferable, where feasible.

Use a wide radius curved path to gain length where land is not adequate for a linear swale (avoid sharp bends to reduce erosion or provide for erosion protection).

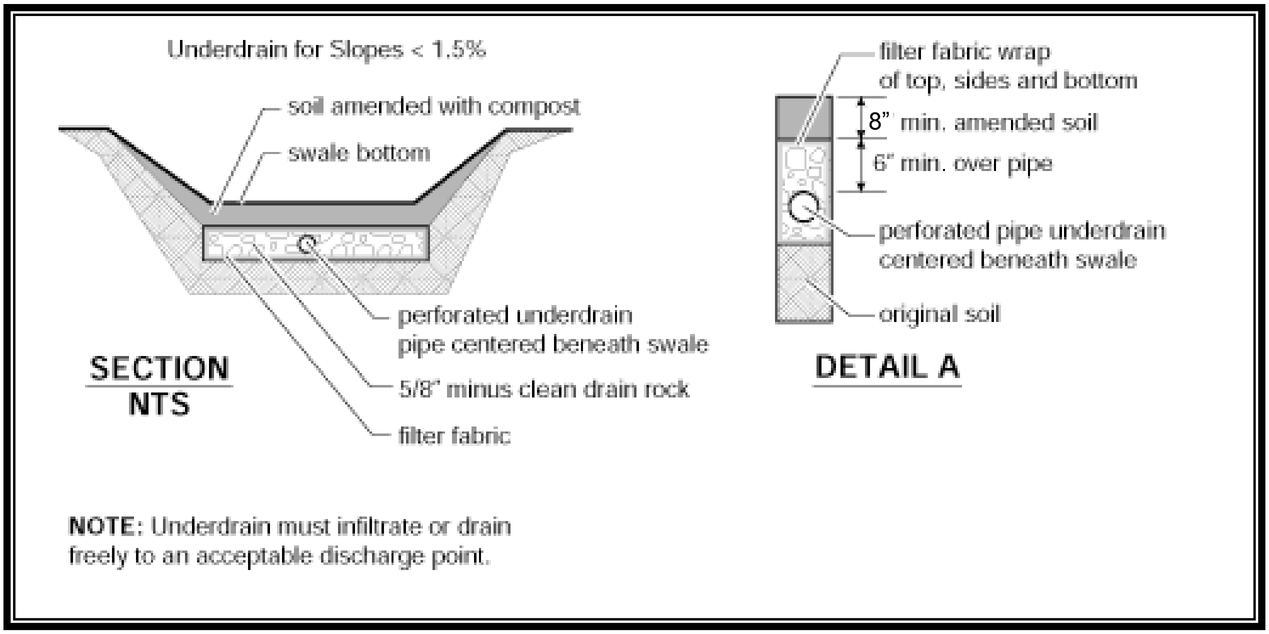


Figure 5.3. Biofiltration Swale Underdrain Detail.

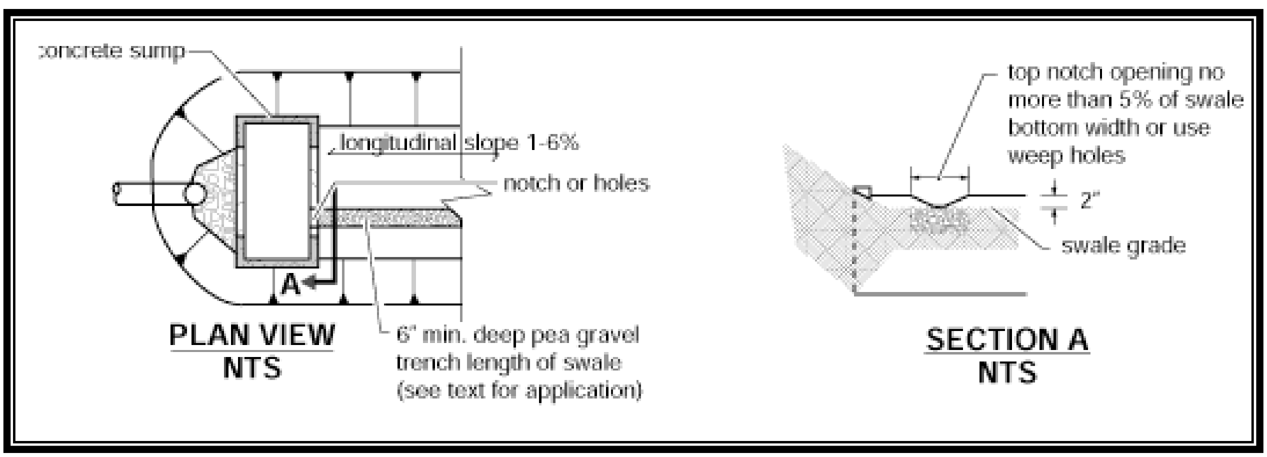
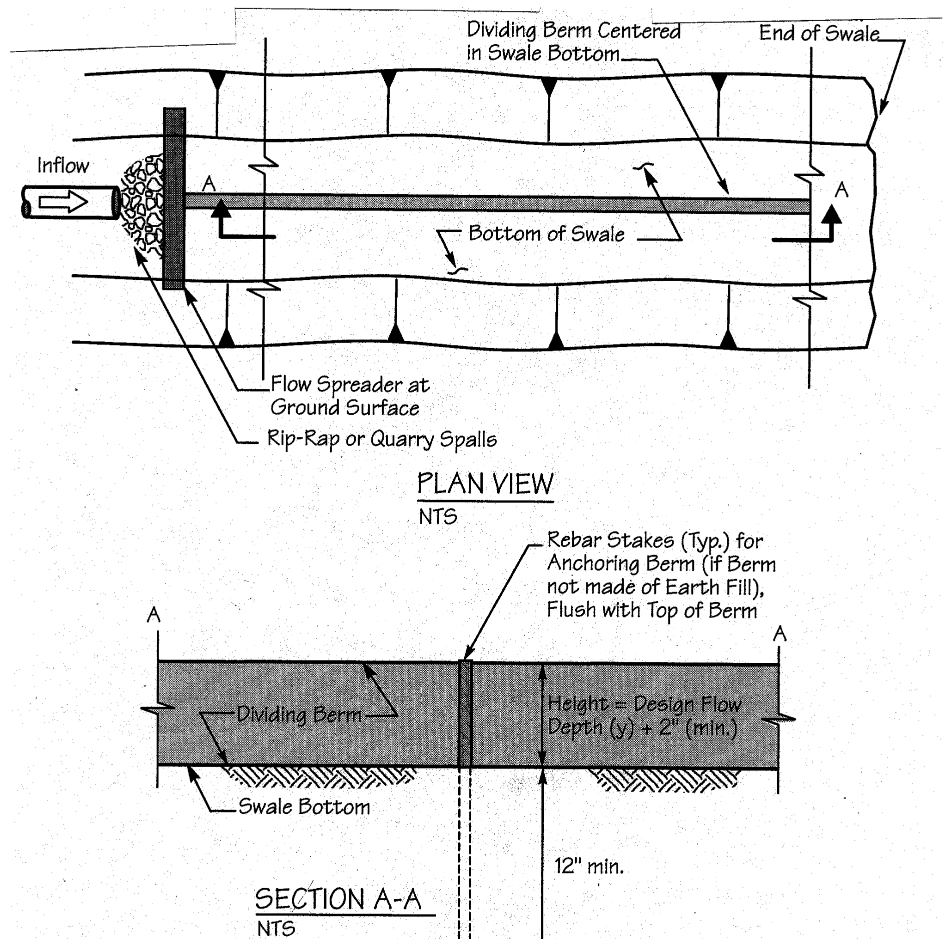


Figure 5.4. Biofiltration Swale Low-Flow Drain Detail.



Notes:

1. Berm may be Made of Compacted Earthfill (seeded with grass), Timber, Concrete Plastic, or Similar Weather - Resistant Non - Erodible Material.

2. Rebar Stakes or Similar Berm Anchoring Materials Needed if Berm Made of Timber, Plastic, or Concrete Curbing - Stake Placement Required at Both Ends of Each Individual Member (at a minimum).

Figure 5.5. Swale Dividing Berm.

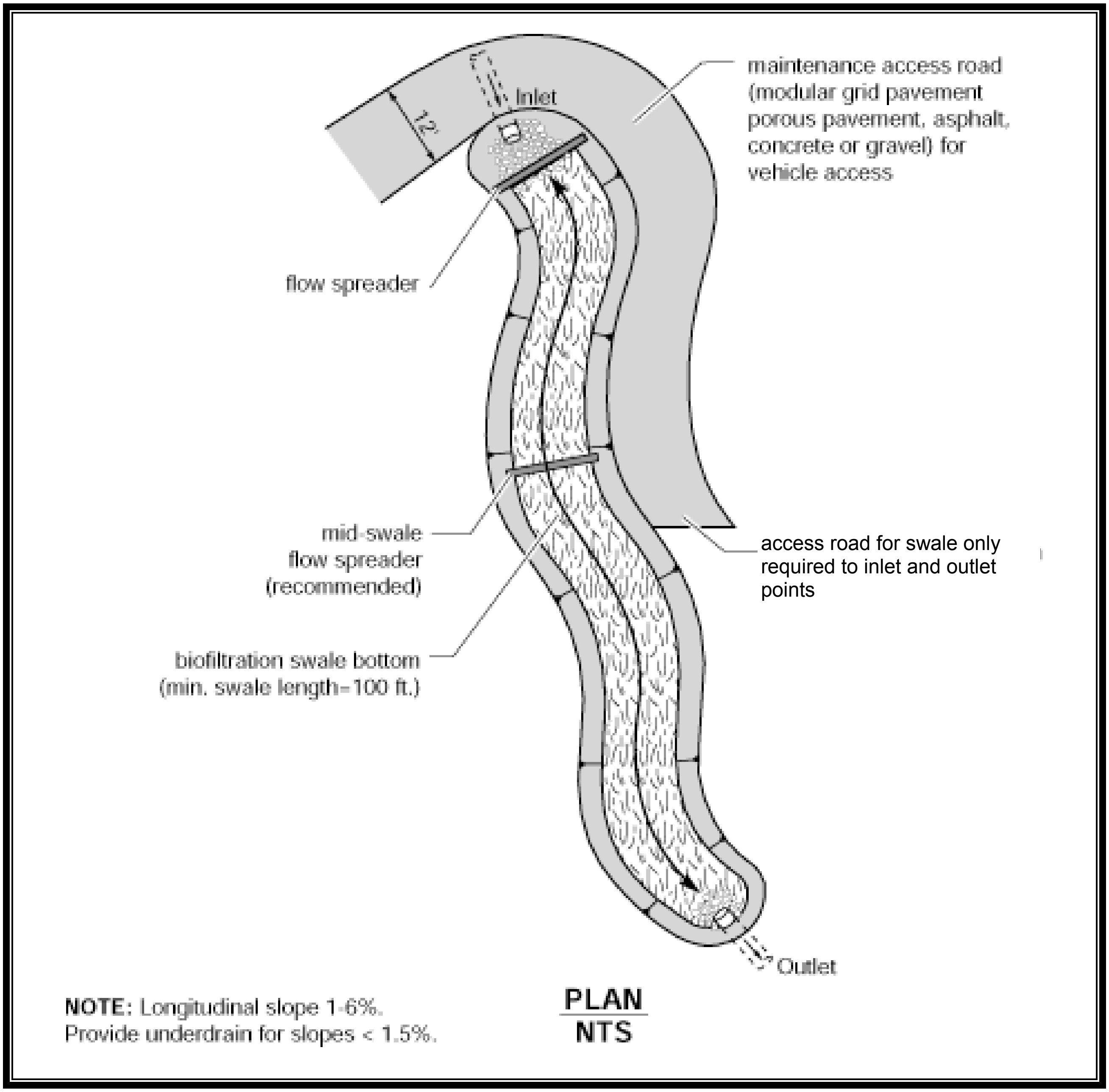


Figure 5.6. Biofiltration Swale Access Features.

Longitudinal Slope

The longitudinal slopes should be between 1.5 percent and 2.5 percent, where feasible. If a flatter or steeper slope is required, the following requirements apply:

- If the slope is less than 1.5 percent, install an underdrain using a perforated pipe or equivalent.
- Amend the soil if necessary to allow effective percolation of water to the underdrain.

- Install the low-flow drain 6 inches deep in the soil.
- Underdrains can be made of 6-inch Schedule 40 PVC perforated pipe with 6 inches of drain gravel on the pipe. The gravel and pipe must be enclosed by geotextile fabric (see Figure 5.3).
- Slopes greater than 2.5 percent need check dams (riprap) at vertical drops of 12 to 15 inches.

Effective treatment depends on flows being dispersed throughout the width of the swale. To avoid channelization, the following design elements are recommended:

- Install level spreaders (minimum 1 inch gravel) at the head and every 50 feet in swales of 4 feet width (or greater). Include sediment cleanouts (weir, settling basin, or equivalent) at the head of the biofilter as needed.

Width and Cross Section

Biofiltration swales are typically trapezoidal in shape.

The swale bottom should be between 2 and 10 feet wide, unless a dividing berm is provided. For swale widths up to 16 feet the cross-section can be divided with a berm (concrete, plastic, compacted earthfill) using a flow spreader at the inlet (Figure 5.5).

Materials

Soil Criteria

The swale shall have a minimum 8 inches of topsoil that conforms to the following:

Table 5.3. Soil Recommendations for Swales

Composition	Percentage	Notes
Sandy Loam	60 to 90	A higher percentage of sand is recommended for soils with longitudinal slopes <2 percent to promote infiltration.
Clay	0 to 10	
Composted organic matter	10 to 30	Use compost amended soil where practicable. Shall not include animal waste or toxic materials.

If groundwater contamination is a concern, seal the bed with clay or a treatment liner (see Appendix V-B).

Vegetation Criteria

Tables 5.4 and 5.5 present recommended grasses and groundcovers. The following invasive species shall not be used:

- *Phalaris arundinaceae* (reed canarygrass)
- *Lythrum salicaria* (purple loosestrife)
- *Phragmites* spp. (reeds)
- *Iris pseudocorus* (yellow iris)
- *Typha* spp (Cattails).

Table 5.4. Grass Seed Mixes Suitable for Biofiltration Swale Treatment Areas

Mix 1		Mix 2	
75-80 percent	tall or meadow fescue	60-70 percent	tall fescue
10-15 percent	seaside/colonial bentgrass	10-15 percent	seaside/colonial bentgrass
5-10 percent	Redtop	10-15 percent	meadow foxtail
		6-10 percent	alsike clover
		1-5 percent	marshfield big trefoil
		1-6 percent	Redtop

Note: all percentages are by weight. * based on Briargreen, Inc.

Table 5.5. Groundcovers and Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington

Groundcovers	
kinnikinnick*	*Arctostaphylos uva-ursi*
Epimedium	*Epimedium grandiflorum*
creeping forget-me-not	*Omphalodes verna*
--	*Euonymus lanceolata*
yellow-root	*Xanthorhiza simplissima*
--	*Genista*
white lawn clover	*Trifolium repens*
white sweet clover*	*Melilotus alba*
-------	*Rubus calycinoides*
strawberry*	*Fragaria chiloensis*
broadleaf lupine*	*Lupinus latifolius*
Grasses (drought-tolerant, minimum mowing)	
dwarf tall fescues	*Festuca* spp. (e.g., Many Mustang, Silverado)
hard fescue	*Festuca ovina duriuscula* (e.g., Reliant, Aurora)
tufted fescue	*Festuca amethystine*
buffalo grass	*Buchloe dactyloides*
red fescue*	*Festuca rubra*
tall fescue grass*	*Festuca arundinacea*
blue oatgrass	*Helictotrichon sempervirens*

Select fine, turf-forming, water-resistant grasses where vegetative growth and moisture will be adequate for growth.

Use sod with low clay content in the bottom of the swale and to a depth of 1 foot to initiate adequate vegetative growth. Consider sun/shade conditions for adequate vegetative growth and avoid prolonged shading of any portion not planted with shade tolerant vegetation.

Construction and Maintenance

The biofiltration swale should not be put into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized.

Effective erosion and sediment control (ESC) measures should remain in place until the swale vegetation is established (see Volume II for ESC BMPs).

Avoid compaction during construction. Grade biofilters to attain uniform longitudinal and lateral slopes.

Eight inches of top soil meeting soil criteria above shall be tilled into the top 8 inches of native soil. Sod of a type meeting the requirements of Table 5.3 shall be installed in the bottom and to a minimum of 1-foot vertical depth above the swale bottom. (Establishing a stand of grass from seed able to hold up to the flows in the swale usually takes too long to establish.) Top soil shall be placed to provide a smooth transition from the sod area to the upper swale area to be seeded.

The swale may need to be irrigated if moisture is insufficient during dry weather season.

Fertilizing a biofilter should be avoided if at all possible. Test the soil for nitrogen, phosphorous, and potassium and consult with a landscape professional about the need for fertilizer in relation to soil nutrition and vegetation requirements. If use of a fertilizer cannot be avoided, use a slow-release fertilizer formulation in the least amount needed.

Maintain access to biofilter inlet, outlet, and for mowing (Figure 5.6).

- If a swale is equipped with underdrains, vehicular traffic on the swale bottom (other than grass mowing equipment) should be avoided to prevent damage to the drainpipes.
- Biofiltration swales located within a residential subdivision shall include signage of a type approved by Thurston County indicating that the biofiltration swale is a water quality treatment facility, that no filling, grading, fertilizing or other disturbance of the swale is

allowed without prior acceptance of Thurston County. One sign shall be located at a minimum along the frontage of each lot and not greater than 200 feet for lot frontages greater than 200 feet. The signs shall be embedded in concrete or otherwise secured to prevent removal.

See Appendix V-C for additional information on maintenance requirements.

5.1.2 BF.02 Wet Biofiltration Swale

A wet biofiltration swale is a variation of a basic biofiltration swale for use where the longitudinal slope is slight, water tables are high, or continuous low base flow is likely to result in saturated soil conditions. When saturation exceeds about 2 weeks, typical grasses will die. Vegetation for wet biofiltration swales, however, is specifically adapted to withstand saturated soil conditions.

Wet swale example

Applicability

Wet biofiltration swales are applied where a basic biofiltration swale is desired but not allowed or advisable due to any of the following conditions:

- The swale is on till soils and is downstream of a detention pond providing flow control
- Saturated soil conditions are likely because of seeps or base flows on the site
- Longitudinal slopes are slight (generally less than 2 percent).

Limitations

The plants selected for wet biofiltration swales are appropriate for saturated soil conditions. Therefore, this BMP is not appropriate where stormwater is likely to infiltrate rapidly, drain quickly, or when saturated soil conditions are otherwise not expected.

Submittals and Approval

As part of submittals made as required in Volume I, include information described under BF.01 for a basic biofiltration swale.

Pretreatment

Pretreatment is not required.

Hydrologic and Hydraulic Design Considerations

Use the same design approach as for basic biofiltration swales except for the following:

- **Adjust for Extended Wet Season Flow:** If the swale will be downstream of a detention pond providing flow control, multiply the treatment area (bottom width times length) of the swale by 2, and readjust the swale length, if desired. Maintain a 5:1 length to width ratio.

- **Intent:** An increase in the treatment area of swales following detention ponds is required because of the differences in vegetation established in a constant flow environment. Flows following detention are much more prolonged. These prolonged flows result in more stream-like conditions than are typical for other wet biofilter situations. Since vegetation growing in streams is often less dense, this increase in treatment area is needed to ensure that equivalent pollutant removal is achieved in extended flow situations.

- **High-Flow Bypass:** A high-flow bypass (i.e., an off-line design) is required for flows greater than the off-line water quality design flow that has been increased by the ratio indicated in Figure 5.1b. The bypass is necessary to protect wetland vegetation from damage. Unlike grass, wetland vegetation will not quickly regain an upright attitude after being laid down by high flows. New growth, usually from the base of the plant, often taking several weeks, is required to regain its upright form. The bypass may be an open channel parallel to the wet biofiltration swale.

- **Water Depth and Base Flow:** Same as for basic biofiltration swales except the design water depth shall be 4 inches for all wetland vegetation selections, and **no underdrains or low-flow drains are required**.

- **Flow Velocity, Energy Dissipation, and Flow Spreading:** Same as for basic biofiltration swales except no flow spreader is needed.

Design Criteria

Geometry

Swale Geometry: Same as specified for basic biofiltration swales except for the following modifications:

- ***Criterion 1:*** The bottom width may be increased to 25 feet maximum, but a length-to-width ratio of 5:1 must be provided. No longitudinal dividing berm is needed. *Note: The minimum swale length is still 100 feet.*
- ***Criterion 2:*** If longitudinal slopes are greater than 2 percent, the wet swale must be stepped so that the slope within the stepped sections averages 2 percent. Steps may be made of retaining walls, log check dams, or short riprap sections. **No underdrain or low-flow drain is required**.

Materials

Soil Criteria

Same as for basic biofiltration swales (see Table 5.3).

Vegetation Criteria

A list of acceptable plants and recommended spacing is shown in Table 5.6. In general, it is best to plant several species to increase the likelihood that at least some of the selected species will find growing conditions favorable.

Table 5.6. Recommended Plants for Wet Biofiltration Swale

Common Name	Scientific Name	Spacing (on center)
Shortawn foxtail	*Alopecurus aequalis*	seed
Water foxtail	*Alopecurus geniculatus*	seed
Spike rush	*Eleocharis spp.*	4 inches
Slough sedge*	*Carex obnupta*	6 inches or seed
Sawbeak sedge	*Carex stipata*	6 inches
Sedge	*Carex* spp.	6 inches
Western mannagrass	*Glyceria occidentalis*	seed
Velvetgrass	*Holcus mollis*	seed
Slender rush	*Juncus tenuis*	6 inches
Watercress*	*Rorippa nasturtium-aquaticum*	12 inches
Water parsley*	*Oenanthe sarmentosa*	6 inches
Hardstem bulrush	*Scirpus acutus*	6 inches
Small-fruited bulrush	*Scirpus microcarpus*	12 inches

* Good choices for swales with significant periods of flow, such as those downstream of a detention facility.

Note: Cattail (*Typha latifolia*) is not appropriate for most wet swales because of its very dense and clumping growth habit which prevents water from filtering through the clump.

A wetland seed mix may be applied by hydroseeding, but if coverage is poor, planting of rootstock or nursery stock is required. Poor coverage is considered to be more than 30 percent bare area through the upper two-thirds of the swale after 4 weeks.

Site Design Elements

Access is only required to the inflow and the outflow of the swale; access along the length of the swale is not required. Also, wheel strips may not be used for access in the swale.

Intent: An access road is not required along the length of a wet swale because of infrequent access needs. Frequent mowing or harvesting is not desirable. In addition, wetland plants are fairly resilient to sediment-induced changes in water depth, so the need for access should be infrequent.

Construction and Maintenance

Construction considerations are the same as for basic biofiltration swales.

Mowing is not required. However, harvesting of very dense vegetation may be desirable in the fall after plant die-back to prevent the sloughing of excess organic material into receiving waters.

5.1.3 BF.03 Continuous Inflow Biofiltration Swale

A continuous inflow biofiltration swale is a basic swale modified by increasing its length to achieve an average residence time equivalent to a regular swale. The continuous design is needed where water enters a biofiltration swale continuously along the side slope rather than discretely at the head.

Applicability

The continuous inflow biofiltration swale is appropriate where inflows are not concentrated, such as locations along the shoulder of a road without curbs. This design may also be used where frequent, small point flows enter a swale, such as through curb inlet ports spaced at intervals along a road, or from a parking lot with frequent curb cuts.

Limitations

No inlet port should carry more than about 10 percent of the flow

A continuous inflow swale is not appropriate where significant lateral flows enter a swale at some point downstream from the head of the swale. In this situation, the swale width and length must be recalculated from the point of confluence to the discharge point, in order to provide adequate treatment for the increased flows.

Submittals and Approval

As part of submittals made as required in Volume I, include information described under BF.01 for a basic biofiltration swale.

Pretreatment

Pretreatment is not required.

Hydrologic and Hydraulic Design Considerations

The design flow for continuous inflow swales must include runoff from the pervious side slopes draining to the swale along the entire swale length. Therefore, they must be online facilities.

If only a single design flow is used, the flow rate at the outlet shall be used. The goal is to achieve an average residence time through the swale of 9 minutes as calculated using the online water quality design flow rate multiplied by the ratio, K, in Figure 5.1a. Assuming an even distribution of inflow along the side of the swale, double the hydraulic residence time to a minimum of 18 minutes.

Design Criteria

Geometry

Same as basic biofiltration swale.

Materials

Same as specified for **basic biofiltration swale**, except for the following:

For continuous inflow biofiltration swales, interior side slopes above the water quality design treatment elevation shall be planted in grass. A typical lawn seed mix or biofiltration seed mixes are acceptable. Landscape plants or groundcovers other than grass may not be used anywhere between the runoff inflow elevation and the bottom of the swale. The use of grass on interior side slopes reduces the chance of soil erosion and transfer of pollutants from landscape areas to the biofiltration treatment area.

5.1.4 BF.04 Basic Filter Strip

A basic filter strip is flat with no side slopes (Figure 5.7). Contaminated stormwater is distributed as sheet flow across the inlet width of a biofilter strip.

Vegetated Filter Strip in Median Along I-5 in Snohomish County

Applicability

A basic filter strip is typically used online, adjacent, and parallel to paved areas like parking lots, driveways, and roadways. The filter strip soil and vegetation criteria can also be modified to provide enhanced treatment – see *Materials under the Design Criteria* section.

Limitations

Filter strips shall only receive sheet flow. The maximum permissible tributary flow path is 150 feet.

Submittals and Approval

No additional submittals (except those described in Volume I as applicable to your project) are required.

Pretreatment

Pretreatment is not required.

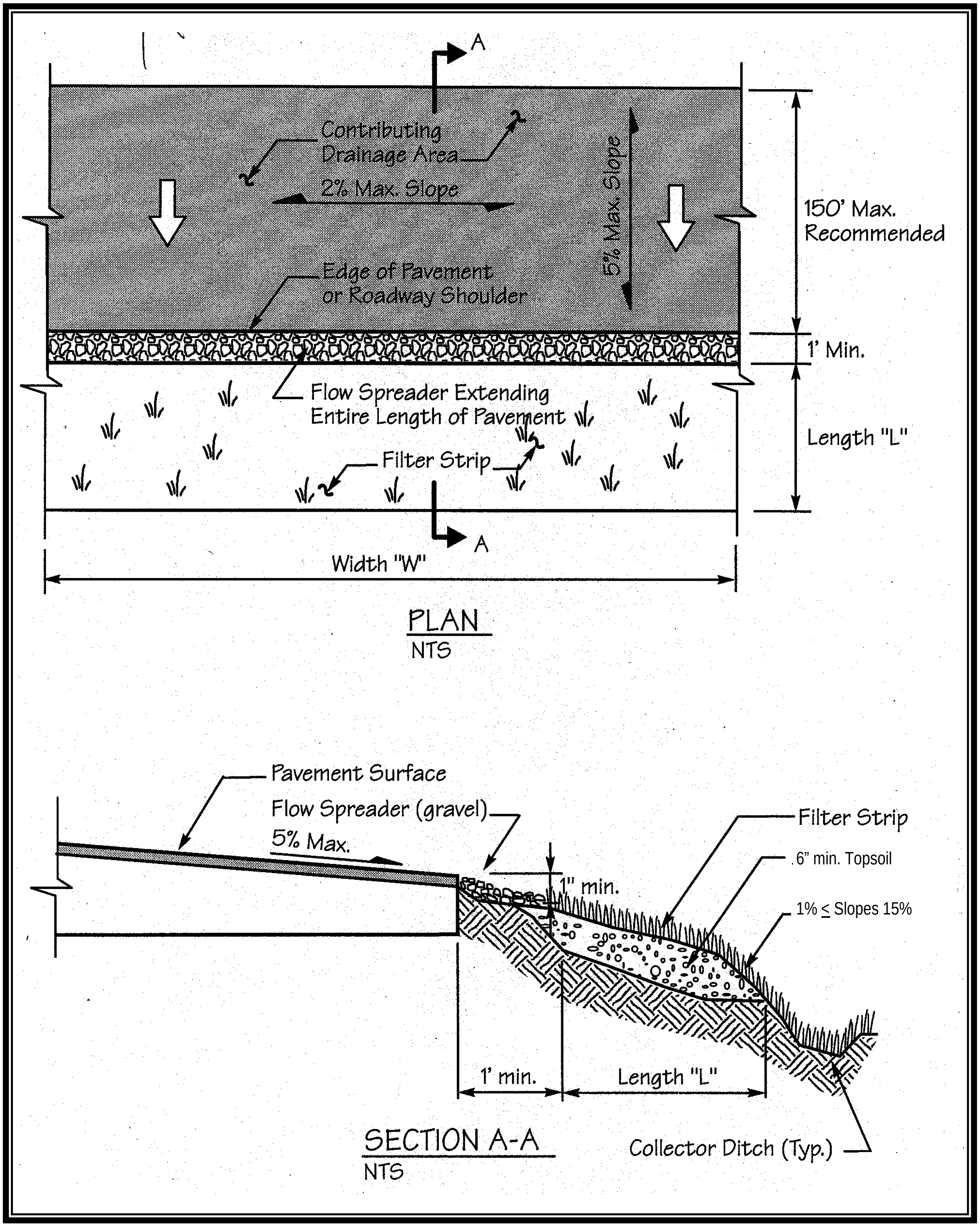


Figure 5.7. Typical Filter Strip.

Hydrologic and Hydraulic Design Considerations

Water Quality Design Flow Rate

Filter strips shall be designed to treat the water quality design storm, as calculated using the Santa Barbara Urban Hydrograph (SBUH) method for a 6-month, 24-hour storm with a Type 1A rainfall distribution (Volume III). If hydrologic calculations are being performed using a continuous hydrologic model, the water quality design flow rate predicted by an approved continuous runoff model may be multiplied by the ratio from Figure 5.1a or 5.1b to obtain the design flow rate. This modified design flow rate is an estimate of the design flow rate determined by using SBUH procedures.

Maximum Water Depth

1 inch.

Maximum Velocity

0.5 feet per second.

Manning Coefficient

0.35 (0.45 if compost-amended, and mowed to maintain grass height ≤ 4 inches)

Hydraulic Residence Time

9 minutes.

Sizing Method

Calculate the design flow depth using Manning’s equation as follows:

$$KQ = (1.49A\ R^{0.67}\ s^{0.5})/n$$

Substituting for AR:

$$KQ = (1.49Ty^{1.67}\ s^{0.5})/n$$

Where:

$Ty = A_{rectangle,\ ft}{}^2$

$y \approx R_{rectangle}$, design depth of flow, ft. (1 inch maximum)

Q = peak Water Quality design flow rate based on an approved continuous runoff model, ft^3/sec

K = The ratio determined by using Figure 5.1a. If SBUH model is used for water quality design flow rate calculations, K = 1.

n = Manning's roughness coefficient

s = Longitudinal slope of filter strip parallel to direction of flow

T = Width of filter strip perpendicular to the direction of flow, ft.

A = Filter strip inlet cross-sectional flow area (rectangular), ft^2

R = hydraulic radius, ft.

Rearranging for y:

$$y = [KQn/1.49Ts^{0.5}]^{0.6}$$

y must not exceed 1 inch

Note: As in swale design an adjustment factor of K accounts for the differential between the WWHM Water Quality design flow rate and the SBUH design flow.

Calculate the design flow velocity V, ft./sec., through the filter strip:

$$V = KQ/Ty$$

V must not exceed 0.5 ft./sec

Calculate required length, in feet, of the filter strip at the minimum hydraulic residence time, t, of 9 minutes:

$$L = tV = 540V$$

Design Criteria

Geometry

The slope of the filter strip (perpendicular to the roadway or other contributing area) shall be between 1 and 15 percent.

The maximum slope of contributing area flowing toward the filter strip is five percent unless flow spreading and energy dissipation is included in the design (see Figure 5.7). The maximum slope of the contributing area parallel to the filter strip is 2 percent.

The inlet edge shall be a minimum of 1 inch lower than contributing paved area.

For roadways with curbs, curb cuts shall be a minimum 12-inch wide and 1-inch above the filter strip inlet. Curb cuts shall be spaced at 10 feet intervals, maximum.

Materials

Compost Amended Vegetated Filter strip: The filter strip may be able to provide enhanced treatment where the following are met:

- Where a filter strip area is compost-amended to a minimum of 10 percent organic content in accordance with BMP LID.02;
- Hydroseeded grass maintained at 95 percent density and a 4-inch length by mowing and periodic re-seeding (possible landscaping with herbaceous shrubs)

If groundwater contamination is a concern, seal the bed with clay or a treatment liner.

5.1.5 BF.05 Narrow Area Filter Strip

A narrow area filter strip is used in impervious areas with flow paths of 30 feet or less and that can drain along their widest dimension to grassy areas.

The narrow area filter strip design method is included here because of technical limitations in the basic design method, which result (counterintuitively) in filter strips proportionately longer as the contributing drainage becomes narrower. Several parties are researching filter strip design parameters; this research may lead to more stringent design requirements that supersede the design criteria presented here.

Applicability

A narrow area filter strip could be used at roadways with limited right-of-way or for narrow parking strips.

Limitations

If space is available to use the basic filter strip design, that design shall be used in preference to the narrow filter strip.

Submittals and Approval

Submittals completed in accordance with the requirements in Chapter 3 of Volume I shall include the following:

- Calculations for filter strip length, including a copy of Figure 5.8
- Justification for use of a narrow area filter strip. Explain why a standard filter strip or other BMP could not be used. Use of a narrow area filter strip requires specific Administrator acceptance.

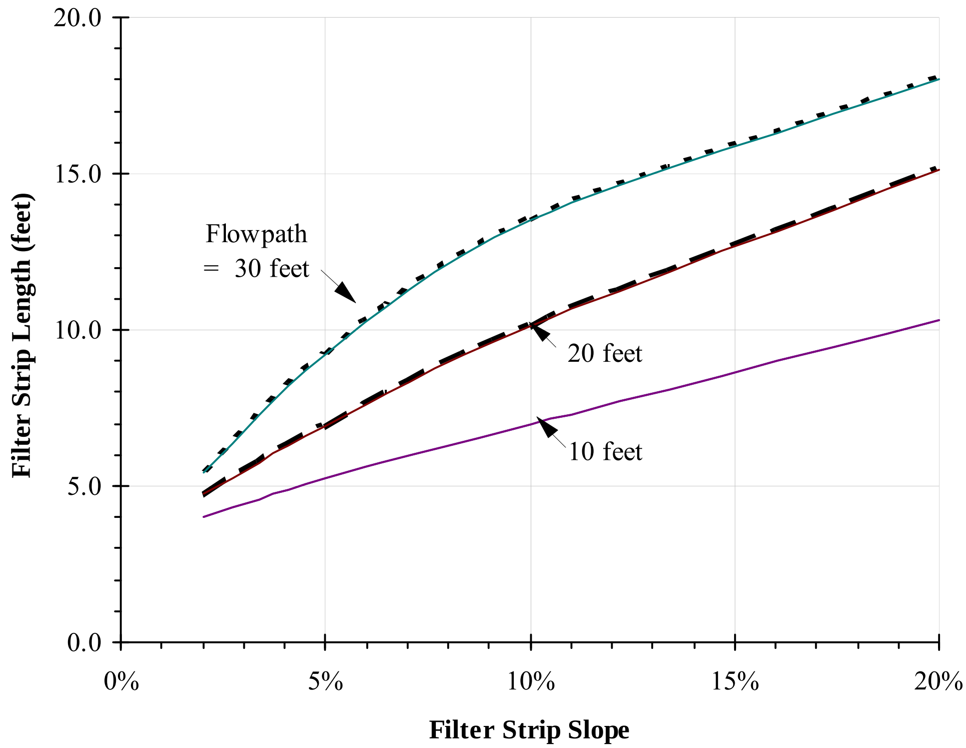
Pretreatment

Pretreatment is not required.

Hydrologic and Hydraulic Design Considerations

Design criteria for narrow area filter strips are the *same as specified for basic filter strips*. The sizing of a narrow area filter strip is based on the length of flow path draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to the flow path).

Step 1: Determine the length of the flow path from the upstream to the downstream edge of the impervious area draining sheet flow to the strip. Normally this is the same as the width of the paved area, but if the site is sloped, the flow path may be longer than the width of the impervious area.



Note: minimum allowable filter strip length is 4 feet

Figure 5.8. Filter Strip Lengths for Narrow Right-of-Way.

Step 2: Calculate the longitudinal slope of the filter strip (along the direction of unconcentrated flow), averaged over the total width of the filter strip. The minimum sizing slope is 2 percent.

If the slope is less than 2 percent, use 2 percent for sizing purposes. The maximum allowable filter strip slope is 20 percent. If the slope exceeds 20 percent, the filter strip must be stepped down the slope so that the treatment areas between drop sections do not have a longitudinal slope greater than 20 percent.

Drop sections must be provided with erosion protection at the base and flow spreaders to re-spread flows. Vertical drops along the slope must not exceed 12 inches in height. If this is not possible, a different treatment facility must be selected.

Step 3: Select the appropriate filter strip length for the flow path length and filter strip longitudinal slope (Steps 1 and 2 above) from the graph in Figure 5.8. The filter strip must be designed to provide this minimum length *L* along the entire stretch of pavement draining into it.

To use the graph: Find the length of the flow path on one of the curves (interpolate between curves as necessary). Move along the curve to the point where the design longitudinal slope of the filter strip (x-axis) is directly below. Read the filter strip length on the y-axis which corresponds to the intersection point.

Chapter 6 - Wet Pool BMPs

6.1 Wet Pool BMPs

Wet pools treat stormwater runoff by allowing particulates to settle during stilling conditions ("sedimentation"), by biological uptake of dissolved pollutants, and by vegetative filtration. Wet pool facilities include wet ponds, wet vaults, and stormwater treatment wetlands. Wet pools may be single-purpose facilities, providing only runoff treatment, or may be combined with a detention pond or vault to provide flow control. If combined, the volume for detention can often be included above the wet pool with little further loss of development area.

The following wet pool BMPs are described in this chapter:

- WP.01 Stormwater Treatment Wetland
- WP.02 Wet Ponds
- WP.03 Wet vaults
- WP.04 Combined Detention/Wet Pond Facilities
- WP.05 Presettling Basins

6.1.1 WP.01 Stormwater Treatment Wetlands

Stormwater treatment wetlands are shallow, man-made ponds designed to treat stormwater using the biological processes of emergent aquatic plants (see stormwater wetland details in Figures 6.1 and 6.2).

Stormwater treatment wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus removal in stormwater treatment wetlands is highly variable.

Note: Wetlands created to mitigate disturbance impacts (e.g., filling) may not be used as stormwater treatment facilities.

Wm Bush Park wetland in Lacey

Applicability

This design occupies about the same surface area as wet ponds, but may be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. Stormwater treatment wetlands are a good water quality facility choice in areas with high winter groundwater levels.

A stormwater treatment wetland may provide treatment only (have a permanent pool with no live storage) or may provide both storage and treatment (have both a permanent pool and live storage). See WP.04, combined detention/wet pond facilities for more information on stormwater treatment wetlands that provide both runoff treatment and detention.

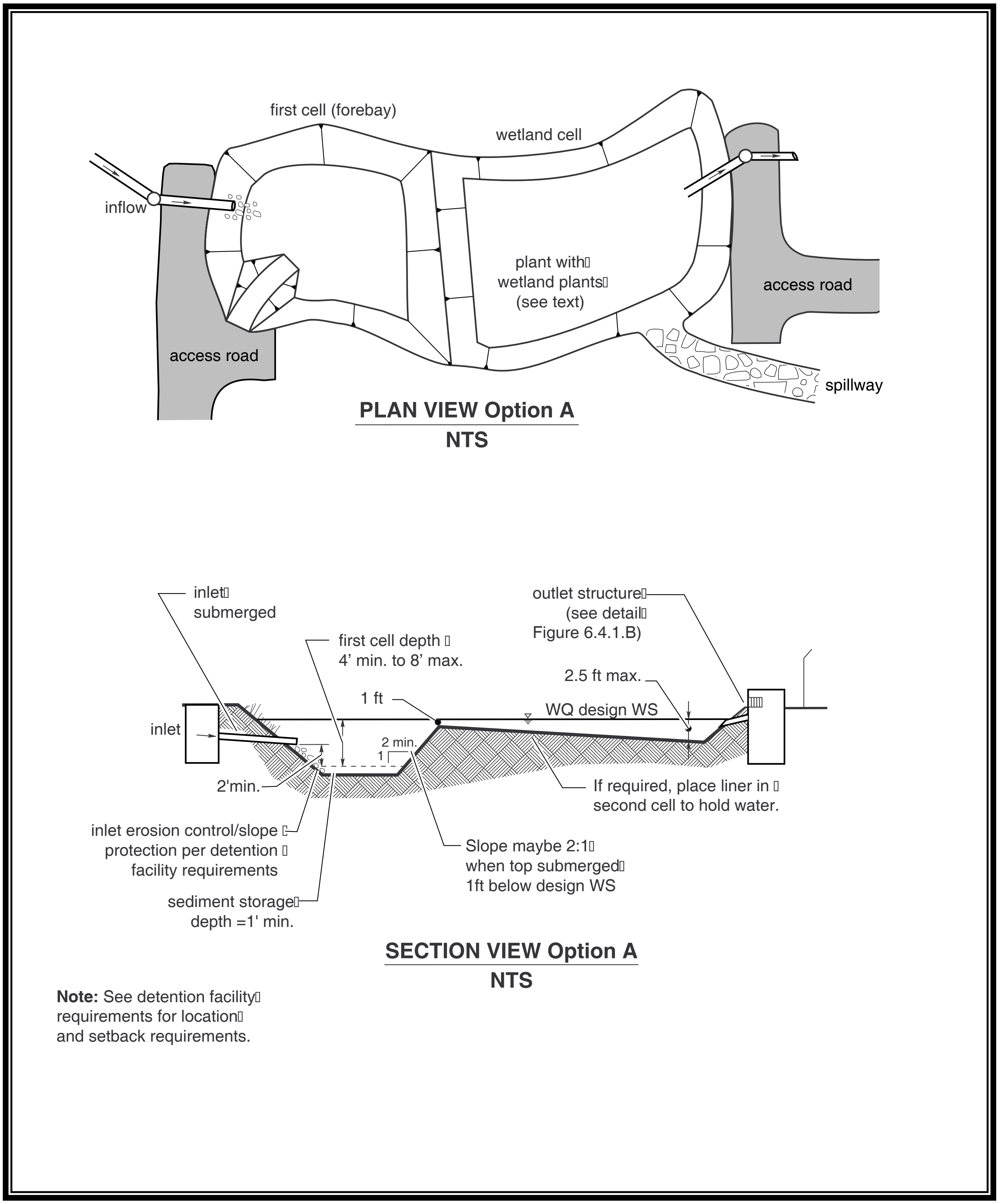


Figure 6.1. Stormwater Wetland – Option One.

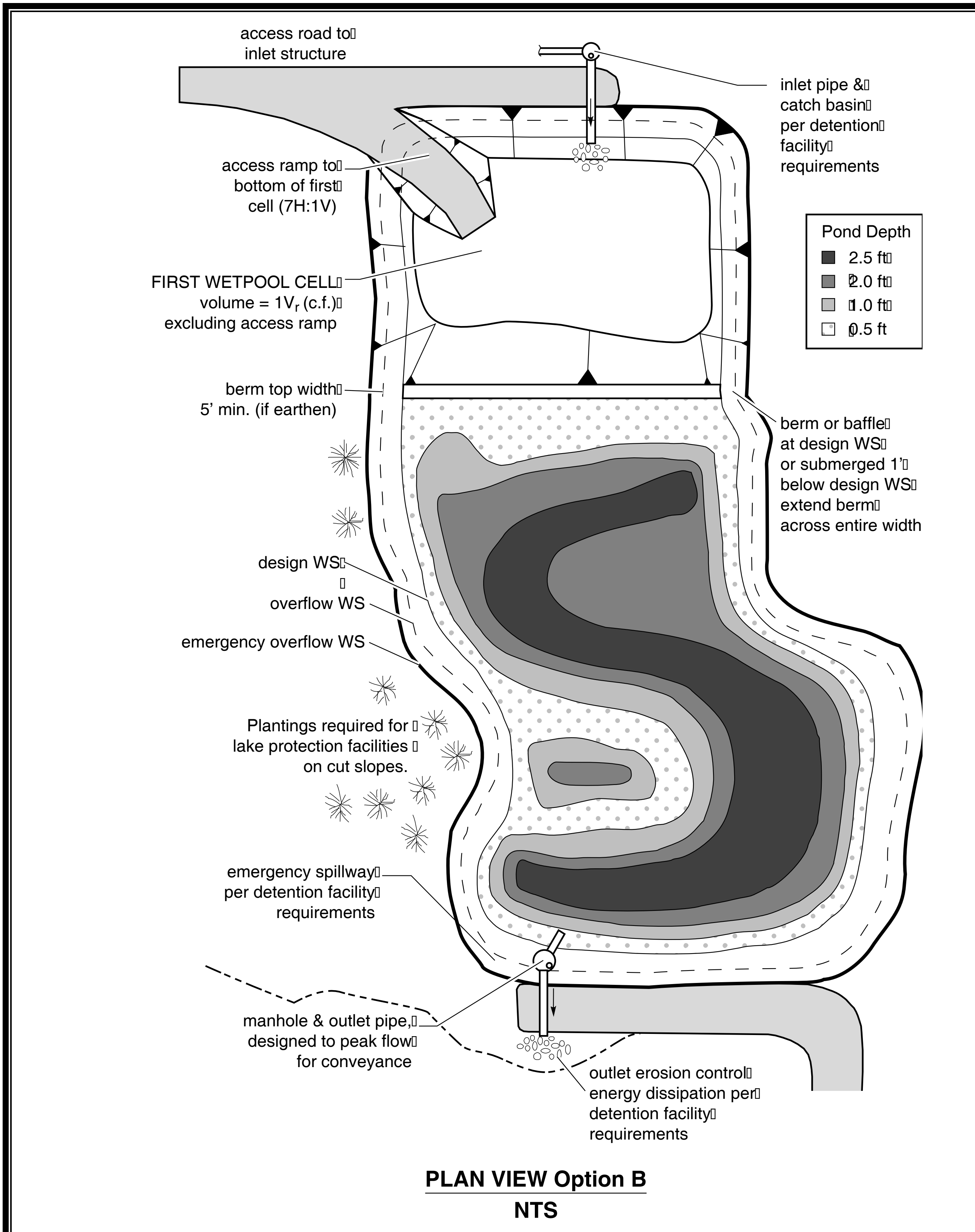


Figure 6.2. Stormwater Wetland — Option Two.

Limitations

The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Since water depths are shallower than in wet ponds, water loss by evaporation is an important concern.

A stormwater treatment wetland placed in soils with a field-saturated percolation rate of greater than 0.5 inches per hour shall be lined.

All constructed wetlands shall be designed by the project engineer in conjunction with a wetland consultant.

For projects located within a designated Well Head Protection Area (WHPA) for a public water system with over 1,000 connections the bottom of the stormwater wetland shall be above the seasonal high groundwater elevation. Where less than 3-feet of separation exists to seasonal high groundwater, the stormwater wetland shall be lined.

Submittals and Approval

Make submittals required by Volume I and include the following information in the submittal:

- Detailed planting plan for the wetland to include species, quantity, location, and special planting considerations for all plantings to be incorporated into the wetland
- Description of liner material to be used. If lining of the stormwater wetland pond is not proposed, submit documentation from a geotechnical professional demonstrating that the soils have an infiltration rate of less than 0.5 in/hr.
- Hydrologic modeling results showing the volume required for the stormwater wetland as well as calculations showing how area and volume requirements are met for each cell
- Details of all structures and material and construction specifications
- Cross section of the stormwater wetland through the outlet structure
- Design calculations for the overflow structures
- Document that facility location meets setback requirements.

Pretreatment

Pretreatment is accomplished in the presettling cell of the wetland, so a separate pretreatment facility is not required.

Hydrologic and Hydraulic Design Considerations

When used for stormwater treatment, stormwater wetlands employ some of the same design features as wet ponds. However, instead of primarily using gravity settling for treatment, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus, when designing wetlands, plant vigor and biomass are primary design concerns, not water volume.

Inlets and Outlets

Inlets and outlets shall be configured using the requirements of wet ponds (see BMP WP.02).

Sizing Procedure

Step 1: The volume of a basic wet pond is used as a template for sizing the stormwater wetland. The design volume is the 91st percentile, 24-hour runoff volume estimated by an approved continuous runoff model.

Step 2: Calculate the surface area of the stormwater wetland. The surface area of the wetland shall be the same as the top area of a wet pond sized for the same site conditions. Calculate the surface area of the stormwater wetland by using the volume from Step 1 and dividing by the average water depth (use 3 feet).

Step 3: Determine the surface area of the first cell of the stormwater wetland. Use the volume determined from Criterion 2 under “Wetland Geometry”, and the actual depth of the first cell.

Step 4: Determine the surface area of the wetland cell. Subtract the surface area of the first cell (Step 3) from the total surface area (Step 2).

Step 5: Determine water depth distribution in the second cell. Decide if the top of the dividing berm will be at the surface or submerged (designer's choice). Adjust the distribution of water depths in the second cell according to Criterion 8 under “Wetland Geometry” below. Note: This will result in a facility that holds less volume than that determined in Step 1 above. This is acceptable.

> Intent: The surface area of the stormwater wetland is set to be roughly equivalent to that of a wet pond designed for the same site so as not to discourage use of this option.

Step 6: Choose plants. See Table 9.1 for a list of plants recommended for wet pond water depth zones, or consult a wetland scientist.

Design Criteria

Geometry

Stormwater wetlands shall consist of two cells, a presettling cell and a wetland cell.

Presettling Cell

The presettling cell shall contain approximately 33 percent of the wet pool volume calculated in Step 1 above. The depth of the presettling cell shall be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage. One foot of sediment storage shall be provided in the presettling cell.

Wetland Cell

The wetland cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches).

Two examples are provided for grading the bottom of the wetland cell.

- One example is a shallow, evenly graded slope from the upstream to the downstream edge of the wetland cell (see Figure 6.1).
- The second example is a "naturalistic" alternative, with the specified range of depths intermixed throughout the second cell (see Figure 6.2). To the extent possible create a complex microtopography within the wetland, and design the flow path to maximize sinuous flow between wetland cells. A distribution of depths shall be provided in the wetland cell depending on whether the dividing berm is at the water surface or submerged (see Table 6.1 below). The maximum depth is 2.5 feet in either configuration. Other configurations within the wetland geometry constraints listed above may be approved by Thurston County.

Table 6.1. Distribution of Depths in Wetland Cell.

Dividing Berm at Water Quality Design Water Surface		Dividing Berm Submerged 1 Foot	
Depth Range (ft)	**Percent**	**Depth Range (ft)**	**Percent**
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

Berm

The "berm" separating the two cells shall be shaped such that its downstream side gradually slopes to form the second shallow wetland cell (see the section view in Figure 6.1). Alternatively, the second cell may be graded naturalistically from the top of the dividing berm (see Criterion 8 below).

The top of berm shall be either at the water quality design water surface or submerged 1 foot below the water quality design water surface, as with wet ponds. Correspondingly, the side slopes of the berm must meet the following criteria:

If the top of berm is at the water quality design water surface, the berm side slopes shall be no steeper than 3H:1V.

If the top of berm is submerged 1 foot, the upstream side slope may be up to 2H:1V. If the berm is at the water surface, then for safety reasons, its slope shall be not greater than 3:1, just as the pond banks shall not be greater than 3:1 if the pond is not fenced. A steeper slope (2:1 rather than 3:1) is allowable if the berm is submerged in 1 foot of water. If submerged, the berm is not considered accessible, and the steeper slope is allowable.

Materials

Lining Requirements

Many wetland plants can adapt to periods of summer drought, however the stormwater wetland design should maximize the duration of wet conditions to the extent possible. Therefore, for all constructed wetlands placed in soils with a field-saturated percolation rate greater than 0.5 inches per hour, both cells of the stormwater wetland shall be lined with a low-permeability liner. The criteria for liners given in Appendix V-B must be observed. A minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with three parts native soil) must be placed over the liner. For geomembrane liners, a soil depth of 3 feet is recommended to prevent damage to the liner during planting. Hydric soils are not required.

Vegetation

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Table 6.2 or the recommendations of the wetland specialist. Note: Cattails (*Typha latifolia*) are not recommended. They tend to escape to natural wetlands and crowd out other species. In addition, the shoots die back each fall and will result in oxygen depletion in the wet pool unless they are removed.

Consultation with a wetland consultant (an individual with education and experience in freshwater or wetland biology landscape architecture, or equivalent) is required for stormwater treatment wetlands on sites with contributing areas of greater than 1 acre. The services of a wetland consultant are highly recommended, but not required, on smaller sites (contributing areas of 1 acre or less). On smaller stormwater treatment wetland projects, the project engineer may adapt the following planting approach for use without requiring a wetland consultant.

Table 6.2. Emergent Wetland Plant Species Recommended for Wet Ponds

Species	Common Name	Notes	Maximum Depth
Agrostis exarata [1]	Spike bent grass	Prairie to coast	to 2 ft
Carex stipata	Sawbeak sedge	Wet ground	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	to 2 ft
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	to 2 ft
Juncus tenuis	Slender rush	Wet soils, wetland margins	
Oenanthe sarmentosa	Water parsley	Shallow water along stream and pond margins; needs saturated soils all summer	
Scirpus atrocinctus (formerly *S. cyperinus*)	Woolgrass	Tolerates shallow water; tall clumps	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sagittaria latifolia	Arrowhead		
INUNDATION 1 TO 2 FT			
Agrostis exarata [1]	Spike bent grass	Prairie to coast	
Alisma plantago-aquatica	Water plantain		
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	
Juncus effusus	Soft rush	Wet meadows, pastures, wetland margins	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sparganium emmersum	Bur reed	Shallow standing water, saturated soils	
INUNDATION 1 TO 3 FT			
Carex obnupta	Slough sedge	Wet ground or standing water	1.5 to 3 ft
Beckmania syzigachne [1]	Western sloughgrass	Wet prairie to pond margins	
Scirpus acutus [2]	Hardstem bulrush	Single tall stems, not clumping	to 3 ft
Scirpus validus [2]	Softstem bulrush		
INUNDATION GREATER THAN 3 FT			
Nuphar polysepalum	Spatterdock	Deep water	3 to 7.5 ft
Nymphaea odorata [1]	White waterlily	Shallow to deep ponds	to 6 ft

Notes:
[1] Non-native species. Beckmania syzigachne is native to Oregon. Native species are preferred.
[2] Scirpus tubers must be planted shallower for establishment, and protected from foraging waterfowl until established. Emerging aerial stems should project above water surface to allow oxygen transport to the roots.
Primary sources: Municipality of Metropolitan Seattle, Water Pollution Control Aspects of Aquatic Plants, 1990. Hortus Northwest, Wetland Plants for Western Oregon, Issue 2, 1991. Hitchcock and Cronquist, Flora of the Pacific Northwest, 1973.

The stormwater treatment wetland bottom and wetted side slopes shall be planted with nursery-grown plants and shrubs. Field-harvested (wild) plants may be used with approval of the wetland consultant and the Administrator or designee. The stormwater treatment wetland bottom must have suitable soil type and be tilled for planting and root establishment. Soil amendments may be necessary. All planting shall occur between the months of October and April unless otherwise approved by the Administrator or designee.

For each 1,500 square feet of stormwater treatment wetland bottom, plant at least 100 open-water or emergent plants in homogeneous groups of 10 or more, on 2-foot centers. In addition, plant at least 30 shrubs on 5-foot centers, midway between the low and high-water level. Shrubs may be from cuttings or stakes if appropriate to the type of plant and proper planting methods are used to improve survival. Plantings used must be from the recommended list in Table 6.2 unless otherwise approved by the Administrator or designee.

The wetland consultant shall monitor performance of the stormwater treatment wetland vegetation for a minimum of 2 years. Monitoring shall occur at least yearly during the summer months. Measures of success are as follows:

1. Minimum survival of shrubs shall be 80 percent. Lesser survivals may be allowed if original planting density exceeded minimums. All plants lost shall be replaced between the months of October and April by like species unless recommended otherwise by the wetland consultant and accepted by the Administrator or designee.

2. Minimum percent vegetated cover of stormwater treatment wetland bottom area, excluding exotic and invasive species, at two years shall be 50 percent. If stormwater treatment wetland cover is less than 50 percent, removal of exotic/invasive species and additional plantings may be required.

A bond or other financial guarantee to ensure the above measures of success are attained may be required.

Site Design Elements

Access and Setbacks

Location of the stormwater wetland relative to site constraints (e.g., buildings, property lines, etc.) shall be the same as described in Appendix V-E for detention ponds.

Access and maintenance roads shall be provided and designed according to the design criteria provided in Appendix V-D. Access and maintenance roads shall extend to both the wetland inlet and outlet structures. An access ramp shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the wetland side slopes.

Construction and Maintenance

The presettling cell must include a gravity drain for maintenance.

Construction of the naturalistic alternative (Option 2) can be easily done by first excavating the entire area to the 1.5-foot average depth. Then soil subsequently excavated to form deeper areas can be deposited to raise other areas until the distribution of depths indicated in the design is achieved.

The presettling cell of a stormwater treatment wetland may be used as a sedimentation pond during construction. However, any sediment that has accumulated in the pond must be removed after construction is complete and before the stormwater treatment wetland is permanently online.

If the berm embankments are greater than 4 feet in height, the berm must be constructed by excavating a key equal to 50 percent of the embankment cross-sectional height and width. This requirement may be waived if recommended by a geotechnical engineer for specific site conditions. The geotechnical analysis shall address situations in which one of the two cells is empty while the other remains full of water.

The county may require a bypass/ shutoff valve to enable the stormwater treatment wetland to be taken off-line for maintenance purposes.

6.1.2 WP.02 Wet Ponds

A wet pond is a constructed stormwater pond that retains a permanent pool of water ("wet pool") during the rainy season. The larger the volume of the wet pool the more effective the pond in settling particulate pollutants. Peak flow control can be provided in the "live storage" area above the permanent pool (see BMP WP.04). Figures 6.3 and 6.4 illustrate a typical wet pond BMP.

Wetpond along Yelm Hwy in Lacey

Applicability

A wet pond requires a larger area than a biofiltration swale or a sand filter, but it can be integrated to the contours of a site fairly easily. In till soils, the wet pond holds a permanent pool of water that provides an attractive aesthetic feature.

Wet ponds may be single-purpose facilities, providing only runoff treatment, or they may be combined with a detention pond to also provide flow control. If combined, the wet pond can often be stacked under the detention pond with little further loss of development area. See BMP WP.04 for a description of combined detention and wet pool facilities.

The following design criteria cover two wet pond applications – the basic wet pond and the large wet pond.

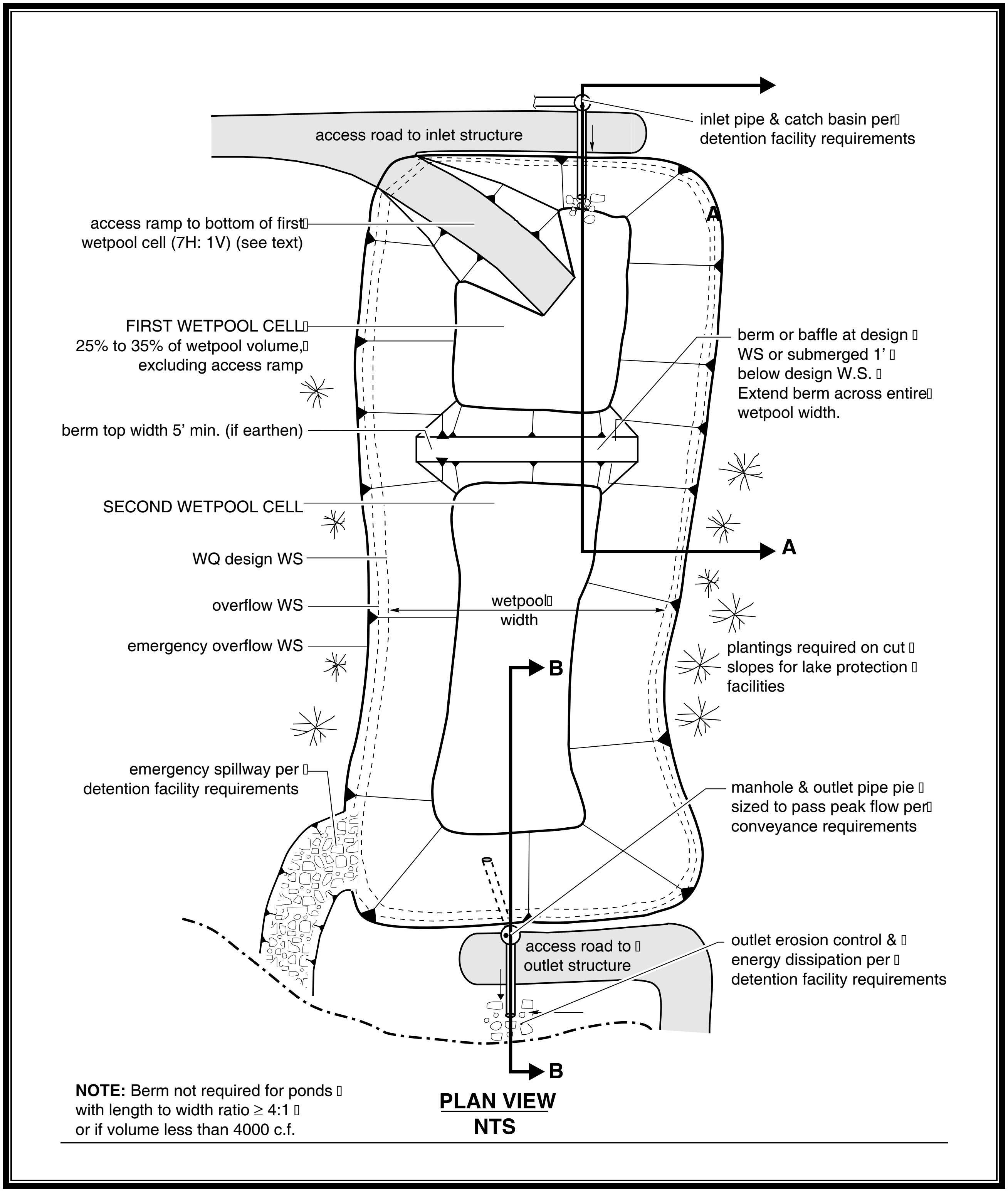


Figure 6.3. Wet Pond.

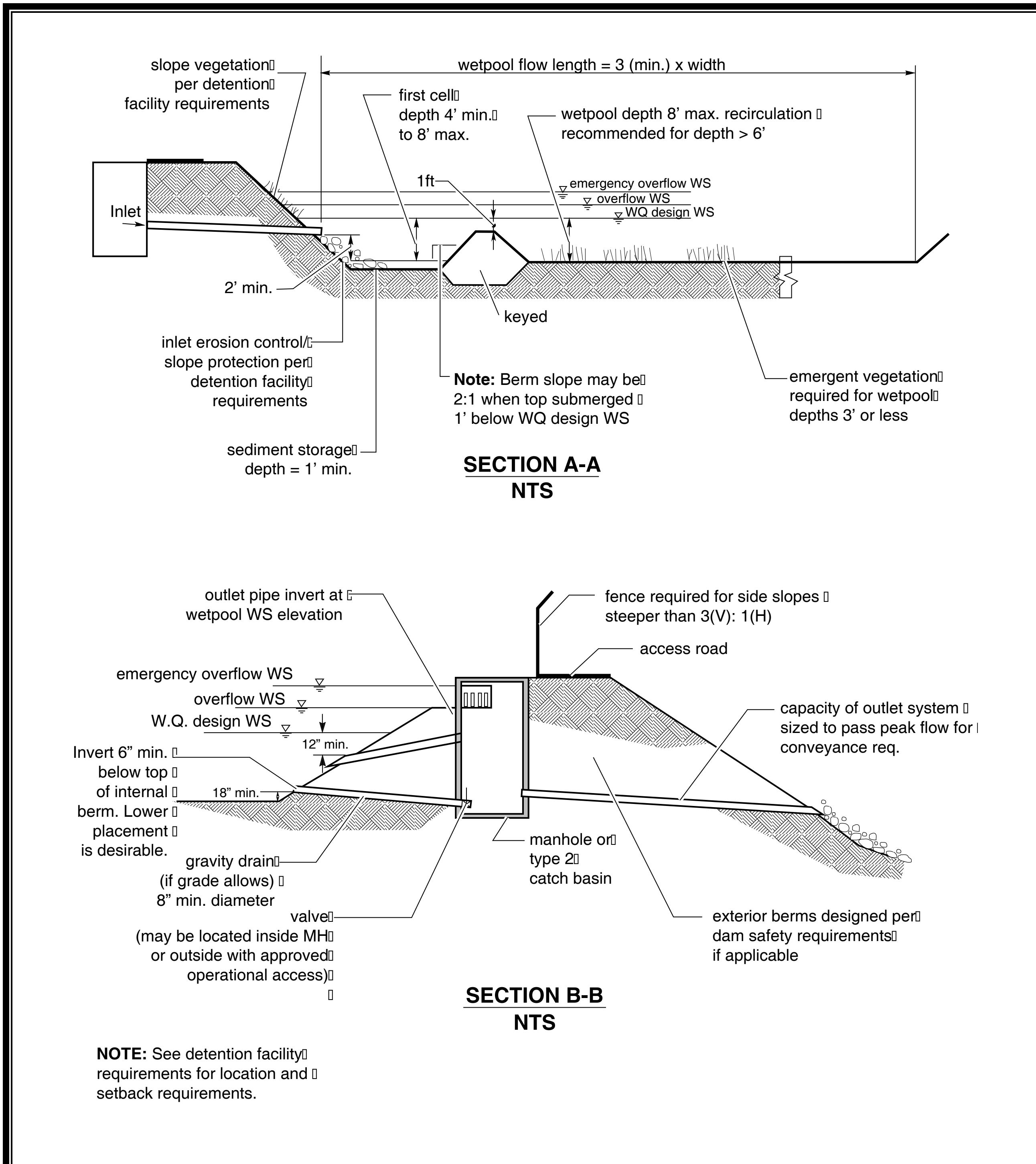


Figure 6.4. Wet Pond.

Large wet ponds are designed for higher levels of pollutant removal (phosphorus treatment).

Limitations

Wet ponds rely on a permanent pool of water for water quality treatment and aesthetics. Bioretention facilities (BMP LID.07) or infiltration basins (BMP IN.01) are better choices where there are porous soils.

If wet ponds are proposed in areas with porous soils (infiltration rate of greater than than 0.5 inches per hour), the pond will be required to be lined to maintain a permanent wet pool.

For projects located within a designated Well Head Protection Area (WHPA) for a public water system with over 1,000 connections the bottom of the wet pond shall be above the seasonal high groundwater elevation. Where less than 3-feet of separation exists to seasonal high groundwater, the wet pond shall be lined.

Submittals and Approval

Complete applicable submittals in accordance with the requirements in Volume I. For projects proposing wet ponds for runoff treatment, provide the following information in the submittal:

- Justification for use of a wet pond. A wet pond is an allowed water quality treatment facility for projects in which a stormwater treatment wetland (BMP WP.01) is not feasible or practicable. The applicant shall explain why a stormwater treatment wetland is infeasible for the project or site, subject to acceptance of the Administrator.

- Documentation from a geotechnical professional demonstrating that the soils have an infiltration rate of less than 0.5 inches per hour if lining of the wet pond is not proposed

- Hydrologic modeling results showing the volume required for the wet pool. If the facility is a combined wet/detention pond, calculations shall also demonstrate compliance with Minimum Requirement #7 (Flow Control).

- Details of all structures and material and construction specifications

- Planting plan showing plant species, quantity, location and any special planting requirements

- Cross section of the pond through outlet structure.

- Design calculations for the overflow structures
- Documentation that facility location meets setback requirements.

Pretreatment

Pretreatment is not required for this BMP.

Hydrologic and Hydraulic Design Considerations

Wet Pool Volume

- The primary design factor that determines a wet pond's treatment efficiency is the volume of the wet pool. The larger the wet pool volume, the greater the potential for pollutant removal.

Conveyance modeling for the stormwater system leading to the wet pond must be shown to include consideration of the backwater effects of the submerged inlet.

Basic Wet Pond

For a basic wet pond, the wet pool volume provided shall be equal to or greater than volume of the 6-month, 24-hour storm or alternatively the 91st percentile, 24-hour runoff volume estimated by an approved continuous runoff model.

Large Wet Pond

A large wet pond requires a wet pool volume at least 1.5 times larger than the basic wet pond.

Sizing Procedure

Procedures for determining a wet pond's dimensions and volume are outlined below.

Step 1: Identify required wet pool volume using an approved continuous runoff model – the 91st percentile, 24-hour runoff volume. A large wet pond requires a volume at least 1.5 times the 91st percentile, 24-hour runoff volume.

Step 2: Determine wet pool dimensions. Determine the wet pool dimensions satisfying the design criteria outlined below. A simple way to check the volume of each wet pool cell is to use the following equation:

$$V = \frac{h(A_1 + A_2)}{2}$$

where V = wet pool volume (cf)
h = wet pool average depth (ft)
A_1 = water quality design surface area of wet pool (sf)
A_2 = bottom area of wet pool (sf)

Step 3: Design pond outlet pipe and determine primary overflow water surface. The pond outlet pipe shall be placed on a reverse grade from the pond's wet pool to the outlet structure. Use the following procedure to design the pond outlet pipe and determine the primary overflow water surface elevation:

- Use the nomographs in Volume III, Appendix III-C to select a trial size for the pond outlet pipe sufficient to pass the online water quality design flow, Q_{wq} indicated by an approved continuous runoff model.
- Use the nomographs in Volume III, Appendix III-C to determine the critical depth d_c at the outflow end of the pipe for Q_{wq}.
- Use the nomographs in Volume III, Appendix III-C to determine the flow area A_c at critical depth.
- Calculate the flow velocity at critical depth using continuity equation ($V_c = Q_{wq} / A_c$).
- Calculate the velocity head V_H ($V_H = V_c^2 / 2g$, where g is the gravitational constant, 32.2 feet per second).
- Determine the primary overflow water surface elevation by adding the velocity head and critical depth to the invert elevation at the outflow end of the pond outlet pipe (i.e., overflow water surface elevation = outflow invert + d_c + V_H).
- Adjust outlet pipe diameter as needed and repeat steps (a) through (e).

Step 4: Determine wet pond dimensions. General wet pond design criteria and concepts are shown in Figures 6.3 and 6.4.

Velocities

The runoff shall be discharged uniformly and at a velocity below 3 feet per second in Type A and B soils, and 5 feet per second in Type C and D soils or as necessary to prevent erosion and to insure quiescent conditions within the BMP.

Outlet Structure

The inverted outlet pipe traps oils and floatables in the wet pond.

An outlet structure shall be provided. Either a Type 2 catch basin with a grated opening (jail house window) or a manhole with a cone grate (birdcage) may be used (see Appendix V-A for an example). The outlet structure receives flow from the pond outlet pipe. The grate or birdcage openings provide an overflow route should the pond outlet pipe become clogged. The overflow criteria provided below specifies the sizing and position of the grate opening.

The pond outlet pipe shall be back-sloped, or have a turn-down elbow, and extend 1 foot below the water quality design water surface. A floating outlet, set to draw water from 1 foot below the water surface, is also acceptable if vandalism concerns are adequately addressed.

The pond outlet pipe shall be sized, at a minimum, to pass the online water quality design flow. **Note**: The highest invert of the outlet pipe sets the water quality design water surface elevation.

Overflow

The overflow criteria for single-purpose (treatment only, not combined with flow control) wet ponds are as follows:

- The requirement for primary overflow is satisfied by either the grated inlet to the outlet structure or by a birdcage above the pond outlet structure.

- The bottom of the grate opening in the outlet structure shall be set at or above the height needed to pass the water quality design flow through the pond outlet pipe. *Note: The grate invert elevation sets the overflow water surface elevation.*

- The grated opening shall be sized to pass the 100-year recurrence interval design flow. The capacity of the outlet system shall be sized to pass the peak flow for the conveyance requirements.

An emergency spillway shall be provided and designed according to the design criteria in Appendix V-A.

Base Flow

A small amount of base flow is desirable to maintain circulation and reduce the potential for low oxygen conditions during late summer.

Design Criteria

Geometry

The wet pond geometry should be designed to avoid short circuiting and promote plug flow.

Plug flow describes the hypothetical condition of stormwater moving through the pond as a unit, displacing the "old" water in the pond with incoming flows. To prevent short-circuiting, water is forced to flow, to the extent practical, to all potentially available flow routes, avoiding "dead zones" and maximizing the time water stays in the pond during the active part of a storm.

Design features that encourage plug flow and avoid dead zones are:

- A tear-drop shape, with the inlet at the narrow end, rather than a rectangular pond is preferred since it minimizes dead zones caused by corners
- Dissipating energy at the inlet
- Providing a large length-to-width ratio
- Providing a broad surface for water exchange using a berm designed as a broad-crested weir to divide the wet pond into two cells rather than a constricted area such as a pipe
- Maximizing the flow path between inlet and outlet, including the vertical path, also enhances treatment by increasing residence time.

Inlets

All inlets shall enter the first cell. The inlet to the wet pond shall be submerged with the inlet pipe invert a minimum of 2 feet from the pond bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible.

> Intent: The inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

Length:width Ratio

Inlets and outlets shall be placed to maximize the flow path through the facility. The ratio of flow path length to width from the inlet to the outlet shall be at least 3:1. The flow path length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be found as follows:

width = (average top width + average bottom width)/2

The number of inlets to the facility should be limited; ideally there should be only one inlet. If there are multiple inlets, the length-to-width ratio shall be based on the average flow path length for all inlets.

Intent: It is anticipated that sediment removal will only be needed for the first cell in the majority of cases. The gravity drain is intended to allow water from the first cell to be drained to the second cell when the first cell is pumped dry for cleaning.

- The drain invert shall be at least 6 inches below the top elevation of the dividing berm or baffle. Deeper drains are encouraged where feasible, but must be no deeper than 18 inches above the pond bottom.

  Intent: To prevent highly sediment-laden water from escaping the pond when drained for maintenance.

- The drain shall be at least 8 inches (minimum) diameter and shall be controlled by a valve. Use of a shear gate is allowed only at the inlet end of a pipe located within an approved structure.

  Intent: Shear gates often leak if water pressure pushes on the side of the gate opposite the seal. The gate shall be situated so that water pressure pushes toward the seal.

- Operational access to the valve shall be provided to the finished ground surface.

- The valve location shall be accessible and well-marked with 1 foot of paving placed around the box. It must also be protected from damage and unauthorized operation.

- A valve box is allowed to a maximum depth of 5 feet without an access manhole. If over 5 feet deep, an access manhole or vault is required.

- All metal parts shall be corrosion-resistant. Galvanized materials should not be used unless unavoidable.

  Intent: Galvanized metal contributes zinc to stormwater, sometimes in very high concentrations.

Wet ponds with wet pool volumes less than or equal to 4,000 cubic feet may be single celled (i.e., no baffle or berm is required). The ratio of flow path length to width shall be at least 4:1 in single celled wet ponds, but should preferably be 5:1.

For wet ponds with wet pool volumes greater than 4,000 cubic feet, the wet pool shall be divided into two cells separated by a baffle or berm. Both cells must have level pond bottoms.

The maximum depth of each cell shall not exceed 8 feet (exclusive of sediment storage in the first cell). For wet pool depths in excess of 6 feet, some form of recirculation shall be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.

Pre-settling Cell

The first cell shall contain between 25 to 35 percent of the total wet pool volume. The minimum depth of the first cell shall be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.

Sediment storage shall be provided in the first cell. The sediment storage shall have a minimum depth of 1 foot.

Second Cell

Pool depths of 3 feet or shallower (second cell) shall be planted with emergent wetland vegetation (see Planting requirements).

Baffle or Berm

A berm or baffle shall extend across the full width of the wet pool, and tie into the wet pond side slopes.

The baffle or berm volume shall not count as part of the total wet pool volume. The full-length berm or baffle promotes plug flow and enhances quiescence and laminar flow through as much of the entire water volume as possible. Alternative methods to the full-length berm or baffle that provide equivalent flow characteristics may be approved on a case-by-case basis by Thurston County.

The term baffle means a vertical divider placed across the entire width of the pond, stopping short of the bottom. A berm is a vertical divider typically built up from the bottom, or if in a vault, connects all the way to the bottom.

Side Slopes

Provide side slopes that are sufficiently gentle to avoid the need for fencing (3H:1V or flatter).

Submerged Berm

The top of the berm may extend to the water quality design water surface, or be 1 foot below the water quality design water surface. If at the water quality design water surface, berm side slopes should be 3H:1V. Berm side slopes may be steeper (up to 2:1) if the berm is submerged 1 foot. Submerging the berm is intended to enhance safety by discouraging pedestrian access when side slopes are steeper than 3H:1V. An alternative to the submerged berm design is the use of barrier planting to prevent easy access to the divider berm in an unfenced wet pond.

If good vegetation cover is not established on the berm, erosion control measures should be used to prevent erosion of the berm back-slope when the pond is initially filled.

Materials

Lining

Liners, if required, shall meet the requirements of Appendix V-B.

Soils

The method of construction of soil/landscape systems can cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations. The soil formulation will impact the plant species that will flourish or suffer on the site, and the formulation should be such that it encourages desired species and discourages undesired species.

On most pond sites, it is important to amend the soil before planting since ponds are typically placed well below the native soil horizon in very poor soils.

Vegetation

Planting requirements for detention ponds also apply to wet ponds.

Evergreen or columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Trees should be set back so that the branches will not extend over the pond.

Large wet ponds intended for phosphorus control shall not be planted within the cells, as the plants will release phosphorus in the winter when they die off.

If the second cell of a basic wet pond is 3 feet or shallower, the bottom area shall be planted with emergent wetland vegetation. See Table 6.2 for recommended emergent wetland plant species for wet ponds.

> Intent: Planting of shallow pond areas helps to stabilize settled sediment and prevent resuspension.

Cattails (*Typha latifolia*) are not recommended because they tend to crowd out other species and will typically establish themselves anyway.

If the wet pond discharges to a phosphorus-sensitive lake or wetland (see Chapter 4 of Volume I), shrubs that form a dense cover should be planted on slopes above the water quality design water surface on at least three sides. For banks that are berms, no planting is allowed if the berm is regulated by dam safety requirements. The purpose of planting is to discourage waterfowl use of the pond and to provide shading. Some suitable trees and shrubs include:

- Vine maple (*Acer circinatum*)
- Wild cherry (*Prunus emarginata*)
- Red osier dogwood (*Cornus stolonifera*)
- California myrtle (*Myrica californica*)
- Indian plum (*Oemleria cerasiformis*)
- Pacific yew (*Taxus brevifolia*)
- Numerous ornamental species.

Structural Design Considerations

The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed civil engineer. If a baffle or retaining wall is used, it should be submerged 1 foot below the design water surface to discourage access by pedestrians.

Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity (including both water and sediment storage volumes) greater than 10 acre-feet (435,600 cubic feet or

3.26 million gallons) above natural ground level, then dam safety design and review are required by Ecology.

No trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety.

Site Design Elements

The following design features should be incorporated to enhance aesthetics where possible:

- Provide pedestrian access to shallow pool areas enhanced with emergent wetland vegetation. This allows the pond to be more accessible without incurring safety risks.
- Create flat areas overlooking or adjoining the pond for picnic tables or seating that can be used by residents. Walking or jogging trails around the pond are easily integrated into site design.
- Include fountains or integrated waterfall features for privately maintained facilities
- Provide visual enhancement with clusters of trees and shrubs
- Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

Setbacks

Location of a wet pond relative to site constraints (e.g., buildings, property lines, etc.) shall be the same as described in Appendix V-E for detention ponds.

Access

Access and maintenance roads shall be provided and designed according to the requirements in Appendix V-D. Access and maintenance roads shall extend to both the wet pond inlet and outlet structures. An access ramp shall be provided to the bottom of all cells, unless trackhoe (maximum reach of 20 feet) can reach all portions of the cell and can load a truck parked at the pond edge or on the internal berm of a wet pond or combined pond.

The access and maintenance road could be extended along the full length of the wet pond and could double as play courts or picnic areas. Placing finely ground bark or other natural material over the road surface would render it more pedestrian friendly.

If the dividing berm is also used for access, it shall be built to sustain loads of up to 80,000 pounds.

Construction and Maintenance

As with other similar BMPs, wet ponds may be used as sedimentation ponds during construction. However, any sediment that has accumulated in the pond must be removed after construction is complete and before the pond is permanently online.

If the berm embankments are greater than 4 feet in height, the berm must be constructed by excavating a key equal to 50 percent of the embankment cross-sectional height and width. This requirement may be waived if recommended by a geotechnical engineer for specific site conditions. The geotechnical analysis shall address situations in which one of the two cells is empty while the other remains full of water.

The County may require a bypass/ shutoff valve to enable the pond to be taken off-line for maintenance purposes.

A gravity drain for maintenance is required where feasible. The engineer must demonstrate why a drain is not feasible and show in the Maintenance Plan how to drain the pond.

6.1.3 WP.03 Wet Vaults

A wet vault is an underground structure similar in appearance to a detention vault, except with a permanent pool of water (wet pool) that dissipates energy and improves the settling of particulate pollutants (see Figure 6.5). Being underground, the wet vault lacks biological pollutant removal mechanisms (e.g., algae uptake) present in surface wet ponds.

Wet vault construction at Bellingham

Applicability

A wet vault requires specific acceptance of the Administrator or designee. With acceptance, a wet vault may be used for commercial, industrial, or roadway projects if there are space limitations precluding the use of other treatment BMPs. The use of wet vaults for residential development is highly discouraged.

If oil control is required for a project, a wet vault may be combined with an API oil/water separator.

Limitations

A wet vault is believed to be ineffective in removing dissolved pollutants such as soluble phosphorus or metals such as copper. There is also concern that oxygen levels will decline, especially in warm summer months, because of limited contact with air and wind. However, the extent to which this potential problem occurs has not been documented.

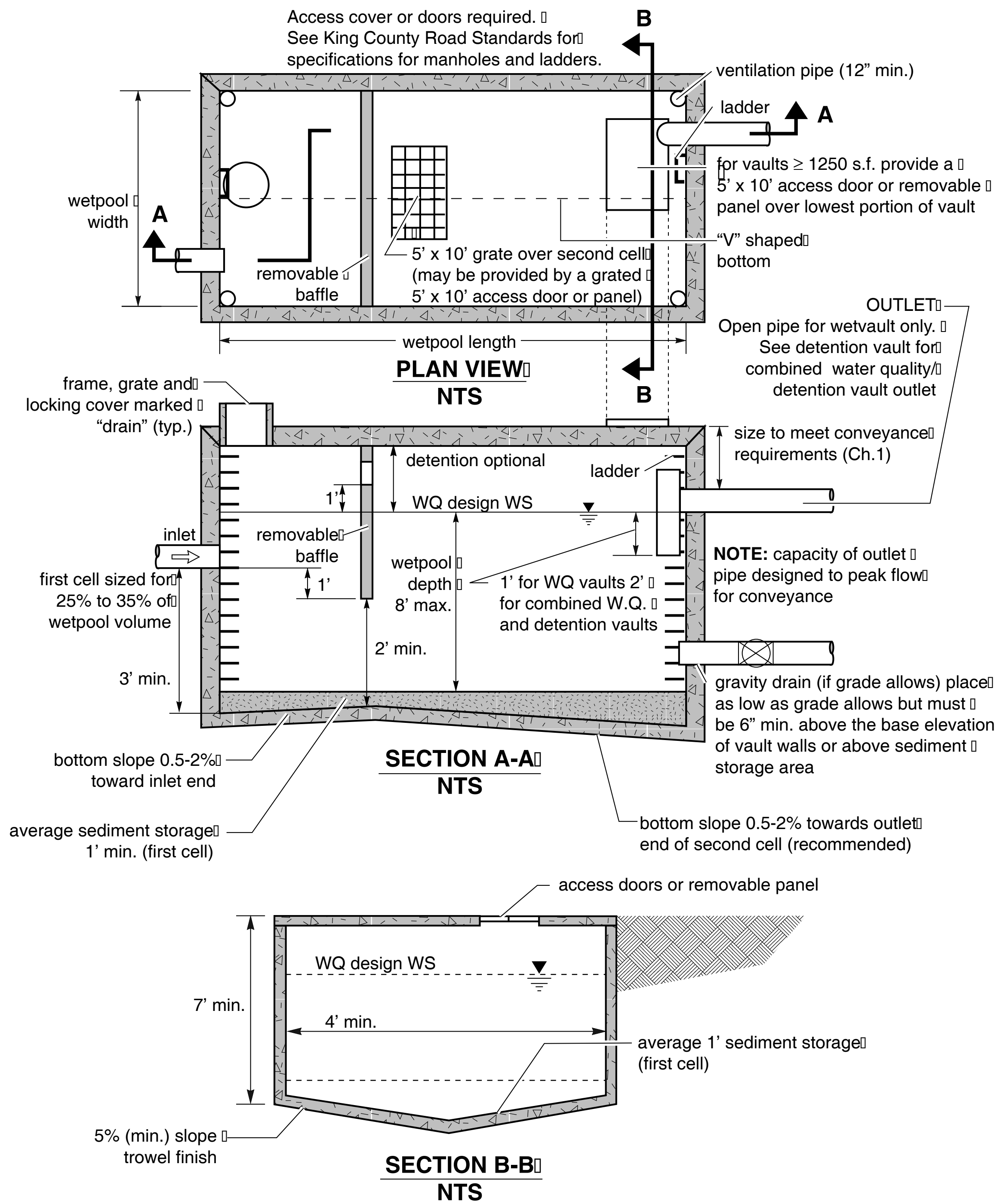


Figure 6.5. Wet Vault.

Below-ground structures like wet vaults are difficult and expensive to maintain. The need for maintenance is often not seen and as a result routine maintenance does not occur.

Submittals and Approval

The use of a wet vault for runoff treatment is restricted to those circumstances where other alternatives are not feasible of practicable due to situations such as limited space or safety concerns. Its use requires the specific acceptance of the Administrator or designee. The applicant shall submit to the Administrator or designee the justification for using a wet vault for the project and why other runoff treatment facilities are not suitable.

If use of a wet vault is approved for the project, include documentation of acceptance and calculations in the submittal prepared for the project in accordance with the requirements of Chapter 3 of Volume I.

Pretreatment

A catch basin structure shall be installed upstream from the wet vault with a minimum sediment storage depth of 2 feet to capture large sediment and debris prior to entry to the vault.

Hydrologic and Hydraulic Design Considerations

Wet Vault Sizing

As with wet ponds, the primary design factor that determines the removal efficiency of a wet vault is the volume of the wet pool. The larger the volume, the more effective the pollutant removal.

The sizing procedure for a wet vault is identical to the sizing procedure for a wet pond. The wet pool volume for the wet vault shall be equal to or greater than the total volume of runoff from the 6-month, 24-hour storm event using a single event hydrologic model (SBUH/SCS). Alternatively, the 91st percentile, 24-hour runoff volume estimated by an approved continuous runoff model may be used.

Design Criteria

Typical design details and concepts for the wet vault are shown in Figure 6.5.

Geometry

Pollutant removal performance of wet vaults may be improved by avoiding dead zones (like corners) where little exchange occurs, using large length-to-width ratios (a flow length-to-width ratio greater than 3:1

minimum is desirable), dissipating energy at the inlet, and ensuring that flow rates are uniform to the extent possible and not increased between cells.

The vault shall be separated into two cells by a wall or a removable baffle.

Where possible, the inlet and outlet should be at opposing corners of the vault to increase the flow path.

Inlet

The number of inlets to the wet vault should be limited, and the flow path length should be maximized from inlet to outlet for all inlets to the vault.

The inlet to the wet vault shall be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom. The top of the inlet pipe should be submerged at least 1 foot, if possible.

> Intent: The submerged inlet is to dissipate energy of the incoming flow. The distance from the bottom is to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

Outlet

Unless designed as an off-line facility, the capacity of the outlet pipe and available head above the outlet pipe shall be designed to convey the 100-year design flow for developed site conditions without overtopping the vault. The available head above the outlet pipe must be a minimum of 6 inches.

The outlet pipe shall be back-sloped or have tee section, the lower arm of which shall extend 1 foot below the WQ design water surface to provide for trapping of oils and floatables in the vault.

Baffle

If a removable baffle is used, the following criteria apply:

- The baffle shall extend from a minimum of 1 foot above the WQ design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.
- The lowest point of the baffle shall be a minimum of 2 feet from the bottom of the vault, and greater if feasible.
- If the vault is less than 2,000 cubic feet (inside dimensions), or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted and the vault may be one-celled.

- The second cell may be level (longitudinally) sloped toward the outlet, with a high point between the first and second cells. The intent of sloping the bottom is to direct the sediment accumulation to the closest access point for maintenance purposes. Sloping the second cell towards the access opening for the first cell is also acceptable.

- The vault bottom shall slope laterally a minimum of 5 percent from each side towards the center, forming a broad "v" to facilitate sediment removal. Note: More than one "v" may be used to minimize vault depth.

  Exception: Thurston County may allow the vault bottom to be flat if removable panels are provided over the entire vault. Removable panels shall be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.

- The highest point of a vault bottom must be at least 6 inches below the outlet elevation to provide for sediment storage over the entire bottom.

- Provision for passage of flows should the outlet plug shall be provided.

- Wet vaults may be constructed using arch culvert sections provided the top area at the WQ design water surface is, at a minimum, equal to that of a vault with vertical walls designed with an average depth of 6 feet.

  Intent: To prevent decreasing the surface area available for oxygen exchange.

- Wet vaults shall conform to the "Materials" and "Structural Stability" criteria specified for detention vaults (BMP D.03).

- Where pipes enter and leave the vault below the WQ design water surface, they shall be sealed using a non-porous, non-shrinking grout.

Presettling Cell

The sediment storage in the first cell shall be an average of 1 foot. Because of the v-shaped bottom, the depth of sediment storage needed above the bottom of the side wall is roughly proportional to vault width according to the schedule below:

Vault Width	Sediment Depth (from bottom of side wall)
15'	10"
20'	9"
40'	6"
60'	4"

Where feasible, the bottom of the first cell shall be sloped toward the access opening. Slope shall be between 0.5 percent (minimum) and 2 percent (maximum).

Second Cell

The second cell shall be a minimum of 3 feet deep since planting cannot be used to prevent resuspension of sediment in shallow water as it can in open ponds.

Where feasible, the floor of the second cell should slope toward the outlet for ease of cleaning.

Materials

Wet Vaults shall meet the material requirements and structural design considerations for Detention Vaults as listed in BMP D.03, Section 4.1.3 of Volume V.

Modifications for Combining with a Baffle Oil/Water Separator

If the project site is a high-use site (see Volume I) and a wet vault is proposed, the vault may be combined with a baffle oil/water separator to meet the runoff treatment requirements with one facility rather than two. Structural modifications and added design criteria are given below. However, the maintenance requirements for baffle oil/water separators must be adhered to, in addition to those for a wet vault. This will result in more frequent inspection and cleaning than for a wet vault used only for TSS removal. See Appendix V-C for information on maintenance of baffle oil/water separators.

The following additional design criteria apply to wet vaults combined with baffle oil/water separators:

- The sizing procedures for the baffle oil/water separator (Chapter 8) shall be run as a check to ensure the vault is large enough. If the oil/water separator sizing procedures result in a larger vault size, increase the wet vault size to match.

- An oil retaining baffle shall be provided in the second cell near the vault outlet. The baffle shall not contain a high-flow overflow, or else the retained oil will be washed out of the vault during large storms.
- The vault shall have a minimum length-to-width ratio of 5:1.
- The vault shall have a design water depth-to-width ratio of between 1:3 to 1:2.
- The vault shall be watertight and shall be coated to protect from corrosion.
- Separator vaults shall have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and to provide emergency shut-off capability in case of a spill. A valve box and riser shall also be provided.
- Wet vaults used as oil/water separators must be off-line and must bypass flows greater than the off-line WQ design flow multiplied by the off-line ratio indicated in Figure 5.1.b. *Intent: This design minimizes the entrainment and/or emulsification of previously captured oil during very high flow events.*

Structural Design Considerations

The two cells of a wet vault shall not be divided into additional subcells by internal walls. If internal structural support is needed, it is preferred that post and pier construction be used to support the vault lid rather than walls. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flow path. *Intent: Treatment effectiveness in wet pool facilities is related to the extent to which plug flow is achieved and short-circuiting and dead zones are avoided. Structural walls placed within the cells can interfere with plug flow and create significant dead zones, reducing treatment effectiveness.*

If a wall is used to separate the two cells, a 5-foot by 10-foot removable maintenance access must be provided for both cells.

Site Design Elements

Access, setbacks and right-of-way requirements are the same as for detention vaults (see Section 4.1.3, BMP D.03, of this Volume).

Construction and Maintenance

Lockable grates instead of solid manhole covers are recommended to increase air contact with the wet pool.

A minimum of 50 square feet of grate shall be provided over the second cell. For vaults in which the surface area of the second cell is greater than 1,250 square feet, 4 percent of the top shall be grated. This requirement may be met by one grate or by many smaller grates distributed over the second cell area. Note: a grated access door can be used to meet this requirement. *Intent: The grate allows air contact with the wetpool in order to minimize stagnant conditions which can result in oxygen depletion, especially in warm weather.*

Thurston County may require a bypass/shutoff valve to enable the vault to be taken off-line for maintenance.

Sediment that has accumulated in the vault must be removed after construction in the drainage area is complete. If no more than 12 inches of sediment have accumulated after the infrastructure is built, cleaning may be left until after building construction is complete. In general, sediment accumulation from stabilized drainage areas is not expected to exceed an average of 4 inches per year in the first cell. If sediment accumulation is greater than this amount, it will be assumed to be from construction unless it can be shown otherwise.

6.1.4 WP.04 Combined Detention and Wet Pool Facilities

Combined detention and water quality wet pool facilities look like detention facilities, but also contain a permanent pool of water. The following design procedures, requirements, and recommendations describe differences in the design of standalone water quality facilities when combined with detention storage.

Applicability

The following combination facilities are summarized in this section:

Table 6.3. Combined Detention and Wetpool Facilities

Facility	Flow Control	Level of Treatment
Basic detention/wetpond	Flow control	Basic treatment
Large detention/wetpond	Flow control	Phosphorus treatment
Detention/wetvault	Flow control	Basic Treatment
Detention/stormwater wetland	Flow Control	Basic Treatment

Combined detention and water quality facilities are very efficient for sites that also have detention requirements. The water quality facility may often be placed beneath the detention facility without increasing the facility surface area.

Limitations

The fluctuating water surface of the live storage will create unique challenges for plant growth and for aesthetics alike.

The basis for pollutant removal in combined facilities is the same as in the stand-alone water quality facilities. However, in the combined facility, the detention function creates fluctuating water levels and added turbulence. For simplicity, the positive effect of the extra live storage volume and the negative effect of increased turbulence are assumed to balance, and are thus ignored when sizing the wet pool volume. For the combined detention/stormwater wetland, criteria that limit the extent of water level fluctuation are specified to better ensure survival of the wetland plants.

Unlike the wet pool volume, the live storage component of the facility shall be provided above the seasonal high water table.

For projects located within a designated Well Head Protection Area (WHPA) for a public water system with over 1,000 connections the bottom of the wet pond shall be above the seasonal high groundwater elevation. Where less than 3-feet of separation exists to seasonal high groundwater, the wet pond shall be lined.

Submittals and Approval

Make submittals required by Volume I and as required for the individual detention or wet pool / wet vault BMP. Include the following information in the submittal:

- Hydrologic modeling results showing the volume required for the wet pool as well as calculations demonstrating compliance with flow control minimum requirements
- Justification for not providing a liner, if lining the facility is not proposed
- Details of all structures and material and construction specifications
- Planting plan showing plant species, quantity, location and any special planting requirements
- Cross section of the pond through the control structure
- Design calculations for the overflow structures
- Documentation of how the facility location meets setback requirements.

Pretreatment

No pretreatment is required. Except that if the combined facility is a wet vault/detention vault then a catch basin with a minimum 2-foot sediment depth shall be installed immediately upstream from the vault.

Hydrologic and Hydraulic Design Considerations

The sizing procedure for combined detention and wet ponds are identical to those outlined for wet ponds and for detention facilities. The wet pool volume for a combined facility shall be equal to or greater than the 91st percentile, 24-hour runoff volume estimated by an approved continuous runoff model. Follow the standard procedure specified in Volume III to size the detention portion of the pond.

Design Criteria

Typical design details and concepts for a combined detention and wet pond are shown in Figures 6.6 through 6.8. The detention portion of the facility shall meet the design criteria and sizing procedures set forth in BMP D.01.

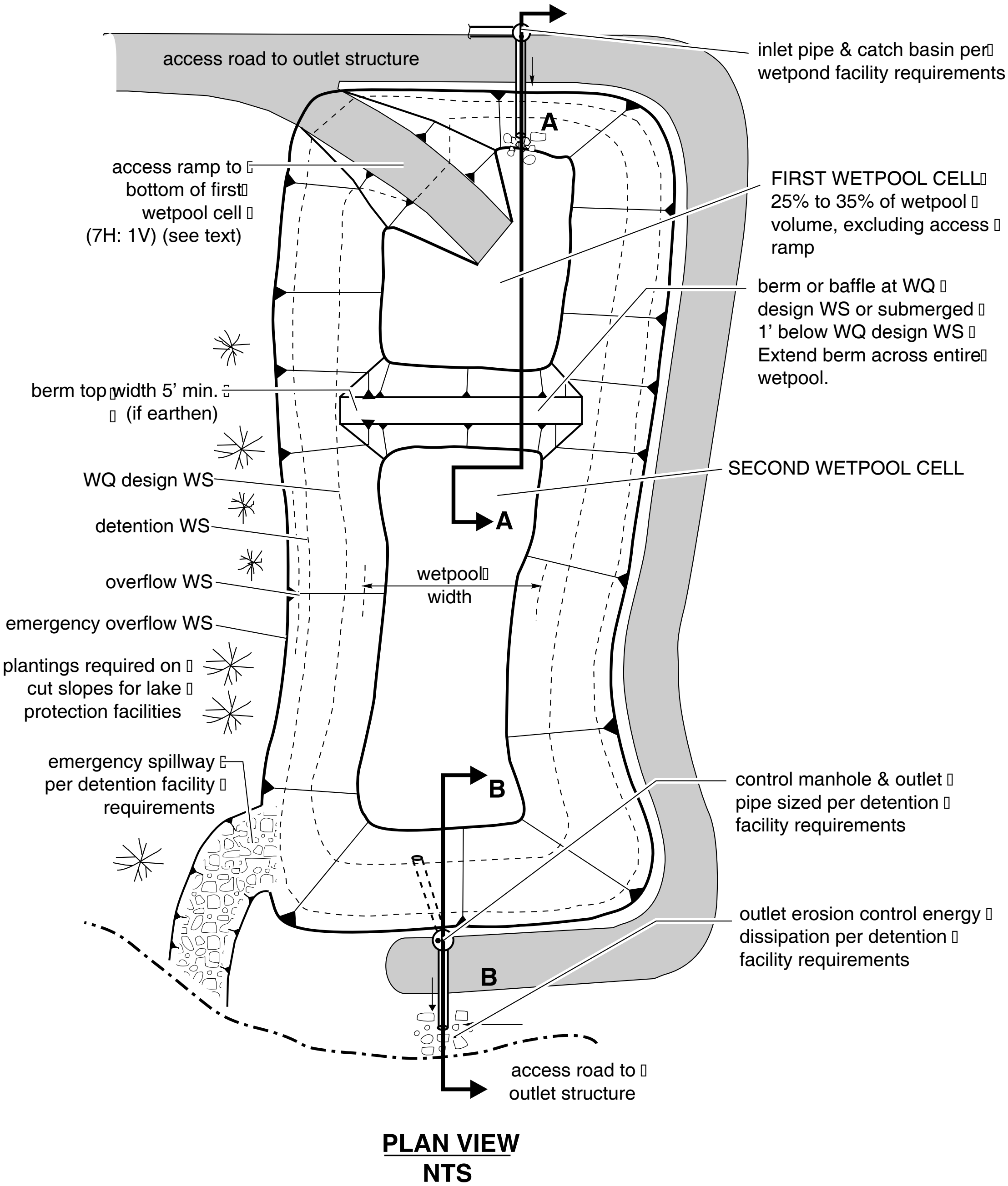


Figure 6.6. Combined Detention and Wetpond.

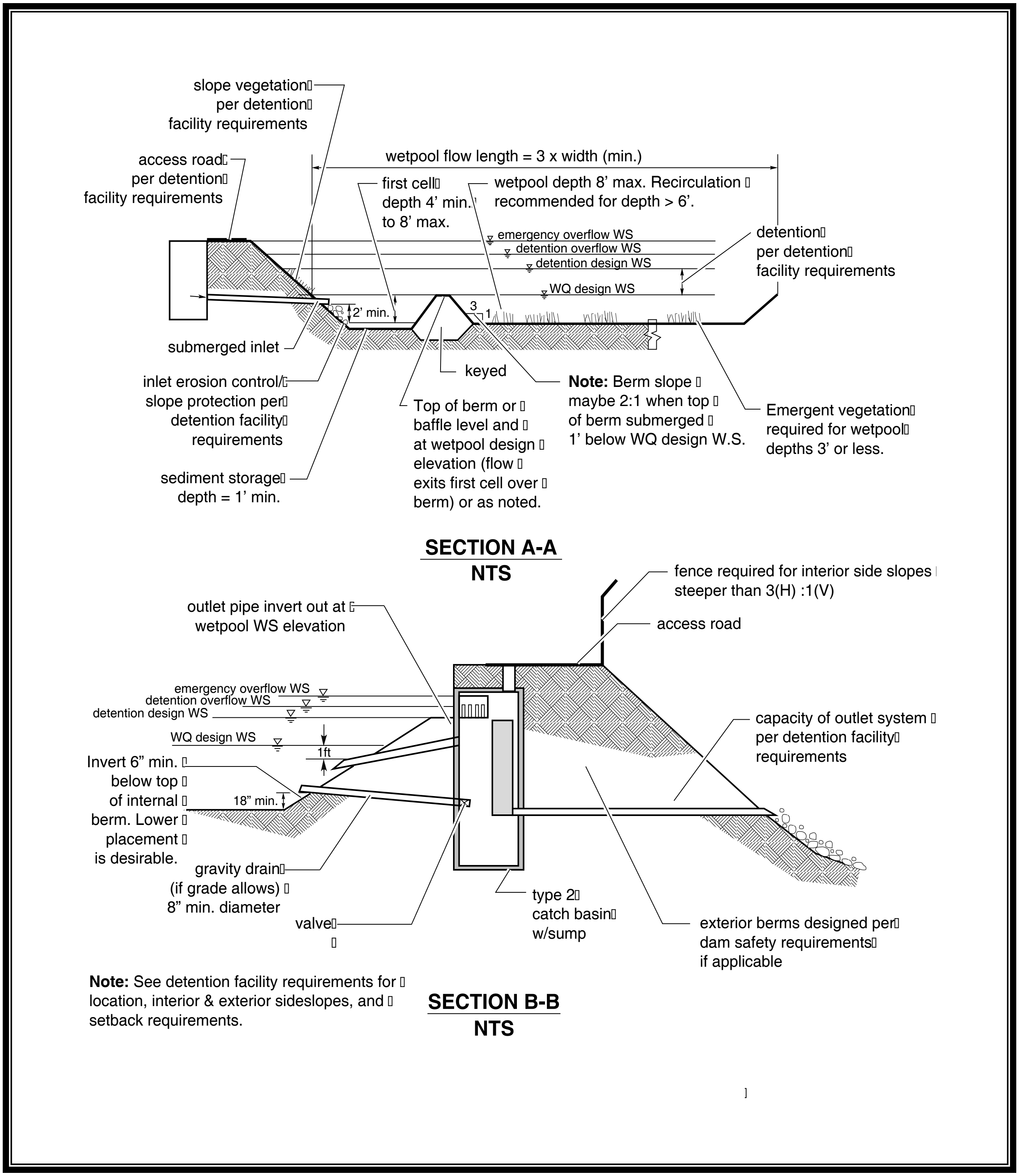
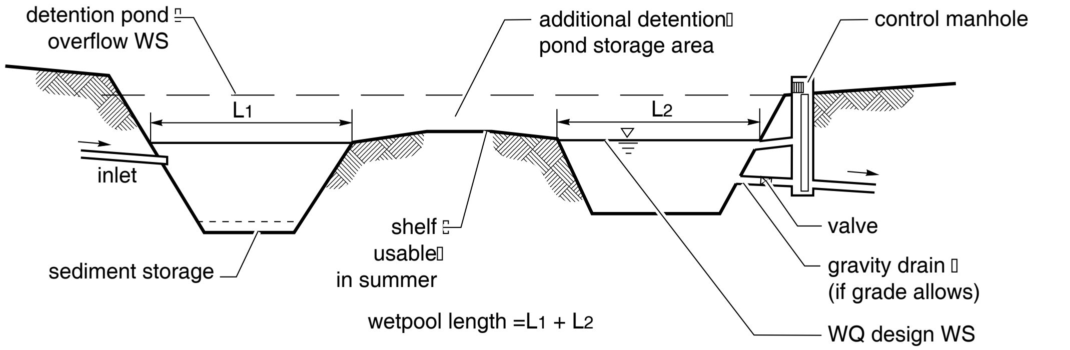
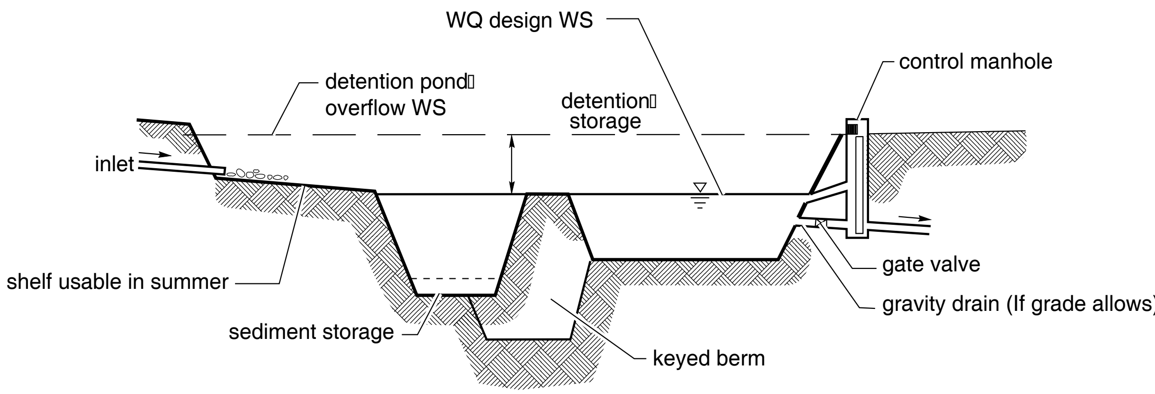


Figure 6.7. Combined Detention and Wetpond (continued).



SECTION VIEW
NTS



SECTION VIEW
NTS

Note: These examples show how the combined detention/wetpool can be configured to allow for "shelves" for joint use opportunities in dry weather. Other options may also be acceptable.

Figure 6.8. Alternative Configurations of Detention and Wetpool Areas.

Detention Pond and Wet Pond

Geometry

The wet pool and sediment storage volumes shall not be included in the required detention volume.

The "Wet Pool Geometry" criteria for wet ponds (see BMP WP.02) shall apply with the following modifications/clarifications:

- Criterion 1: The permanent pool may be made shallower to take up most of the pond bottom, or deeper and positioned to take up only a limited portion of the bottom. Note, however, that having the first wet pool cell at the inlet allows for more efficient sediment management than if the cell is moved away from the inlet. Wet pond criteria governing water depth must, however, still be met. See Figure 6.8 for two possibilities for wet pool cell placement.

  Intent: This flexibility in positioning cells is provided to allow for multiple use options, such as volleyball courts in live storage areas in the drier months.

- Criterion 2: The minimum sediment storage depth in the first cell is 1 foot. The 6 inches of sediment storage required for detention ponds do not need to be added to this, but 6 inches of sediment storage must be added to the second cell to comply with the detention sediment storage requirement.

Berms, Baffles, and Slopes

Same as for wet ponds (see BMP WP.02).

Inlet and Outlet

The "Inlet and Outlet" criteria for wet ponds shall apply with the following modifications:

- A sump must be provided in the outlet structure of combined ponds.
- The detention flow restrictor and its outlet pipe shall be designed according to the requirements for control structures in Volume V-A.

Planting Requirements

Same as for wetponds.

Access and Setbacks

Same as for wetponds.

Combined Detention and Wetvault

Geometry

Minimum sediment storage depth in the first cell shall average 1 foot. The 6 inches of sediment storage required for detention vaults do not need to be added to this, but 6 inches of sediment storage must be added to the second cell to comply with detention vault sediment storage requirements.

The oil retaining baffle shall extend a minimum of 2 feet below the WQ design water surface.

If a vault is used for detention as well as water quality control, the facility may not be modified to function as a baffle oil/water separator.

Inlet and Outlet

The inlet and outlet criteria for wet vaults shall apply with the following modifications:

- Provide a sump in the outlet structure of the vault
- Design the detention flow restrictor and its outlet pipe according to the requirements for detention vaults.

Combined Detention and Stormwater Wetland

Sizing Criteria

The sizing procedure for combined detention and stormwater wetlands is identical to those outlined for stormwater wetlands and for detention facilities. Follow the procedure outlined in BMP WP.01 to determine the stormwater wetland size. Follow the standard procedure for sizing a detention pond for the detention portion of the wetland.

Water Level Fluctuations Restrictions: The difference between the WQ design water surface and the maximum water surface associated with the 2-year runoff shall not be greater than 3 feet. If this restriction cannot be met, the size of the stormwater wetland must be increased. The additional area may be placed in the first cell, second cell, or both. If placed in the second cell, the additional area need not be planted with wetland vegetation or counted in calculating the average depth.

Geometry

The design criteria for detention ponds and stormwater wetlands must both be met, except for the following modifications or clarifications:

- The minimum sediment storage depth in the first cell is 1 foot. The 6 inches of sediment storage required for detention ponds does not need to be added to this, nor does the 6 inches of sediment storage in the second cell of detention ponds need to be added.

Inlet and Outlet Criteria

The inlet and outlet criteria for wetponds shall apply with the following modifications:

- Provide a sump in the outlet structure of combined facilities
- Design the detention flow restrictor and its outlet pipe according to the requirements for detention ponds.

Planting Requirements

The Planting Requirements for stormwater wetlands are modified to use the following plants which are better adapted to water level fluctuations:

- *Scirpus acutus* (hardstem bulrush) 2 – 6' depth
- *Scirpus microcarpus* (small-fruited bulrush) 1 – 2.5' depth
- *Sparganium emersum* (burreed) 1 – 2' depth
- *Sparganium eurycarpum* (burrreed) 1 – 2' depth
- *Veronica* sp. (marsh speedwell) 0 – 1' depth

In addition, the shrub *Spirea douglasii* (Douglas spirea) may be used in combined facilities.

Access and Setbacks

Same as for stormwater wetlands.

6.1.5 WP.05 Presettling Basins & Pretreatment

A presettling basin is a structure that provides pretreatment of runoff to remove coarser-grained suspended solids, which can impact other runoff treatment BMPs.

Applicability

Removal of suspended solids pretreatment helps prevent clogging or excessive sedimentation in the main water quality facility. Pretreatment is required:

- For sand filters and infiltration BMPs to protect them from excessive siltation and debris
- Where the basic treatment facility or the receiving water may be adversely affected by non-target pollutants (e.g., oil), or may be overwhelmed by a heavy load of targeted pollutants (e.g., suspended solids).

Presettling basins are a typical pretreatment BMP used to remove suspended solids. All basic, enhanced, and phosphorus treatment options may be used for pretreatment to reduce suspended solids.

A detention pond sized to meet the flow control standard in Volume I may also be used to provide pretreatment for suspended solids removal.

This remainder of this section discusses Presettling Basins as a BMP.

Limitations

Runoff treated by a presettling basin may not be discharged directly to a receiving water or to groundwater because it only removes coarse particulates—not fine-grained or dissolved materials. It must be further treated by a basic or enhanced runoff treatment BMP.

Hydrologic and Hydraulic Design Considerations

Treatment Volume

The total treatment volume of the presettling basin shall be at least 30 percent of the total water quality treatment design volume (e.g., 30 percent of the size of a wetpond designed per BMP WP.02).

Drawdown Time

Drawdown time of the presettling storage area (excluding wet pool area) must not exceed 40 hours.

Design Criteria

Geometry

A presettling basin shall be designed to include a wet pool sedimentation area at least 6 inches deep at the bottom of the facility.

If the runoff in the presettling basin will be in direct contact with the soil, it must be lined per the liner requirement in Appendix V-B.

The presettling basin shall meet the following requirements:

- The length-to-width ratio shall be at least 3:1. Berms or baffles may be used to lengthen the flow path.
- The minimum depth shall be 4 feet; the maximum depth shall be 6 feet.
- Inlets and outlets shall be designed to minimize velocity and reduce turbulence. Inlet and outlet structures should be located at opposite ends of the basin in order to maximize particle-settling opportunities.

Structural Design Considerations

Embankments that impound water must comply with the *Washington State Dam Safety Regulations* (Chapter 173-175 WAC). If the impoundment has a storage capacity (including both water and sediment storage volumes) greater than 10 acre-feet (435,600 cubic feet or 3.26 million gallons) above natural ground level, then dam safety design and review are required by Ecology.

Site Design Elements

Setbacks

Setbacks shall be the same as for wet ponds.

Construction and Maintenance

A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation, unless an alternative gauging method is proposed.

Applicable maintenance requirements for a wet pond also apply to a pre-settling basin and are further described in Appendix V-C.

Chapter 7 - Media Filtration BMPs

Media filtration BMPs rely on the physical, biological, and chemical properties of various media such as sand, perlite, zeolite, and activated carbon to remove pollutants. Filter systems are commonly configured as basins, trenches, vaults, or proprietary cartridge filtration systems.

NOTE: Thurston County will not accept ownership of media filtration facilities without prior acceptance. See Appendix V-C for maintenance requirements:

7.1 Media Filtration Design BMPs

The following media filtration BMPs are described in this section:

- MF.01 Sand Filter Basin
- MF.02 Sand Filter Vault
- MF.03 Linear Sand Filter.
- MF.04 Media Filter Drain.

Proprietary media filters which have been approved by Ecology with a General Use Level Designation for the required level of treatment may be proposed for some projects with there is insufficient land available for surface facilities. Acceptance by the Manual Administrator or designee is required. For information on current approved proprietary media filters and other emerging technologies, see Ecology's website: <http://www.ecy.wa.gov/programs/wq/stormwater/newtech/>.

7.1.1 MF.01 Sand Filter Basin

The sand filter basin is a technology adopted from wastewater treatment. Stormwater passes through a sand layer, which filters out particulates—and in the case of amended sand, dissolved substances as well.

Applicability

Sand filtration can be used in most types of developments. Applications include residential subdivisions, parking lots for commercial and industrial establishments, gas stations, high-use sites, high-density multifamily housing, roadways, and bridge decks. They are not recommended in areas undergoing construction or otherwise generating high sediment loads.

Sand filter basins may be designed to provide basic or enhanced treatment, depending on the media:

Basic Sand Filter

Basic sand filters are expected to achieve the performance goals for basic treatment. Based on experience in King County, Washington and Austin, Texas, basic sand filters should be capable of achieving the following average pollutant removals:

- 80 percent total suspended solids at influent Event Mean Concentrations (EMCs) of 30 to 300 mg/L (King County, 1998) (Chang, 2000)
- Oil and grease to below 10 mg/L daily average and 15 mg/L at any time, with no ongoing or recurring visible sheen in the discharge.

Amended Sand Filter

Sand filters can also be amended to provide enhanced treatment. Use of amended sand filters for enhanced treatment requires prior County and Ecology approval.

Large Sand Filter

Large sand filters are approved for phosphorus treatment. They are expected to remove at least 50 percent of total phosphorous compounds by collecting and treating 95 percent of the runoff volume (ASCE and WEF, 1998).

Limitations

Sand filter basins require a large amount of space, and so are not appropriate for tightly constrained sites.

There must be adequate hydraulic head between the inlet and outlet (see *Hydrologic and Hydraulic Design Considerations*). They are not appropriate for areas subject to large loadings of debris, heavy sediment loads, and oils and greases that could clog or prematurely overload the sand.

Submittals and Approval

Submit design calculations, drawings and details as part of submittal requirements of Volume I.

Pretreatment

Pretreatment is necessary to reduce velocities to the sand filter and remove debris, floatables, large particulate matter, and oils. In high water table areas, adequate drainage of the sand filter may require additional engineering analysis and design considerations. An underground filter (BMP MF.02) should be considered in areas subject to freezing conditions (Urbonas, 1997).

Hydrologic and Hydraulic Design Considerations

Sand filters may be located either online or off-line, subject to the following:

- ***Online*** sand filters must NOT be placed upstream of a detention facility. This is to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants.

- ***Offline*** sand filters placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at the 15-minute water quality flow rate, as predicted by an approved continuous runoff model, to the sand filter.

- ***Offline*** sand filters placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at the 2-year recurrence interval flow from the detention pond, as predicted by an approved continuous runoff model, to the treatment facility.

Sand Filter Sizing Procedure

Sand filters must capture and treat the Water Quality Design Storm volume, which is 91 percent of the total runoff volume (95 percent for large sand filter) as predicted by an approved, equivalent, continuous runoff model.

General facility sizing methods are described below, followed by design criteria to be used when designing a sand filter with an approved continuous runoff model.

General Design Method

Whether designing the sand filter manually or with an approved model, either method uses Darcy's law for modeling flow through a porous media like sand or soil:

$$Q = KiA$$

Where:

Q = water quality design flow (cfs)

K = hydraulic conductivity of the media (fps)

A = surface area perpendicular to the direction of flow (sf)

i = hydraulic gradient (ft/ft) for a constant head and constant media depth

$$i = \frac{h + L}{L}$$

and:

h = average depth of water above the filter (ft), defined as d/2

d = maximum water storage depth above the filter surface (ft)

L = thickness of sand media (ft).

Darcy's law underlies both the manual and the modeling design methods. V, or more correctly, 1/V, is the direct input in the sand filter design. The relationship between V and K is revealed by equating Darcy's law and the equation of continuity, Q = VA. (Note: When water is flowing into the ground, V is commonly called the filtration rate. It is ordinarily measured via a soil infiltration test.)

Specifically:

$$Q = KiA \quad \text{and} \quad Q = VA \text{ so,}$$
$$VA = KiA \quad \text{or} \quad V = Ki$$

Note that $V \neq K$. The filtration rate is not the same as the hydraulic conductivity, but they do have the same units (distance per time). K can be equated to V by dividing V by the hydraulic gradient i, which is defined above.

The hydraulic conductivity K does not change with head nor is it dependent on the thickness of the media, only on the characteristics of the media and the fluid. The hydraulic conductivity of 1 inch per hour

(2.315×10^{-5} fps) specified for sand filter design is based on bench-scale tests of conditioned rather than clean sand.

This design hydraulic conductivity represents the average sand bed condition as silt is captured and held in the filter bed. Unlike the hydraulic conductivity, the filtration rate V changes with head and media thickness, although the media thickness is constant in the sand filter design. Table 7.1 shows values of V for different water depths d (d=2h).

Table 7.1. Sand Filter Design Parameters

	Sand Filter Design Parameters					
Facility ponding depth d (ft)	1	2	3	4	5	6
Filtration rate V (in/hr) [a]	1.33	1.67	2.00	2.33	2.67	3.00
1/V (min/in)	45	36	30	26	22.5	20

[a] The filtration rate is not used directly, but is provided for information. V equals the hydraulic conductivity, K, times the hydraulic gradient, i. The hydraulic conductivity used is 1 inch/hr. The hydraulic gradient = (h + L)/L, where h = d/2 and L = the sand depth (1.5 ft).

Modeling Method

When using continuous modeling to size a sand filter, apply the assumptions listed in Table 7.2. Several available modeling programs include built-in modules to size sand filters.

Table 7.2. Sand Filter Design and Sizing Criteria

Variable	Assumption
Computational Time Step	15-minutes
Inflows to Facility	Model output for water quality design
Ponding Depth	Maximum water depth over the filter media
Precipitation Applied to Facility	Checked (always activated when sizing above ground sand filters)
Evaporation Applied to Facility	Checked (always activated when sizing above ground sand filters)
Media depth	18 inches or other as designed
Sand Media Hydraulic Conductivity	1 inch per hour
Use Wetted Surface Area	Only if side slopes are 3:1 or flatter

Inlet

Inlet bypass and flow spreading structures (e.g., flow spreaders, weirs or multiple orifice openings) shall be designed to capture the applicable design flow rate, minimize turbulence and to spread the flow uniformly across the surface of the sand filter. Stone riprap or other energy dissipation devices shall be installed to prevent gouging of the sand medium and to promote uniform flow. Include emergency spillway or overflow structures (see Appendix V-A).

Overflow

An overflow shall be included in the design of the basic and large sand filter basin (see Appendix V-A). The overflow height shall be at the maximum hydraulic head of the pond above the sand bed.

Underdrain

The following are design criteria for the underdrain piping: (types of underdrains include: a central collector pipe with lateral feeder pipes, or, a geotextile drain strip in an 8-inch gravel backfill or drain rock bed, or, longitudinal pipes in an 8-inch gravel backfill or drain rock with a collector pipe at the outlet end.)

- Upstream of detention underdrain piping shall be sized to handle double the 2-year recurrence interval flow indicated by an approved continuous runoff model (the doubling factor is a safety factor used in the absence of a conversion factor from the 1-hour time step to a 15-minute time step). Downstream of detention the underdrain piping shall be sized for the 2-year recurrence interval flow indicated by an approved continuous runoff model. In both instances there shall be at least 1 foot of hydraulic head above the invert of the upstream end of the collector pipe (King County, 1998).

- Internal diameters of underdrain pipes shall be a minimum of 6 inches and two rows of three-eighth-inch holes spaced 6 inches apart longitudinally (maximum), with rows 120 degrees apart (laid with holes downward). Maximum perpendicular distance between two feeder pipes must be 10 feet. Drain piping could be installed in basin and trench configurations.

- Main collector underdrain pipe shall be at a slope of 1 percent minimum.

- A geotextile fabric (specifications in Appendix V-B) must be used between the sand layer and drain rock or gravel and placed so that 2 inches of drain rock/gravel is above the fabric.

- Cleanout wyes with caps or junction boxes must be provided at both ends of the collector pipes. Cleanouts must extend to the surface of the filter.

Design Criteria

Figures 7.1, 7.2, 7.3, and 7.4 provide details of a sand filter basin.

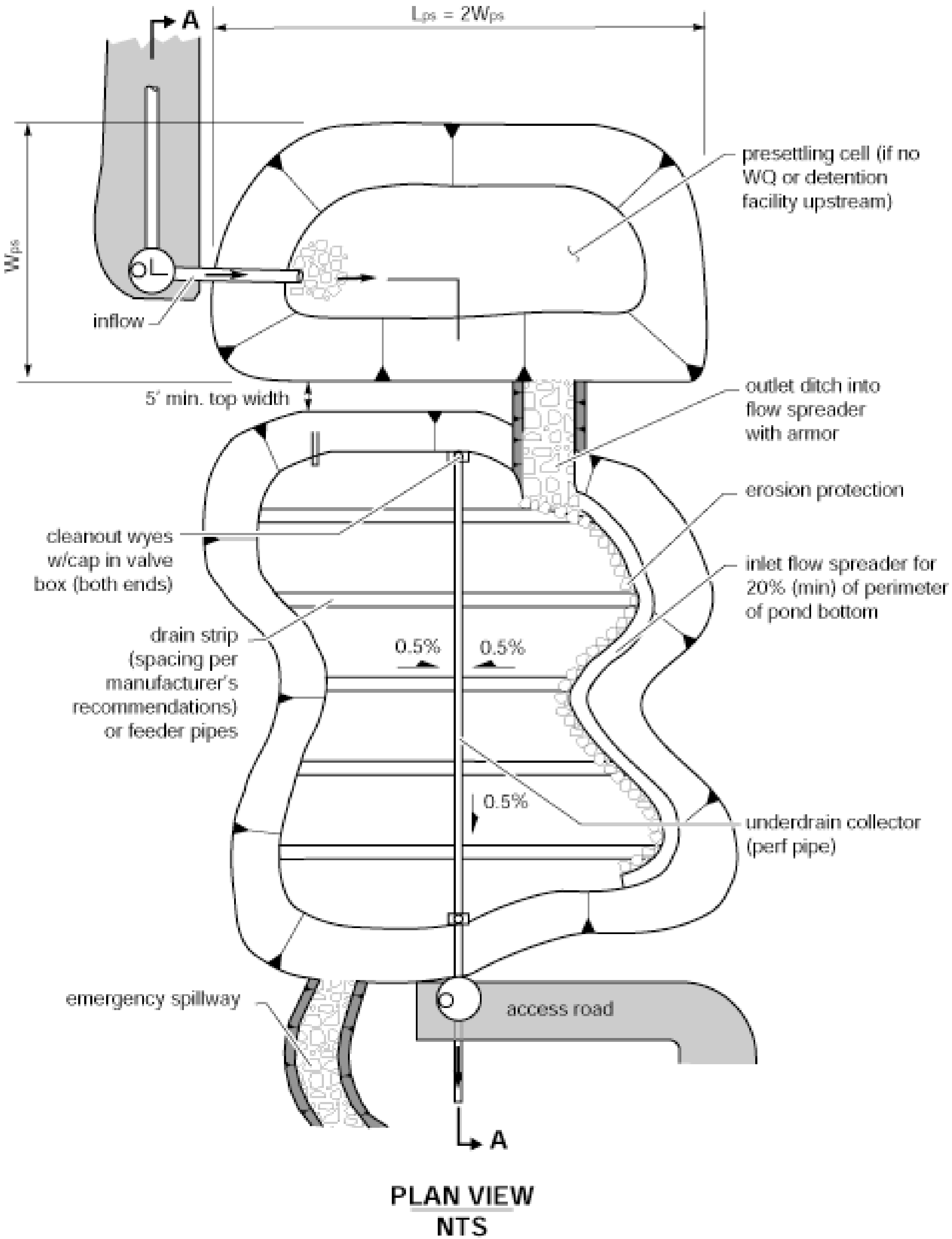


Figure 7.1. Sand Filter with Pretreatment Cell.

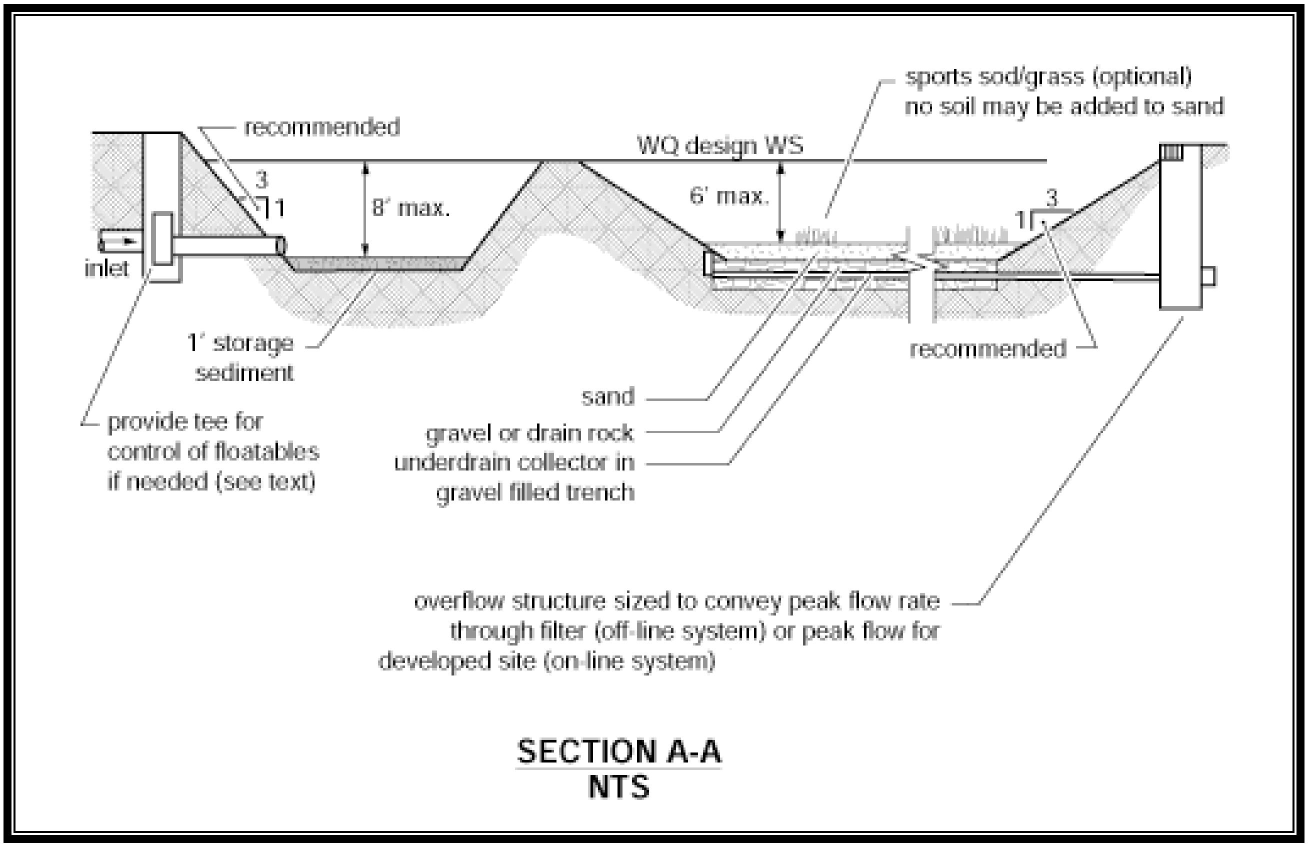


Figure 7.2. Sand Filter with Pretreatment Cell – Section.

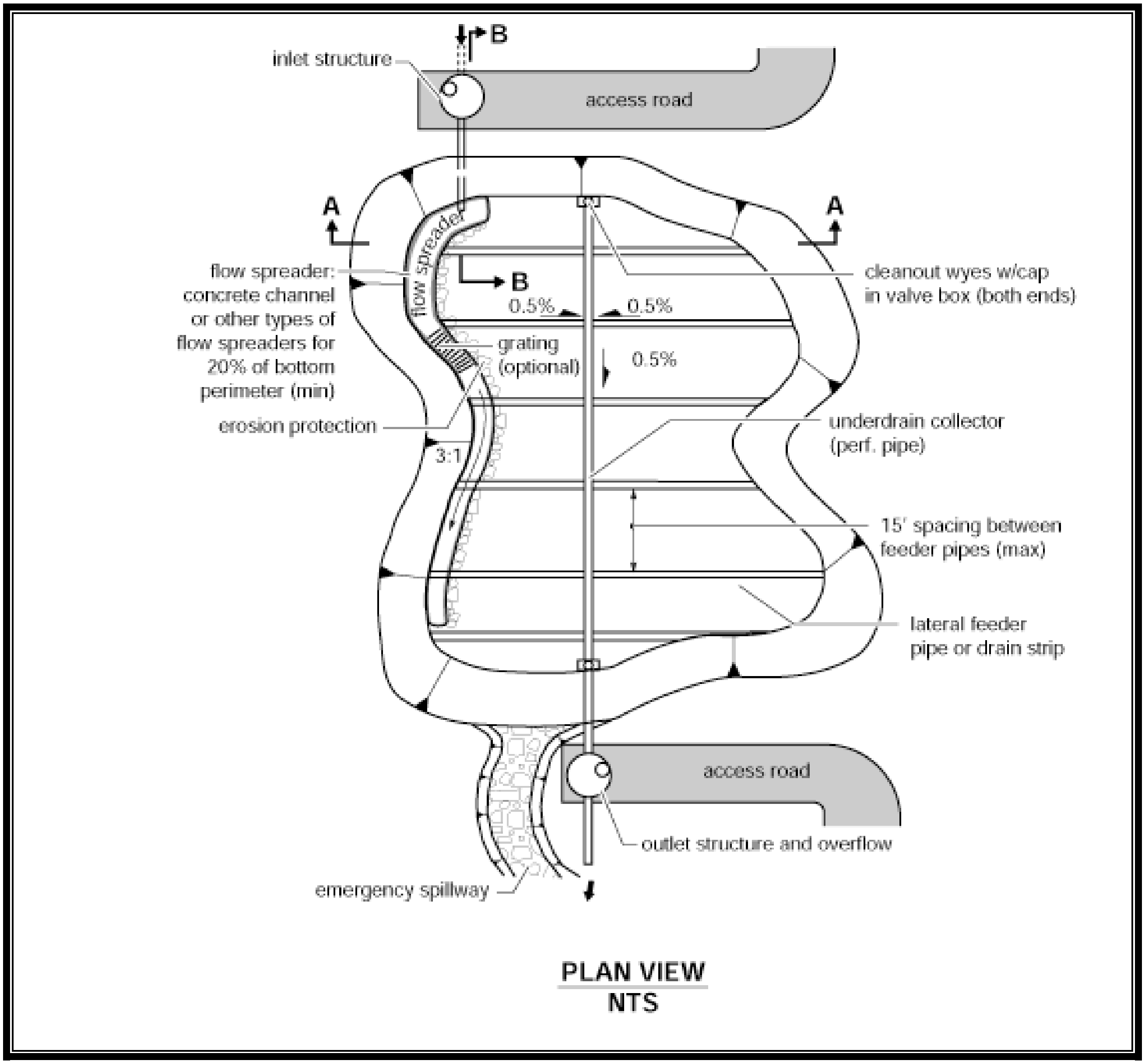


Figure 7.3. Sand Filter with Level Spreader.

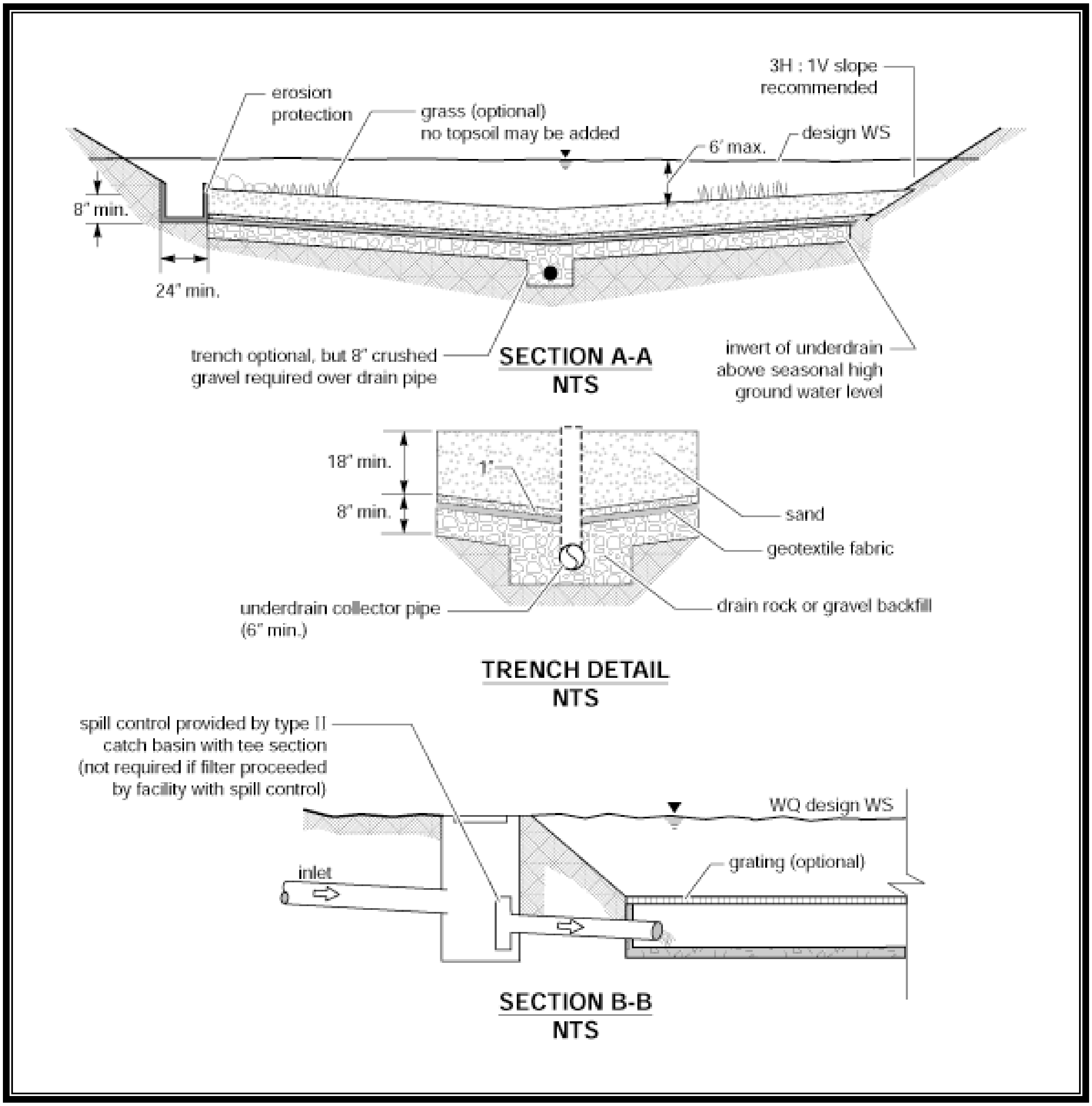


Figure 7.4. Sand Filter with Level Spreader – Sections and Details.

Geometry

Side slopes for earthen/grass embankments must not exceed 3:1 to facilitate mowing.

Materials

Drain Rock

Drain rock shall be 0.75 to 1.5 inch rock or gravel backfill, washed free of clay and organic material.

Underdrain Piping

All piping is to be schedule 80 PVC or greater wall thickness.

Sand

Sand bed depth shall be a minimum of 18 inches. The sand in a filter must consist of a medium sand meeting the size gradation (by weight) given in Table 7.3 below. The contractor must obtain a grain size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met. (**Note**: Standard backfill for sand drains, WA. Std. Spec. 9-03.13, does not meet this specification and shall not be used for sand filters.)

Table 7.3. Sand Medium Specification

U.S. Sieve Number	Percent Passing
4	100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Impermeable Liners for Sand Bed Bottom

Impermeable liners are required where the underflow could cause problems with structures. If an impermeable liner is not provided, then an analysis must be provided identifying possible adverse effects of seepage zones on groundwater, and near building foundations, basements, roads, parking lots and sloping sites.

Impermeable liners may be clay, concrete, or geomembrane. Clay liners shall have a minimum thickness of 12 inches and meet the specifications given in Table 7.4. If a geomembrane liner is used it must have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane liner must be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane.

Table 7.4. Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	1×10^{-6} max.
Plasticity Index of Clay	ASTM D-423 and D-424	percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	percent	Not less than 30
Clay Particles Passing	ASTM D-422	percent	Not less than 30
Clay Compaction	ASTM D-2216	percent	95 percent of Standard Proctor Density

Source: City of Austin, 1988.

If an impermeable liner is not required then a geotextile fabric liner must be installed that retains the sand and meets the specifications listed in Appendix V-A, unless the basin has been excavated to bedrock.

Structural Design Considerations

Concrete liners may also be used for sedimentation chambers and for sedimentation and sand filtration basins less than 1,000 square feet in area. Concrete must be 5 inches thick Class A or better and shall be reinforced by steel wire mesh. The steel wire mesh must be 6 gauge wire or larger and 6-inch by 6-inch mesh or smaller. An “Ordinary Surface Finish” is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete must have a minimum 6-inch compacted aggregate base. This base must consist of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch.

Site Design Elements

High groundwater may damage underground structures or affect the performance of filter underdrain systems. There must be sufficient clearance (at least 2 feet) between the seasonal high groundwater level and the bottom of the sand filter to obtain adequate drainage.

Sand filters without impermeable liners shall not be built on fill sites and shall be located at least 20 feet downslope and 100 feet upslope from building foundations.

Construction and Maintenance

Construction Considerations

Until all project improvements which produce surface runoff are completed, and all exposed ground surfaces are stabilized by revegetation or landscaping, sand filtration systems may not be operated, and no surface runoff may be permitted to enter the system.

Careful level placement of the sand is necessary to avoid formation of voids within the sand that could lead to short-circuiting (particularly around penetrations for underdrain cleanouts), and to prevent damage to the underlying geomembranes and underdrain system. Over-compaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 psig or less).

After the sand layer is placed, water settling is recommended. To enable settling, flood the sand with 10 to 15 gallons of water per cubic foot of sand.

Maintenance Access

Include a maintenance access ramp with a slope not greater than 7:1 at the inlet and the outlet of a surface filter. Consider installing an access port for inspection and maintenance.

Cleanouts and Underdrain Piping

A valve box must be provided for access to the cleanouts.

Access for cleaning all underdrain piping shall be provided. This may consist of installing cleanout ports, which tee into the underdrain system and surface above the top of the sand bed.

7.1.2 MF.02 Sand Filter Vault

A sand filter vault (see Figures 7.5 and 7.6) is similar to a sand filter basin, except that the sand layer and underdrains are installed below grade. A sand filter vault consists of presettling and sand filtration cells.

Applicability

A sand filter vault is appropriate where space limitations preclude aboveground facilities or in areas subject to freezing.

Limitations

A sand filter vault is not appropriate in high water table areas. There must be adequate hydraulic head (approximately 4 feet) between the inlet and outlet. As with sand filter basins, vaults are not appropriate for areas subject to large loadings of debris, heavy sediment loads, and oils and greases that could clog or prematurely overload the sand.

Submittals and Approval

Submit design calculations, drawings and details as part of submittal requirements of Volume I.

Pretreatment

Design shall include a forebay, pre-settling basin or other treatment BMP prior to the sand filter for coarse sediment removal.

Hydrologic and Hydraulic Design Considerations

Sand filter sizing is the same as for MF.01 (sand filter basin).

Vaults may be designed as off-line systems or online for small drainages.

Off-line Systems

In an off-line system a diversion structure (see Appendix V-A) shall be installed to divert the design flow rate into the sediment chamber and bypass the remaining flow to detention/retention (if necessary to meet Minimum Requirement #7), or to surface water.

Inlet

Optimize sand inlet flow distribution with minimal sand bed disturbance. A maximum of 8-inch distance between the top of the spreader and the top of the sand bed is suggested. Flows may enter the sand bed by spilling over the top of the wall into a flow spreader pad or alternatively a pipe and manifold system may be used. Any pipe and manifold system must retain the required dead storage volume in the first cell, minimize turbulence, and be readily maintainable.

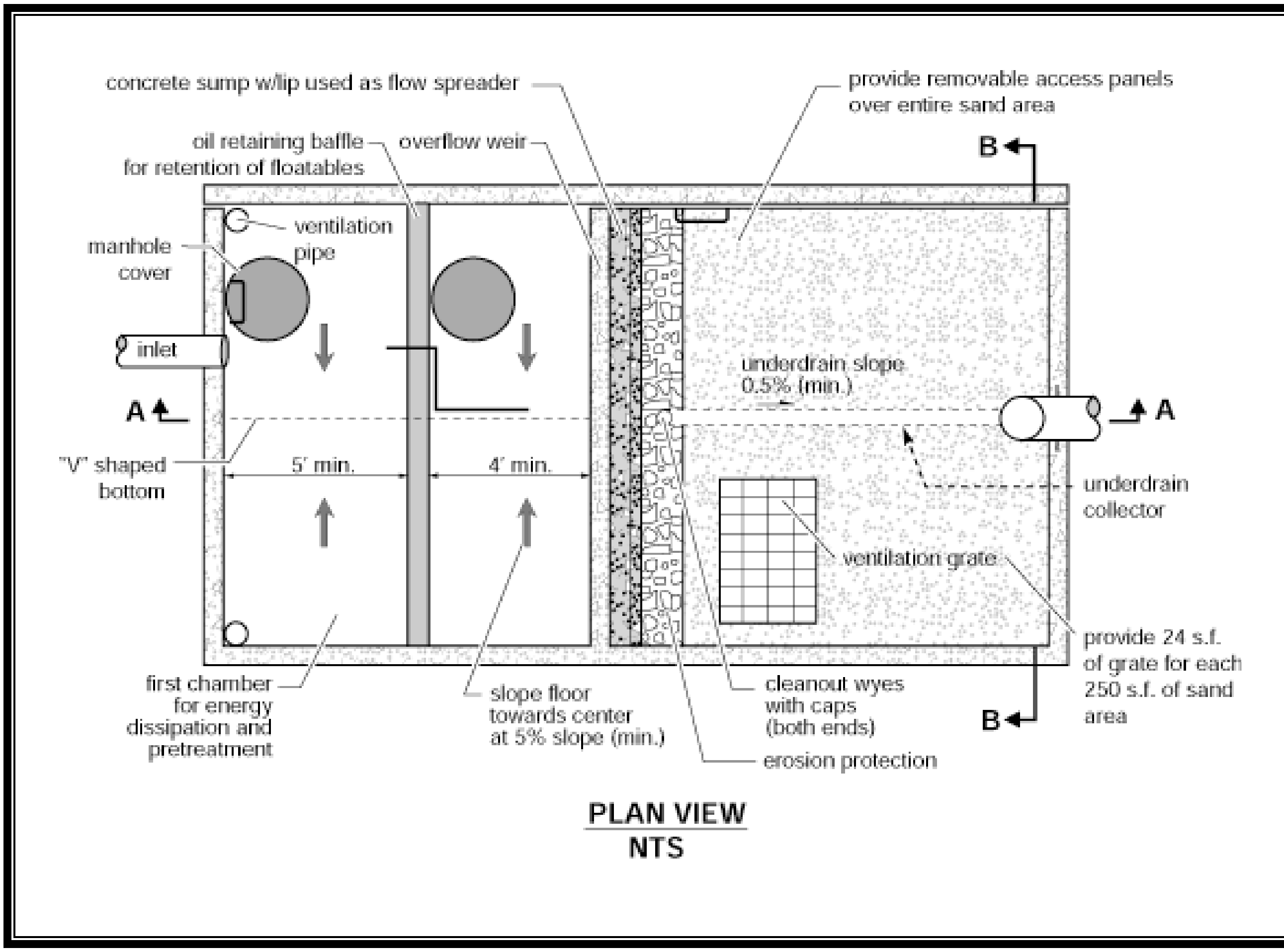


Figure 7.5. Sand Filter Vault.

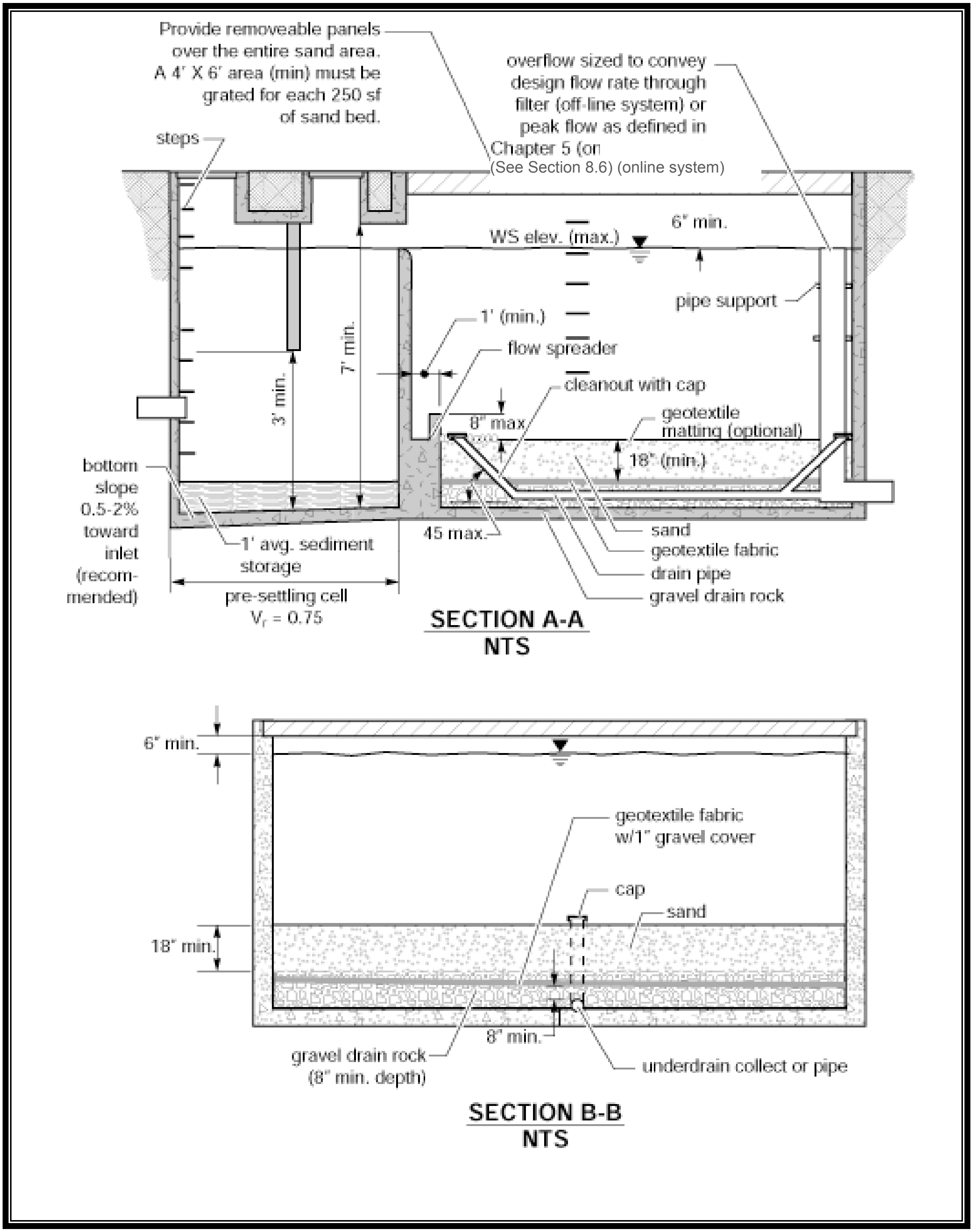


Figure 7.6. Sand Filter Vault: Sections.

If an inlet pipe and manifold system is used, the minimum pipe size shall be 8 inches. Multiple inlets are recommended to minimize turbulence and reduce local flow velocities.

Erosion protection must be provided along the first foot of the sand bed adjacent to the spreader. Geotextile fabric secured on the surface of the sand bed, or equivalent method, may be used.

Design Criteria

The filter bed shall consist of a sand top layer, and a geotextile fabric second layer with an underdrain system.

Geometry

Presettling Cell

Design the presettling cell for sediment collection and removal. A V-shaped bottom, removable bottom panels, or equivalent sludge handling system should be used. One foot of sediment storage in the presettling cell must be provided.

The presettling chamber must be sealed to trap oil and trash. This chamber is usually connected to the sand filtration chamber through an invert elbow to protect the filter surface from oil and trash.

Baffle

If a retaining baffle is necessary for oil/floatables in the presettling cell, it must extend at least 1 foot above to 1 foot below the design flow water level. Provision for the passage of flows in the event of plugging must be provided. Access opening and ladder must be provided on both sides of the baffle.

Materials

Sand filter vaults must conform to the materials and structural suitability criteria specified for wet vaults

A geotextile fabric (see Appendix V-B) over the entire sand bed may be installed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter.

Structural Design Considerations

Sand filters vaults shall conform to the structural suitability and materials criteria specified for wetvaults.

Site Design Elements

Access, setbacks and right-of-way requirements are the same as for detention vaults (see Section 4.1.3, BMP D.03 of this Volume).

Construction and Maintenance

Provide a sand filter inlet shutoff/bypass valve for maintenance

Provision for access is the same as for wet vaults. Removable panels must be provided over the entire sand bed.

To prevent anoxic conditions, a minimum of 24 square feet of ventilation grate shall be provided for each 250 square feet of sand bed surface area. For sufficient distribution of airflow across the sand bed, grates may be located in one area if the sand filter is small, but placement at each end is preferred. Small grates may also be dispersed over the entire sand bed area.

7.1.3 MF.03 Linear Sand Filter

A linear sand filter (see Figure 7.7) is typically a long, shallow, two-celled, rectangular vault. The first cell is designed for settling coarse particles, and the second cell contains the sand bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader.

Applicability

Linear sand filters are well-suited to small drainages (less than 2 acres of impervious area), and can fit well into long narrow spaces such as the perimeter of a paved surface.

A linear sand filter can be used to treat runoff from high-use sites for total suspended solids and oil/grease removal or, alternatively, as a part of a treatment train to provide enhanced or phosphorus treatment.

Limitations

Below-ground structures like wetvaults are relatively difficult and expensive to maintain. The need for maintenance is often not seen and as a result routine maintenance does not occur.

Submittals and Approval

Submit design calculations, drawings and details as part of submittal requirements of Volume I.

Pretreatment

Pretreatment is achieved in the upstream cell of the linear sand filter which provides for settling of coarse particles. Therefore, a separate pretreatment facility is not required.

Hydrologic and Hydraulic Design Considerations

Maximum sand bed ponding depth is 1 foot.

Drain pipe must be sloped a minimum of 0.5 percent.

Design Criteria

Figure 7.7 shows a plan view and sections of a linear sand filter. The linear sand filter has a sediment chamber and a sand filter chamber.

The two chambers shall be divided by a divider wall that is level and extends a minimum of 12 inches above the sand bed.

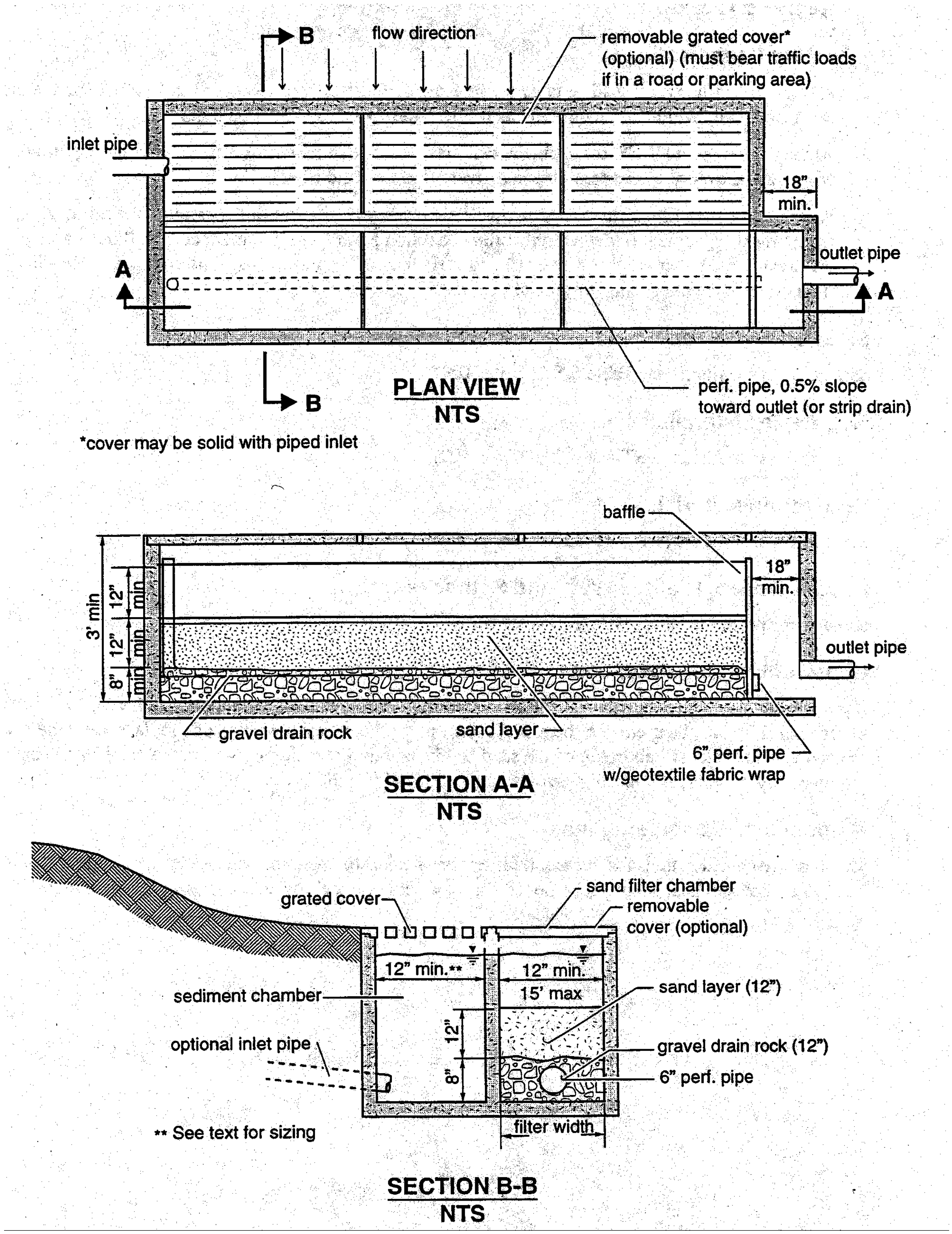


Figure 7.7. Linear Sand Filter.

Geometry

Sediment Chamber

The sediment chamber width shall be as follows:

Sand filter width, inches	12-24	24-48	48-72	72+
Sediment chamber width, inches	12	18	24	w/3

Stormwater may enter the sediment cell by sheet flow or a piped inlet.

Sand Filter Chamber

The width of the sand filter chamber must be between 1 foot and 15 feet.

The sand filter bed must be a minimum of 12 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.

Materials

Linear sand filters must conform to the materials criteria specified for wet vaults.

The drainpipe must be a minimum of 6 inches in diameter and be wrapped in geotextile.

Structural Design Considerations

Linear sand filters must conform to the structural suitability materials criteria specified for wet vaults.

Site Design Elements

Access, setbacks and right-of-way requirements are the same as for detention vaults (see Section 4.1.3, BMP D.03 of this Volume).

Construction and Maintenance

Linear sand filters must be vented as for sand filter vaults.

7.1.4 MF.04 Media Filter Drain (Formerly Ecology Embankment)

The media filter drain (MFD), previously referred to as the ecology embankment, is a linear flow-through stormwater runoff treatment device The MFD can be sited adjacent to roadside embankments (conventional design) and medians (dual media filter drain), borrow ditches, or other linear depressions.

The media filter drain (MFD), previously referred to as the *ecology embankment*, is a linear flow-through stormwater runoff treatment device that was developed by the Washington State Department of Transportation (WSDOT). The MFD can be sited along roadway side slopes (conventional design) and medians (dual media filter drains), borrow ditches, or other linear depressions.

MFD's have four basic components: a gravel no-vegetation zone, a grass strip, the MFD mix bed, and a conveyance system for flows leaving the MFD mix. This conveyance system usually consists of a gravel-filled underdrain trench or a layer of crushed surface base course (CSBC). This layer of CSBC must be porous enough to allow treated flows to freely drain away from the MFD mix.

Typical MFD configurations are shown in Figures 7.8, 7.9, and 7.10.

The MFD has a general use level designation (GULD) from the Department of Ecology for basic, phosphorus, and enhanced treatment. The MFD removes suspended solids, phosphorus, and metals from stormwater runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration.

Applicability

The MFD can be used where available right-of-way is limited, sheet flow is feasible (i.e., no curbs), lateral gradients are generally less than 25 percent (4H:1V), and longitudinal gradients are less than 5 percent.

Media Filter Drains

Since maintaining sheet flow across the media filter drain is required for its proper function, the ideal locations for media filter drains are roadside embankments or other long, linear grades.

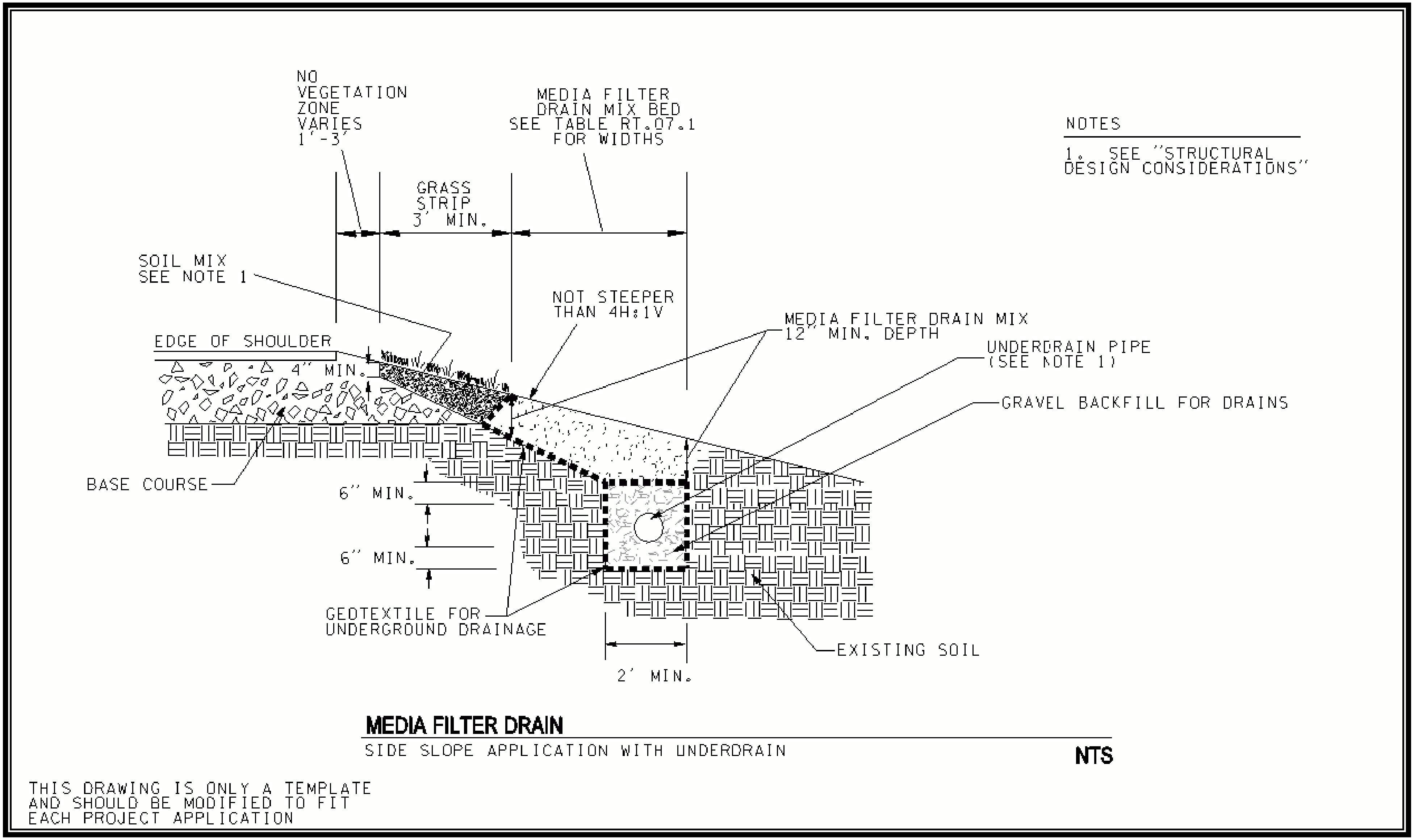


Figure 7.8. Media Filter Drain: Side Slope Application with Underdrain.

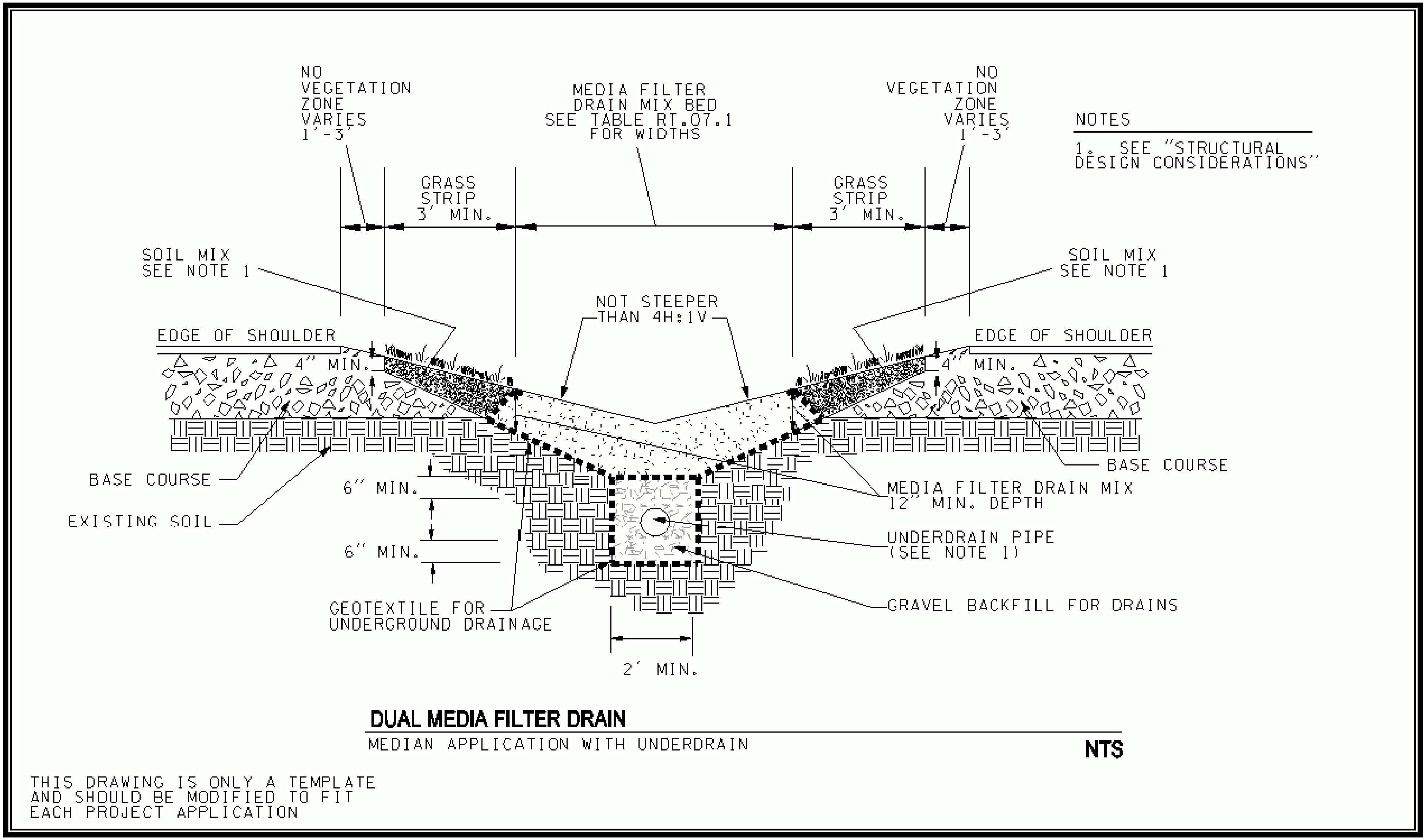


Figure 7.9. Dual Media Filter Drain: Median Application with Underdrain.

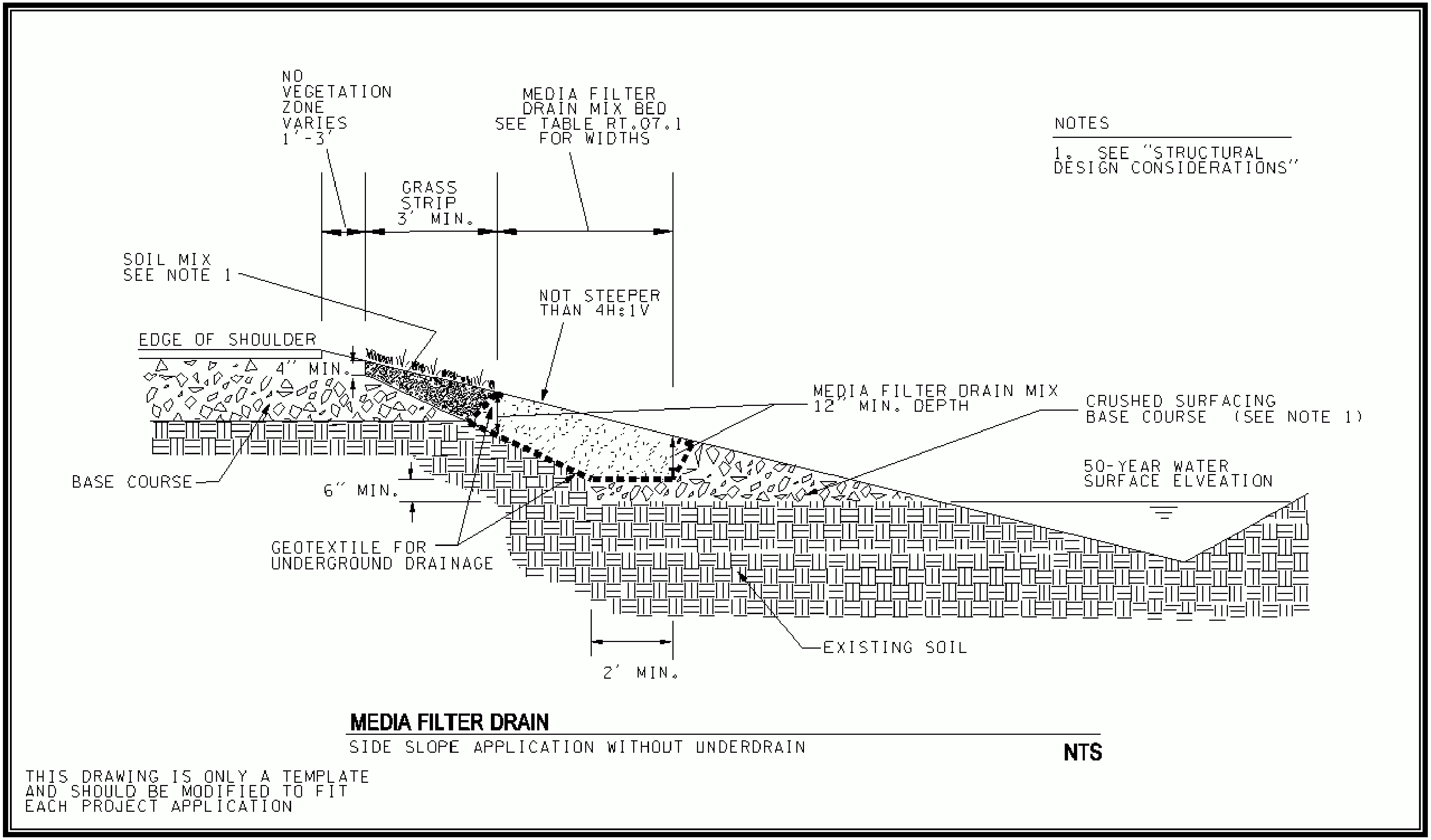


Figure 7.10. Media Filter Drain: Side Slope Application without Underdrain.

Dual Media Filter Drains

The dual media filter drain is fundamentally the same as the side-slope version. It differs in siting and is more constrained with regard to drainage options. Prime locations for dual media filter drains are medians, roadside drainage or borrow ditches, or other linear depressions. It is especially critical for water to sheet flow across the dual media filter drain.

Limitations

Flow Path

The longest flow path from the contributing area delivering sheet flow to the media filter drain shall not exceed 75 feet for impervious surfaces and 150 feet for pervious surfaces.

Channelized Flow

Media filter drains shall not be used where continuous off-site inflow may result in channelized flows or ditch flows running down the middle of the dual media filter drain.

Steep Slopes

- Avoid construction on longitudinal slopes steeper than 5 percent.
- Avoid construction on 3H:1V lateral slopes, and preferably use flatter than 4H:1V slopes. As slopes approach 3H:1V, without design modifications, sloughing may become a problem due to friction limitations between the separation geotextile and underlying soils. In areas where lateral slopes exceed 4H:1V, it may be possible to construct terraces to create 4H:1V slopes, or to otherwise stabilize up to 3H:1V slopes.
- In areas where slope stability may be problematic, consult a geotechnical engineer.

Wetlands

- Do not construct in wetlands and wetland buffers.
- In many cases, a media filter drain (due to its small lateral footprint) can fit within the fill slopes adjacent to a wetland buffer. In those situations where the fill prism is located adjacent to wetlands, an interception trench/underdrain will need to be incorporated as a design element in the media filter drain.

Shallow Groundwater

- Mean high water table levels in the project area need to be determined to ensure that the MFD mix bed and the underdrain will not become saturated by shallow groundwater.

- There must be at least 1 foot of depth between the seasonal high groundwater table and the bottom of the facility.

Submittals and Approval

As part of the submittals required by Volume I include the following:

- Design information and calculations for the MFD including sizing criteria, assumptions for hydrologic modeling of the MFD and other data necessary to evaluate the suitability of the MFD in the proposed application.

- The Maintenance Plan shall include maintenance procedures for the MFD, frequency of maintenance and other information necessary for the ongoing maintenance of the MFD.

- The Drawings and Specifications for the project shall show the location of the MFD in the site plan, cross-sections and details of the MFD with all necessary information to construct it according to the plans, and specifications for all components of the MFD including seeding mix design, MFD bed design and testing requirements, and soil/material placement and compaction requirements.

- The Soils Management Plan required by BMP LID.02 shall include the area of the MFD and proposed soil amendments.

Pretreatment

No pretreatment is required. Sheet flow runoff from the roadway surface can be routed directly to the MFD.

Hydrologic and Hydraulic Design Considerations

The basic design concept behind the media filter drain and dual media filter drain is to fully filter all runoff through the MFD mix. Therefore, the infiltration capacity of the MFD mix and of the drainage below the MFD mix bed needs to match or exceed the hydraulic loading rate.

Infiltration Rate

The MFD mix has an estimated initial filtration rate of 50 inches per hour and a long-term filtration rate of 28 inches per hour, which accounts for siltation. With an additional safety factor, the rate used to size the length of the media filter drain should be 14 inches per hour.

Design Flow Rate

For western Washington, $Q_{Roadway}$ is the flow rate at or below which 91 percent of the runoff volume will be treated, based on a 15-minute time step, and can be determined using the water quality analysis feature in WWHM.

Sizing MFD Mix Bed

For runoff treatment, sizing the MFD mix bed is based on the requirement that the runoff treatment flow rate from the contributing roadway area $Q_{Roadway}$ cannot exceed the long-term infiltration capacity of the media filter drain, $Q_{Infiltration}$:

$$Q_{Roadway} \leq Q_{Infiltration}$$

$Q_{Roadway}$ is described under *Design Flow Rate*. $Q_{infiltration}$ may be calculated as follows.

$Q_{infiltration}$, the long-term infiltration capacity of the media filter drain is based on the following equation:

$$\frac{LTIR_{EM} * L_{EE} * W_{EE}}{C * SF} = Q_{Infiltration}$$

where:
- $LTIR_{EM}$ = Long-term infiltration rate of the MFD mix (use 10 inches per hour for design) (in/hr)
- L_{EE} = Length of media filter drain (parallel to contributing pavement) (ft)
- W_{EE} = Width of the MFD mix bed (ft)
- C = Conversion factor of 43,200 ((in/hr)/(ft/sec))
- SF = Safety Factor (equal to 1.0, unless unusually heavy sediment loading is expected)

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

$$W_{EE} \geq \frac{Q_{Roadway} * C * SF}{LTIR_{EM} * L_{EE}}$$

Project applications of this design procedure have shown that, in almost every case, the calculated width of the media filter drain does not exceed 1.0 foot. Therefore, Table 7.5 was developed by WSDOT to simplify the design steps and should be used to establish an appropriate width.

Table 7.5. Design Widths for Media Filter Drains

Pavement Width that Contributes Runoff to the Media Filter Drain	Minimum Media Filter Drain Width*
≤ 20 feet	2 feet
≥ 20 and ≤ 35 feet	3 feet
> 35 feet	4 feet

Width does not include the required 1–3 foot gravel vegetation-free zone or the 3-foot filter strip width (see Figure 7.8).

Design Criteria

Media filter drains have four basic components: a gravel no-vegetation zone, a grass strip, the MFD mix bed, and a conveyance system for flows leaving the MFD mix.

Inflow

Runoff is always conveyed to a media filter drain using sheet flow from the pavement area. The longitudinal pavement slope contributing flow to a media filter drain should be less than 5 percent. Although there is no lateral pavement slope restriction for flows going to a media filter drain, the designer should ensure that flows remain as sheet flow.

No-Vegetation Zone

Stormwater runoff is conveyed to the MFD via sheet flow over a vegetation-free gravel zone to ensure sheet dispersion, and to provide some pollutant trapping. The no-vegetation zone is a shallow gravel trench located directly adjacent to the impervious surface to be treated. The no-vegetation zone is a crucial element in a properly functioning media filter drain or other BMPs that use sheet flow to convey runoff from the impervious surface to the BMP. The no-vegetation zone functions as: a level spreader to promote sheet flow, a deposition area for coarse sediments, and an infiltration area to reduce runoff volumes.

Grass Strip

Adjacent to the no-vegetation zone, a grass strip, which may be amended with compost, is incorporated into the top of the fill slope to provide pretreatment, further enhancing filtration and extending the life of the system.

Media Filter Drain Mix Bed

The runoff is then filtered through a bed of porous, alkalinity-generating granular medium—the MFD mix. Geotextile lines the underside of the MFD mix bed.

Conveyance System Below Media Filter Drain Mix

Treated water drains from the MFD mix bed into the conveyance system below the MFD mix. The conveyance system must be porous enough to allow treated flows to freely drain away from the MFD mix.

This conveyance system usually consists of a gravel-filled underdrain trench or a layer of crushed surfacing base course (CSBC).

Underdrain Trench

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.

The underdrain trench shall be a minimum of 2 feet wide for either the conventional or dual media filter drain. The gravel underdrain trench may be eliminated (see Figure 7.9) if there is evidence to support that flows can be conveyed laterally to an adjacent ditch or onto a fill slope that is properly vegetated to protect against erosion. The MFD mix shall drain freely, draining up to the 50-year storm event water surface elevation represented in the downstream ditch.

Underdrain Pipe

The trench's perforated underdrain pipe is a protective measure to ensure free flow through the MFD mix. It may be possible to omit the underdrain pipe if it can be demonstrated that the pipe is not necessary to maintain free flow through the MFD mix and underdrain trench.

In Group C and D soils, an underdrain pipe would help to ensure free flow of the treated runoff through the MFD mix bed. In some Group A and B soils, an underdrain pipe may be unnecessary if most water percolates into subsoil from the underdrain trench. The need for underdrain pipe should be evaluated in all cases.

Geometry

The no-vegetation zone should be between 1 foot and 3 feet wide. Depth will be a function of how the adjacent paved section is built from subgrade to finish grade; the resultant cross section will typically be triangular to trapezoidal.

The width of the vegetated filter strip is dependent on the availability of space within the sloped area where the media filter drain is to be constructed. The baseline design criterion for the grass strip within the media filter drain is a 3-foot-minimum-width, but wider grass strips are recommended if the additional space is available.

The MFD mix shall be a minimum of 12 inches deep, including the section on top of the underdrain trench. The MFD mix bed shall have a bottom width of at least 2 feet in contact with the conveyance system below the media filter drain mix.

In general, the length of a media filter drain or dual media filter drain is the same as that of the contributing pavement. Any length is acceptable as long as the surface area of the MFD mix bed is sufficient to fully infiltrate the runoff treatment design flow rate.

In profile, the surface of the media filter drain should preferably have a lateral slope less than 4H:1V (<25 percent). On steeper terrain, it may be possible to construct terraces to create a 4H:1V slope, or other engineering may be employed if approved by Thurston County and Ecology, to ensure slope stability up to 3H:1V. If sloughing is a concern on steeper slopes, consideration should be given to incorporating permeable soil reinforcements, such as geotextiles, open-graded/permeable pavements, or commercially available ring and grid reinforcement structures, as top layer components to the MFD mix bed. Consultation with a geotechnical engineer is required.

Materials

WSDOT Standard Specifications should be consulted for the following:

- Gravel Backfill for Drains, 9-03.12(4)
- Underdrain Pipe, 7-01.3(2)
- Construction Geotextile for Underground Drainage, 9-33.1.

MFD Mix

The MFD mix is a mixture of crushed rock (screened to 3/8" to #10 sieve), dolomite, gypsum, and perlite. The crushed rock provides the support matrix of the medium. The dolomite and gypsum additives serve to buffer acidic pH conditions and exchange light metals for heavy metals. Perlite is incorporated to improve moisture retention, which is critical for the formation of biomass epilithic biofilm to assist in the removal of solids, metals, and nutrients.

The MFD mix used in the construction of media filter drains consists of the amendments listed in Table 7.6. Mixing and transportation must be done in a manner that ensures the materials are thoroughly mixed prior to pouring into the ground, and that separation does not occur during transportation or pouring.

Table 7.6. Media Filter Drain Mix

Amendment	Quantity
Mineral aggregate: Crushed screenings 3/8-inch to #10 sieve Crushed screenings shall be manufactured from ledge rock, talus, or gravel in accordance with Section 3-01 of the *Standard Specifications for Road, Bridge, and Municipal Construction* (2002), which meets the following test requirements: Los Angeles Wear, 500 Revolutions — 35% max. Degradation Factor — 30 min. Crushed screenings shall conform to the following requirements for grading and quality: <u>Sieve Size</u> — <u>Percent Passing (by weight)</u> 1/ 2" square — 100 3/8" square — 90-100 U.S. No. 4 — 30-56 U.S. No. 10 — 0-10 U.S. No. 200 — 0-1.5 % fracture, by weight, min. — 75 Static stripping test — Pass The fracture requirement shall be at least one fractured face and will apply to material retained on the U.S. No. 10 if that sieve retains more than 4% of the total sample. The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials. Crushed screenings shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50% of the surface area of any size between successive laboratory sieves.	3 cubic yards
Perlite: Horticultural grade, free of any toxic materials 0-30% passing US No. 18 Sieve 0-10% passing U.S. No. 30 Sieve	1 cubic yard per 3 cubic yards of mineral aggregate.
Dolomite: CAMg(CO3)2 (calcium magnesium carbonate) Agricultural grade, free of any toxic materials 100% passing US No. 8 Sieve 0% passing U.S. No. 16 Sieve	10 pounds per cubic yard of perlite
Gypsum: Noncalcined, agricultural gypsum CaSO4+2H2O (hydrated calcium sulfate) Agricultural grade, free of any toxic materials 100% passing US No. 8 Sieve 0% passing US No. 16 Sieve	1.5 pounds per cubic yard of perlite.

Crushed Surfacing Base Course (CSBC)

If the design is configured to allow the media filter drain to drain laterally into a ditch, the crushed surfacing base course below the media filter drain shall conform to Section 9-03.9(3) of the WSDOT *Standard Specifications*. The designer should consult with a professional to ensure that the CSBC will not impede the flow of water out of the media filter drain mix. If needed, a different gradation may be specified to ensure the free flow of water out of the media filter drain mix.

Soil Mix for Grass Strip

The designer should consult a landscape architect for soil mix recommendations. The designer may consider adding aggregate to the soil mix to help minimize rutting problems from errant vehicles. The soil mix should ensure grass growth for the design life of the MFD.

Site Design Elements

Landscaping (Planting Considerations)

Landscaping is the same as for biofiltration swales (see BMP BF.01) unless otherwise specified and approved by Thurston County.

Signing

Non-reflective guideposts shall be installed to delineate the MFD. The guideposts shall indicate that the area is a stormwater treatment facility and not to disturb without contacting Thurston County. This practice allows road maintenance personnel to identify where the system is installed and to make appropriate repairs should damage occur to the system. If the MFD is in a critical aquifer recharge area for drinking water supplies, signage prohibiting the use of pesticides must be provided.

Construction and Maintenance

Maintenance will consist of routine roadside management. While herbicides should not be applied directly over the MFD, it may be necessary to periodically control noxious weeds with herbicides in areas around the MFD as part of a roadside management program. The use of pesticides may be prohibited if the MFD is in a critical aquifer recharge area for drinking water supplies. The designer should check with the local area water purveyor and Thurston County Environmental Health. Areas of the MFD that show signs of physical damage will be replaced based on the original design which should be included in the Maintenance Plan.

Chapter 8 - Oil and Water Separation BMPs

Oil and water separators treat stormwater runoff by removing oil floating on top of the water. There are two general types of separators: American Petroleum Institute (API) separators and coalescing plate (CP) separators. Both types use gravity to remove floating and dispersed oil. API separators (or "baffle" separators) are composed of three chambers, separated by baffles. Separator efficiency depends on detention time in the center, or detention chamber, and on droplet size. CP separators use a series of parallel plates to improve separation efficiency by providing more surface area, thus reducing space needed for the separator.

Oil and water separators must be located off-line from the primary conveyance and detention system, bypassing flows greater than the water quality design flow. Linear sand filters may also be used for oil removal. Oil control devices and facilities shall always be placed upstream of other treatment facilities and as close to the source of oil generation as possible.

Note: Thurston County will not accept ownership of some types of oil control facilities without prior acceptance.

8.1 Oil and Water Separation BMPs

Three oil and water separation BMPs are described in this section:

- OW.01 API (Baffle type) Separator Bay
- OW.02 Coalescing Plate (CP) Separator Bay
- OW.03 Oil Containment Booms.

8.1.1 OW.01 API (Baffle Type) Separator Bay

This type of separator uses internal baffles to separate the oil from the water. (API stands for American Petroleum Institute.)

Applicability

API separators are designed for use on sites larger than 2 acres.

Limitations

Ecology's 2005 *Stormwater Management Manual for Western Washington* (Ecology 2005) presents a design modification for using API separators in drainage areas smaller than 2 acres (e.g., fueling stations and commercial parking lots). However, Ecology also requires each developer to complete a detailed performance verification during at least one wet season when using their modified design. Given this requirement, Thurston County has elected not to allow the use of API separators on sites smaller than 2 acres. The following approach only applies to contributing drainage areas larger than 2 acres.

Submittals and Approval

As part of submittal required by Volume I include the following:

- Hydrologic modeling indicating design storm flows and volumes
- Design calculations demonstrating compliance with design criteria
- Manufacturer data for vault and appurtenances.

Pretreatment

No pretreatment required.

Hydrologic and Hydraulic Design Considerations

Design Storm

The separator shall be designed to treat the water quality design storm, as calculated using the Santa Barbara Urban Hydrograph (SBUH) method for a 6-month, 24-hour storm with a Type 1A rainfall distribution (See Volume III). If hydrologic calculations are performed using a continuous hydrologic model, the water quality design flow rate predicted by an approved continuous runoff model may be multiplied by the ratio in Figure 5.1a or 5.1b to obtain the design flow rate. This modified design flow rate is an estimate of the design flow rate determined by using SBUH procedures.

The separator shall be located off-line, receiving only the water quality design storm flows. If it is necessary to locate the separator online, try to minimize the size of the area needing oil control, and use the online water quality design flow rate multiplied by the ratio indicated in Figure 5.1b (if hydrologic calculations are being performed using a continuous hydrologic model).

Size the separator bay for the Water Quality design flow rate.

Sizing

The API design criteria is based on the horizontal velocity of the bulk fluid (V_h), the oil rise rate (V_t), the residence time (t_m), width, depth, and length considerations.

Size APIs using the following procedure:

- Step 1. Determine the oil rise rate, V_t, in centimeters per second, using Stokes' Law (Water Pollution Control Federation, 1985) or empirical determination.
    - Stokes Law equation for rise rate, V_t (ft/min):

      $$V_t = 1.97g(\sigma_w - \sigma_o)D^2 / 18\eta_w)$$

      Where: 1.97 = conversion factor (centimeters per second/ft per minute)

      g = gravitational constant (981 centimeters per second squared)

      D = diameter of the oil particle (centimeters).
    - Use:
        - oil particle size diameter, D = 60 microns (0.006 centimeters)
        - σ_w = water density = 0.999 grams per cubic centimeter (gm/cc) at 32°F
        - σ_o: Select conservatively high oil density,
        - For example, if diesel oil @ σ_o=0.85 gm/cc and motor oil @ σ_o = 0.90 gm/cc can be present then use σ_o=0.90 gm/cc
        - η_w = dynamic viscosity of water = 0.017921 poise (gm/cm-sec), at water temperature of 32°F, (see API publication 421, February, 1990)

- Step 2. Determine Q:
  - Q = the 15-minute Water Quality design flow rate in ft^3/min multiplied by the ratio indicated in Figure 5.1b for the site location (k). Note that WWHM gives the water quality design flow rate in ft^3/sec. Multiply this flow rate by 60 to obtain the flow rate in ft^3/min.

- Step 3. Calculate horizontal velocity of the bulk fluid, Vh (in ft/min), and depth (d), ft.

$$Vh = 15Vt$$

  - $d = (Q/2Vh)^{1/2}$, with
  - Separator water depth, $3 \leq d \leq 8$ feet (to minimize turbulence). If the calculated depth is less than 3 feet, an API separator is not appropriate for the site. If the calculated depth exceeds 8 feet, consider using two separators (American Petroleum Institute, 1990; U.S. Army Corps of Engineers, 1994).

- Step 4. Calculate the minimum residence time (tm), in minutes, of the separator at depth d:

$$t_m = d/V_t$$

  - Calculate the minimum length of the separator section, l(s), using:
    - F = 1.65
    - Depth/width (d/w) of 0.5 (American Petroleum Institute, 1990)
    - $l(s) = FQt_m/wd = F(V_h/V_t)d$

- Step 5. For other dimensions, including the length of the forebay, the length of the afterbay, and the overall length, L; refer to Figure 8.1.

- Step 6. Calculate V = l(s)wd = FQtm, and Ah = wl(s)
  - V = minimum hydraulic design volume, in cubic feet.
    A_h = minimum horizontal area of the separator, in square feet.

Design Criteria

Figure 8.1 provides a plan and section view of the API Separator.

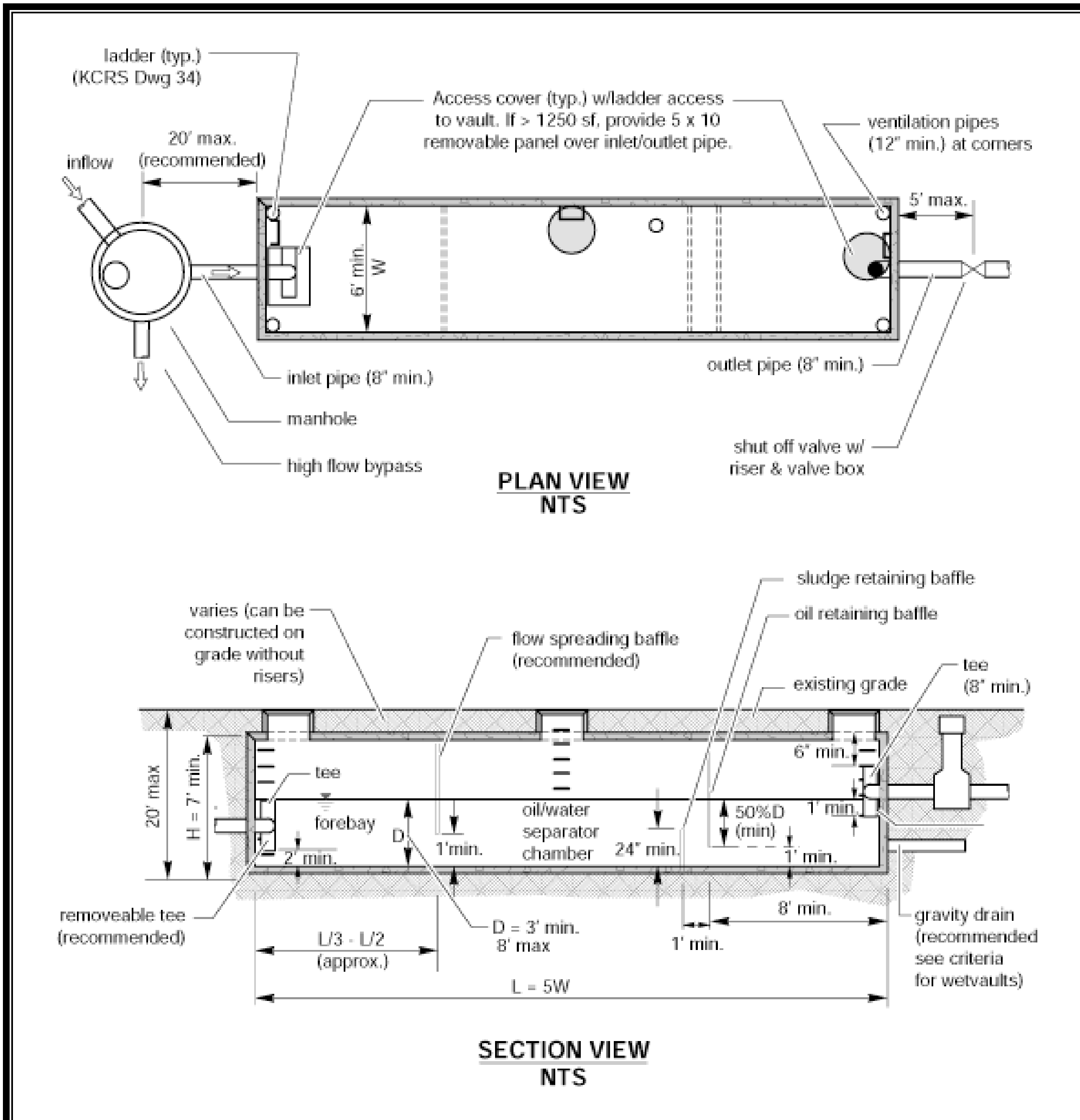


Figure 8.1. API (Baffle Type) Separator.

Geometry

Criteria for Separator Bays

To collect floatables and settleable solids, design the surface area of the forebay at ≥ 20 ft^2 per 10,000 ft^2 of area draining to the separator. The length of the forebay shall be one-third to one-half of the length of the entire separator.

Include a submerged inlet pipe with a turn-down elbow in the first bay at least 2 feet from the bottom. The outlet pipe shall be a Tee, sized to pass the design peak flow and placed at least 12 inches below the water surface.

Include a shutoff valve at the separator outlet pipe.

Criteria for Baffles

Oil retaining baffles (top baffles) shall be located at least at one-fourth of the total separator length from the outlet, and shall extend down at least 50 percent of the water depth and at least 1 foot from the separator bottom.

Baffle height to water depth ratios shall be 0.85 for top baffles and 0.15 for bottom baffles.

Materials

Include roughing screens for the forebay or upstream of the separator to remove debris. Screen openings should be about three-fourths inch.

Use only impervious conveyances for oil contaminated stormwater.

Structural Design Considerations

Conform to the structural and materials criteria specified for wet vaults.

Site Design Elements

Access, setbacks and right-of-way requirements are the same as for detention vaults (see Section 4.1.3, BMP D.03 of this Volume).

Construction and Maintenance

Thurston County may require a bypass/shutoff valve to enable the vault to be taken off-line for maintenance.

Inspect oil/water separators monthly during the wet season of October 1-April 30 (WEF & ASCE, 1998; Woodward-Clyde Consultants) to ensure proper operation, and, during and immediately after a large storm event of ≥ 1 inch per 24 hours

Clean oil/water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde Consultants), after all spills, and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and washwater removal. (King County Surface Water Management, 1998) Replace wash water in the separator with clean water before returning it to service.

Remove the accumulated oil when the thickness reaches 1-inch. Also remove sludge deposits when the thickness reaches 6 inches (King County Surface Water Management, 1998).

8.1.2 OW.02 Coalescing Plate (CP) Separator Bay

This type of device uses a series of stacked plates to coalesce the oil into larger droplets to enhance removal from the stormwater (see Figure 8.2).

Applicability and Limitations

Applicable for all sites requiring oil control.

Submittals and Approval

As part of submittal required by Volume I include the following:

- Hydrologic modeling indicating design storm flows and volumes
- Design calculations demonstrating compliance with design criteria
- Manufacturer data for vault and appurtenances.

Pretreatment

Add pretreatment for total suspended solids that could clog the coalescing plate separator or otherwise impair the long-term effectiveness of the separator.

Hydrologic and Hydraulic Design Considerations

Design inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow, especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay should be less than 500 (laminar flow).

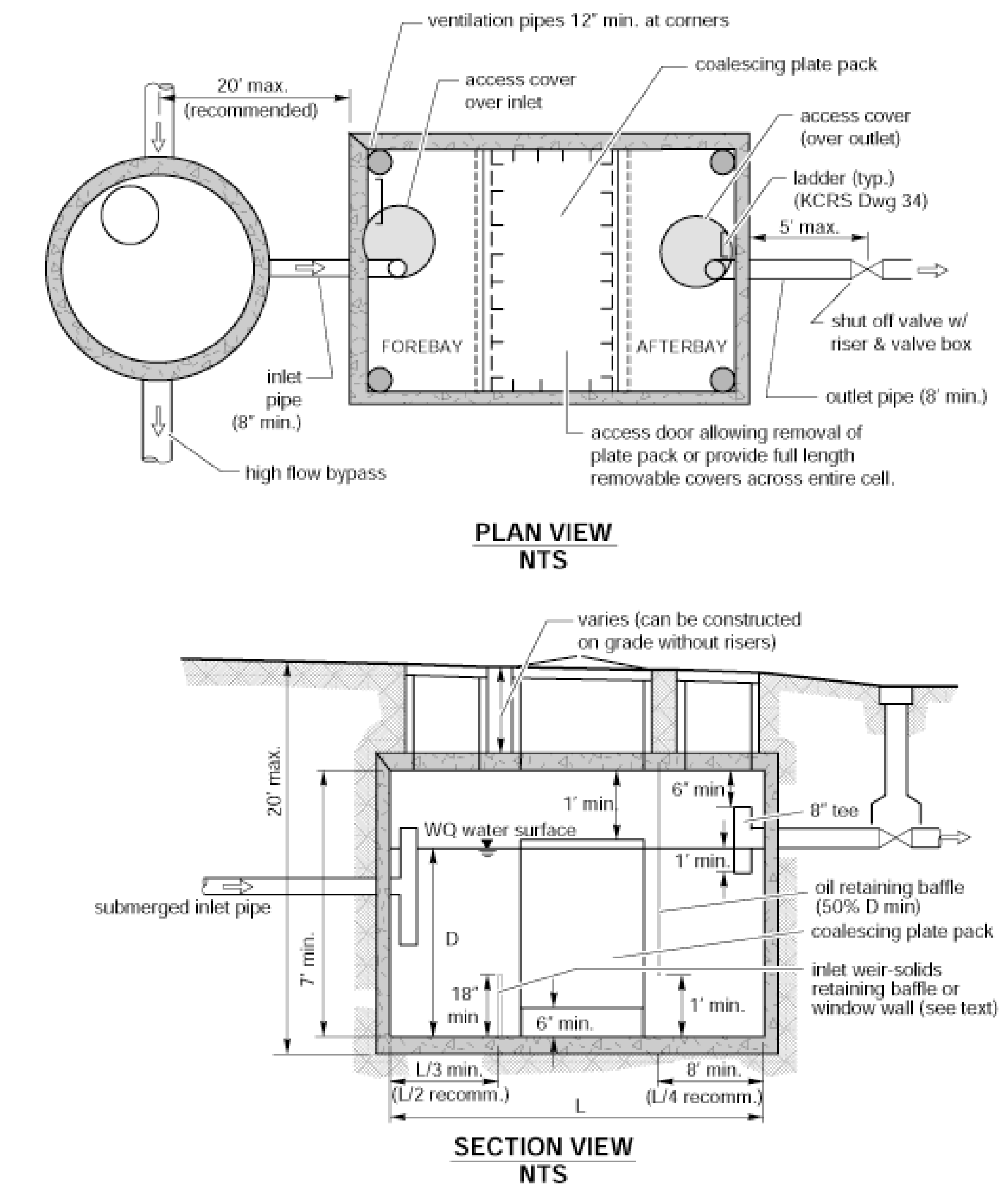
Locate the separator off-line and bypass the incremental portion of flows that exceed the off-line 15-minute, Water Quality design flow rate multiplied by the ratio indicated in Figure 5.1a of this volume. If it is necessary to locate the separator online, try to minimize the size of the area needing oil control, and use the online water quality design flow rate multiplied by the ratio indicated in Figure 5.1b.

Sizing

Calculate the projected (horizontal) surface area of plates needed using the following equation:

$$A_p = Q/V_t = Q/0.00386(\sigma_w\text{-}\sigma_o/\eta_w)$$

$$A_p = A_a(\text{cosine b})$$



Source: King County

Figure 8.2. Coalescing Plate Separator.

Where:

Q = k (the ratio appropriate for the project location) indicated by Figure 5.1b x the 15-minute water quality design flow rate, ft^3/min

V_t = Rise rate of 0.033 ft/min, or empirical determination, or Stokes Law based

A_p = projected surface area of the plate in ft^2; .00386 is unit conversion constant

σ_w=density of water at 32ºF

σ_o= density of oil at 32ºF

A_a = actual plate area in ft^2 (one side only)

b = angle of the plates with the horizontal in degrees (usually varies from 45-60 degrees).

η_w=viscosity of water at 32ºF.

Design Criteria

Geometry

Plate spacing shall be a minimum of three-fourths of an inch (perpendicular distance between plates) (WEF and ASCE, 1998; U.S. Army Corps of Engineers, 1994; US Air Force, 1991; Jaisinghani, R., 1979).

Select a plate angle between 45° to 60° from the horizontal.

Locate plate pack at least 6 inches from the bottom of the separator for sediment storage.

Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.

Include forebay for floatables and afterbay for collection of effluent (WEF and ASCE, 1998).

The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 inches.

Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

8.1.2 OW.03 Oil Containment Booms

The *oil containment boom* is a weather-resistant, hydrophobic, absorbent-filled boom for removing hydrocarbon sheens from water.

Applicability

Oil containment booms can be used to remove oil from the following stormwater facilities to meet performance goals at high use intersections in the public right-of-way where oil control is required:

- BMP WP.01 – Stormwater Treatment Wetland
- BMP WP.02 – Wet Pond
- BMP WP.03 – Wet Vault
- BMP WP.04 – Combined Detention/Wet Pool Facility
- BMP WP.05 – Pre-Settling Basin.

Oil containment boom technology is a low-cost, effective, and easily maintained option for surface ponds. Offers the following advantages over other treatment options:

- Fully functional at flow rates exceeding treatment flow criteria
- Easy and complete removal and disposal of absorbed oil
- Higher reliability because sediment clogging is avoided
- Effectiveness easily assessed due to aboveground installation
- Reduced exposure of maintenance workers to traffic and confined-space hazards.

Limitations

Oil containment booms may not be used in stormwater BMPs that manage runoff from private development.

The oil containment boom is used in a surface pond or treatment vault. If a surface stormwater pond or vault is not included as part of the project this BMP will not be available to meet oil control requirements.

Submittals and Approval

A description of the oil containment boom proposed by the applicant shall be included in the drainage report to include manufacturer data and specifications and manufacturer's recommendations.

Pretreatment

No pretreatment is required.

Hydrologic and Hydraulic Design Considerations

No hydrologic or hydraulic design considerations are involved in using an oil containment boom.

Design Criteria

Geometry

The boom must be cylindrical, with a minimum diameter of 2 inches. It should be installed near the outlet end of the facility so that the oil has a maximum amount of time to rise to the water surface. Maximizing boom distance from inlet currents also maximizes contact time between the boom and the oil. The boom must span the entire width of ponds when they are filled to capacity. The boom must be placed so that it is in direct contact with the water across the entire water surface. In treatment ponds, the boom must be installed diagonally across the water surface to maximize contact area and contact time between hydrocarbons and the boom. When used in a vault, the boom must completely encircle the outlet structure (see Figure 8.3).

Materials

The absorbent material must consist of high-molecular-weight polymers capable of absorbing (1) C5-C18 hydrocarbons associated with fuels, and (2) longer chain hydrocarbons with frequently attached cyclic hydrocarbon structures associated with lubricating oils.

The absorbent material must exhibit the following characteristics:

- Absorb and solidify a minimum of three times its weight in liquid hydrocarbons
- Have sufficient buoyancy at the exhausted condition to continue to trap oil
- Irreversibly absorb and permanently hold the hydrocarbons so that oil leachate is not released from the sorbent. U.S. EPA guidelines for solidified hazardous waste without chemical bonds being formed or broke must also be met.

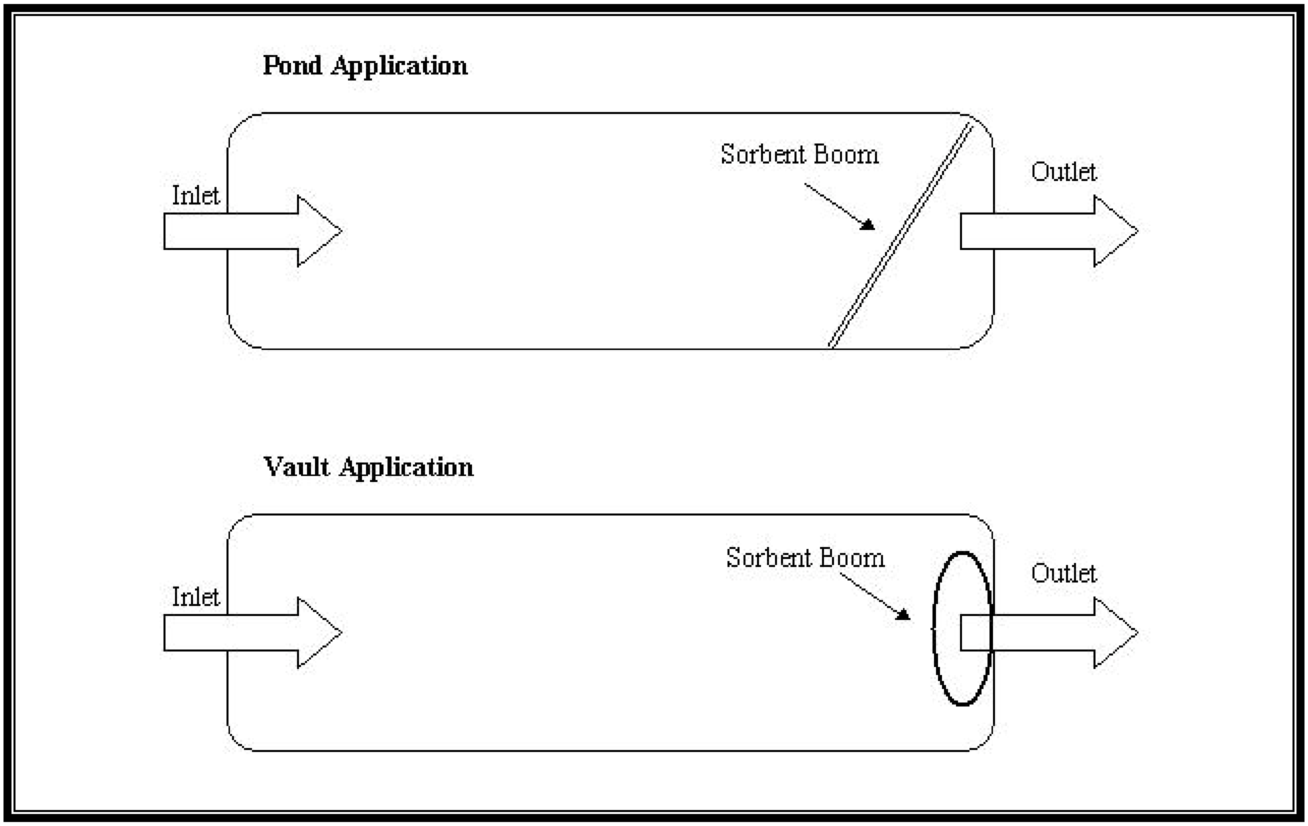


Figure 8.3. Oil Containment Boom.

- Contain a minimum of 99 percent active ingredient and no leachable toxicant to fish and other aquatic life. The supplier must provide appropriate information demonstrating that toxicity will not be a problem.

The absorbent boom cover fabric must meet the following criteria:

- Be fabricated of photo-resistant mesh that meets the ultraviolet (UV) stability requirement for permanent erosion control blankets in Section 9-14.5 of the *Standard Specifications*
- Be sized to allow for the expansion of the absorbent material to hold the specified absorption volume per foot.

Additional requirements for materials related to booms include the following:

- Booms must include a weather-resistant tag to enable labeling with installation and inspection dates for tracking long-term effectiveness and maintenance activities.
- Boom ends must be configured so that they can be secured to immobile structures or metal stakes with weather-resistant rope.

Chapter 9 - Chapter 9 - Emerging Technologies

This Chapter addresses emerging (new) technologies that have not been evaluated in sufficient detail to be acceptable for general usage in new development or redevelopment situations.

9.1 Background

It has become clear that the treatment BMPs described in Ecology's 1992 Stormwater Manual, in some situations, are either not applicable or do not provide reliable and cost-effective removal of pollutants. For these reasons a need to develop new stormwater treatment technologies has emerged in this State as well as nationwide.

Emerging technologies are new technologies that have not been evaluated using approved protocols, but for which preliminary data indicate that they may provide a desirable level of stormwater pollutant removal. Some emerging technologies have already been installed in Washington as parts of treatment trains or as stand-alone systems for specific applications. In some cases, emerging technologies are necessary to remove metals, hydrocarbons, and nutrients. Emerging technologies can also be used for retrofits and where land availability is unavailable

9.2 Ecology Role in Evaluating Emerging Technologies

Ecology currently facilitates a process to evaluate emerging permanent and construction site stormwater treatment technologies and to convey judgments made by local jurisdictions and others on their acceptance. Based on recommendations from Ecology's Volume V Stormwater Technical Advisory Committee (TAC), Ecology is implementing the following process:

- Maintaining a web site for publishing information on emerging technologies and the protocols (TAPE and C-TAPE) used in their evaluation, which is housed at:

  http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

- Organizing and convening Technical Review Committees (TRC) which evaluate emerging technologies, and

- Based on performance and other pertinent data from manufacturers, and recommendations of the review committees, Ecology assesses emerging technology development levels, and posts relevant decisions and supporting documentation at its stormwater website.

9.3 Emerging Technology Use in Retrofit Situations

To achieve the goals of the Clean Water Act and the Endangered Species Act, local governments may find it necessary to retrofit existing stormwater discharges. In retrofit situations, the use of any BMPs that make substantial progress toward these goals is a step forward and is encouraged by Ecology. To the extent practicable, the performance of these BMPs should be evaluated, using approved protocols.

9.4 Acceptable Evaluation Protocols (TAPE and C-TAPE)

To properly evaluate new technologies, performance data must be obtained using an accepted protocol. Ecology has published recommended protocols at its website for use by local governments, suppliers of new technologies, and consultants.

9.5 Acceptance and Use of Emerging Technologies for New Developments and Re-developments

New developments and re-developments may propose to use emerging technologies. These technologies must be:

- Approved and listed on Ecology's website,
- Proposed for use in accordance with Ecology's approval conditions,
- Appropriate to the development site, and
- Approved by the Administrator or designee.

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Appendix V-A – Structures

Control structures are catch basins or manholes with a restrictor device that controls outflow from a facility to meet the desired performance. Riser-type restrictor devices ("tees" or "FROP-Ts") also provide some incidental oil and water separation, temporarily detaining oil or other floatable pollutants entering runoff due to accidental spill or illegal dumping.

Bypass and diversion structures are used to isolate flows when only part of the contributing flows are being directed to water quality.

Control Structures

Control structures are used when there is a need to control outflow flow rates from a BMP facility.

Applicability

The structures included in this appendix apply to the following BMPs:

- BMP D.01 Detention Ponds
- BMP D.02 Detention Tanks
- BMP D.04 Detention Vaults
- BMP WP.02 Wet Ponds.

Bypass and diversion structures apply to any BMPs that are designed to be "off-line", where only part of the contributing stormwater flow is routed to the treatment BMP.

Hydrologic and Hydraulic Design Considerations

Control structure restrictor devices usually consist of two or more orifices and/or a weir section sized to meet performance requirements. Several publicly available and proprietary stormwater modeling programs are capable of designing control structures.

Methods of Analysis

This section presents methods and equations for design of *control structure restrictor devices*. Included are details for the design of orifices, rectangular sharp-crested weirs, v-notch weirs, sutro weirs, and overflow risers.

Rectangular notched weirs are typically most efficient and will result in the optimal detention system design using WWHM.

Orifices

Flow-through orifice plates in the standard tee section or turn-down elbow may be approximated by the general equation:

$$Q = C\,A\,\sqrt{2gh} \qquad \text{(equation 4)}$$

where:
Q = flow (cfs)
C = coefficient of discharge (0.62 for plate orifice)
A = area of orifice (ft^2)
h = hydraulic head (ft)
g = acceleration of gravity (32.2 ft/sec^2)

Figure A-1 illustrates this simplified application of the orifice equation.

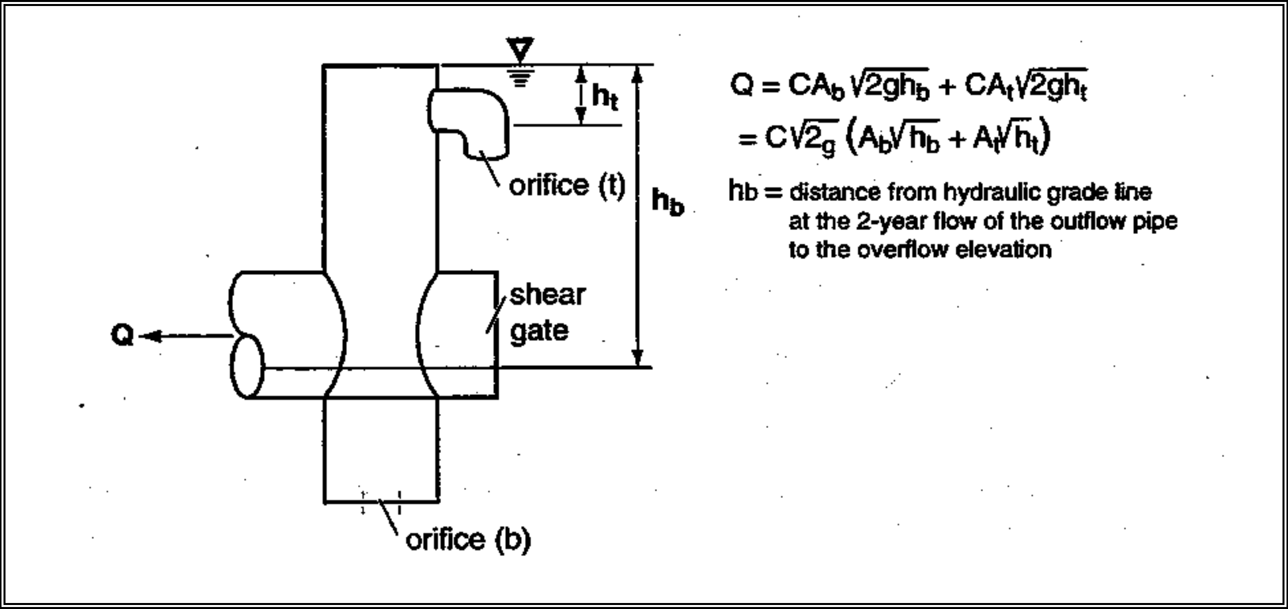


Figure A-1. Simple Orifice.

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(equation 5)}$$

where d = orifice diameter (inches)
Q = flow (cfs)
h = hydraulic head (ft)

Rectangular Sharp-Crested Weir

The rectangular, sharp-crested weir design shown in Figure A-2 may be analyzed using standard weir equations for the fully contracted condition.

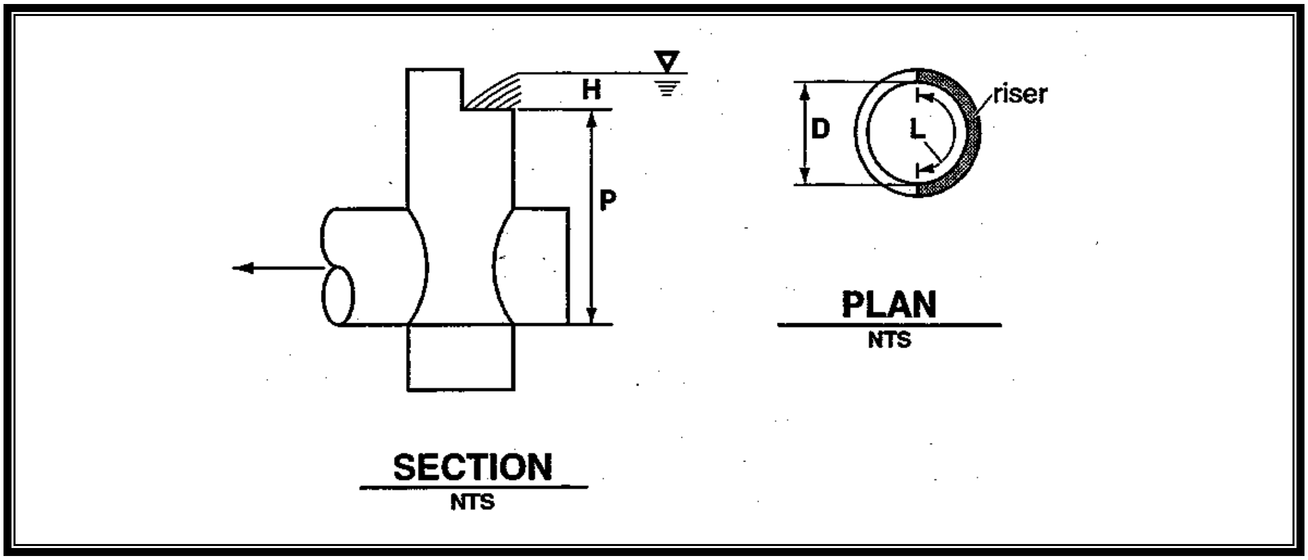


Figure A-2. Rectangular, Sharp-Crested Weir.

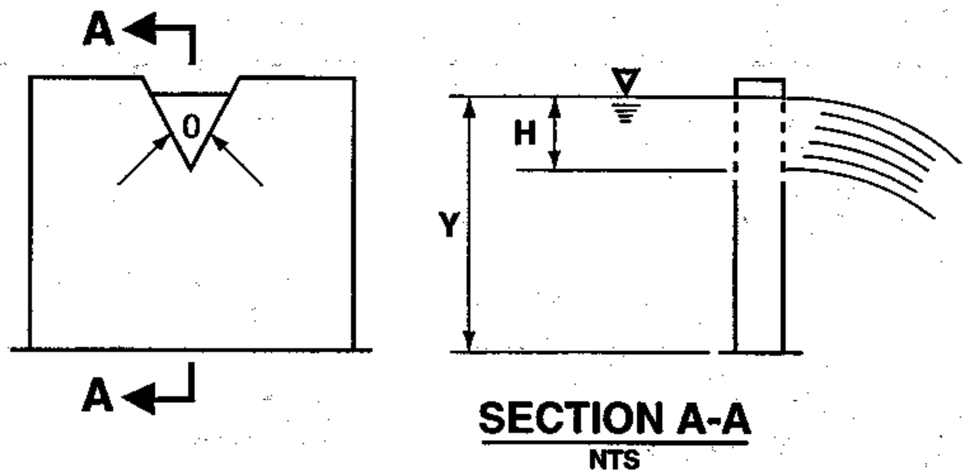
$$Q=C\,(L - 0.2H)H^{3/2} \qquad \text{(equation 6)}$$

where Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P are as shown above
L = length (ft) of the portion of the riser circumference as necessary not to exceed 50 percent of the circumference
D = inside riser diameter (ft)

Note that this equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.

V-Notch Sharp - Crested Weir

V-notch weirs as shown in Figure A-3 may be analyzed using standard equations for the fully contracted condition.



$Q = C_d(\tan \Theta/2)H^{5/2}$, in cfs

Where values of C_d may be taken from the following chart:

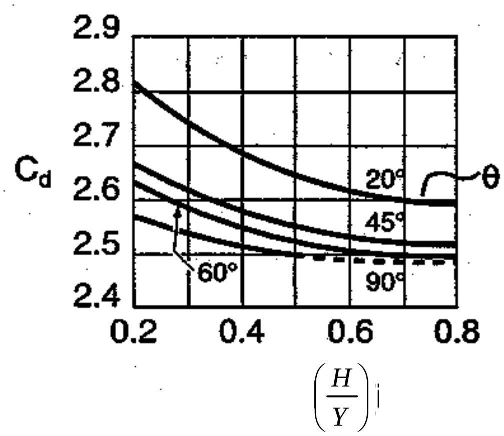


Figure A-3. V-Notch, Sharp-Crested Weir.

Proportional or Sutro Weir

Sutro weirs are designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet performance requirements.

The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B (see Figure A-4). The weir may be symmetrical or non-symmetrical.

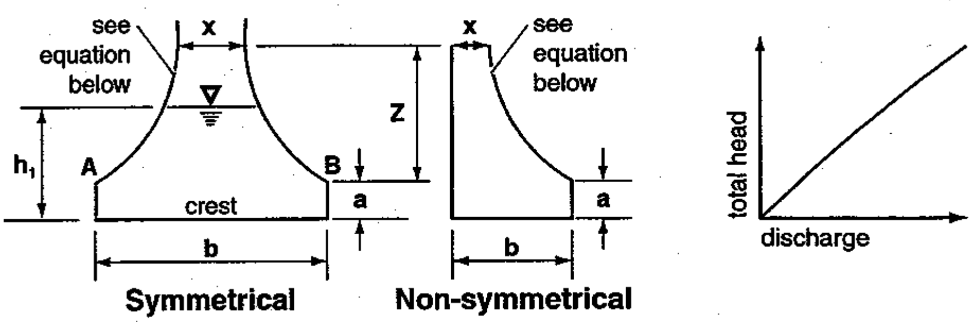


Figure A-4. Sutro Weir.

For this type of weir, the curved portion is defined by the following equation (calculated in radians):

$$\frac{x}{b} = 1 - \frac{2}{\pi} Tan^{-1} \sqrt{\frac{Z}{a}} \qquad \text{(equation 7)}$$

where a, b, x and Z are as shown in Figure A-4. The head-discharge relationship is:

$$Q = C_d \, b \sqrt{2ga(h_1 - \frac{a}{3})} \qquad \text{(equation 8)}$$

Values of *Cd* for both symmetrical and non-symmetrical sutro weirs are summarized in Table A-1.

Note: When b > 1.50 or a > 0.30, use Cd=0.6.

Table A-1. Values of C_d for Sutro Weirs

Cd Values, Symmetrical b (ft)					
a (ft)	0.50	0.75	1.0	1.25	1.50
0.02	0.608	0.613	0.617	0.6185	0.619
0.05	0.606	0.611	0.615	0.617	0.6175
0.10	0.603	0.608	0.612	0.6135	0.614
0.15	0.601	0.6055	0.610	0.6115	0.612
0.20	0.599	0.604	0.608	0.6095	0.610
0.25	0.598	0.6025	0.6065	0.608	0.6085
0.30	0.597	0.602	0.606	0.6075	0.608
Cd Values, Non-Symmetrical b (ft)					
a (ft)	0.50	0.75	1.0	1.25	1.50
0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.603	0.608	0.612	0.6135	0.614

Broad-Crested Weir

The equation for flow through a broad-crested weir that is used as a spillway section would be:

$$Q_{100} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}(\mathrm{Tan}\,\theta)\,H^{5/2}\right] \qquad \text{(equation 1)}$$

Where: Q_{100} = Peak flow for the 100-year runoff event (cfs)
- C = Discharge coefficient (0.6)
- g = Acceleration due to gravity (32.2 ft/sec^2)
- L = Length of weir (ft)
- H = Height of water over weir (ft)
- θ = Angle of side slopes

Q_{100} is either the 100-year, 1-hour flow, indicated by an approved continuous runoff model, multiplied by a factor of 1.6, or the peak 10-minute flow computed from the 100-year, 24-hour storm and a Type 1A distribution.

Assuming C = 0.6 and Tan $\theta = 3$ (for 3:1 slopes), the equation becomes:

$$Q_{100} = 3.21[LH^{3/2} + 2.4\ H^{5/2}] \qquad \text{(equation 2)}$$

To find width L for the weir section, the equation is rearranged to use the computed Q_{100} and trial values of H (0.2 feet minimum):

$$L = [Q_{100}/(3.21H^{3/2})] - 2.4\ H \quad \text{or} \quad 6 \text{ feet minimum} \qquad \text{(equation 3)}$$

Riser Overflow

The nomograph in Figure A-5 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions).

Standard control structure details are shown in Figures A-6 through A-8.

Multiple Orifice Restrictor

In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

- Minimum orifice diameter is 0.5 inches. In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth shall not be reduced to less than 3 feet in an attempt to meet the performance standards. Also, under such circumstances, flow-throttling devices may be a feasible option. These devices will throttle flows while maintaining a plug-resistant opening.

- Orifices may be constructed on a tee section as shown in Figure A-6 or on a baffle as shown in Figure A-7.

- In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g., a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements (see Figure A-8).

- Consideration must be given to the backwater effect of water surface elevations in the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.

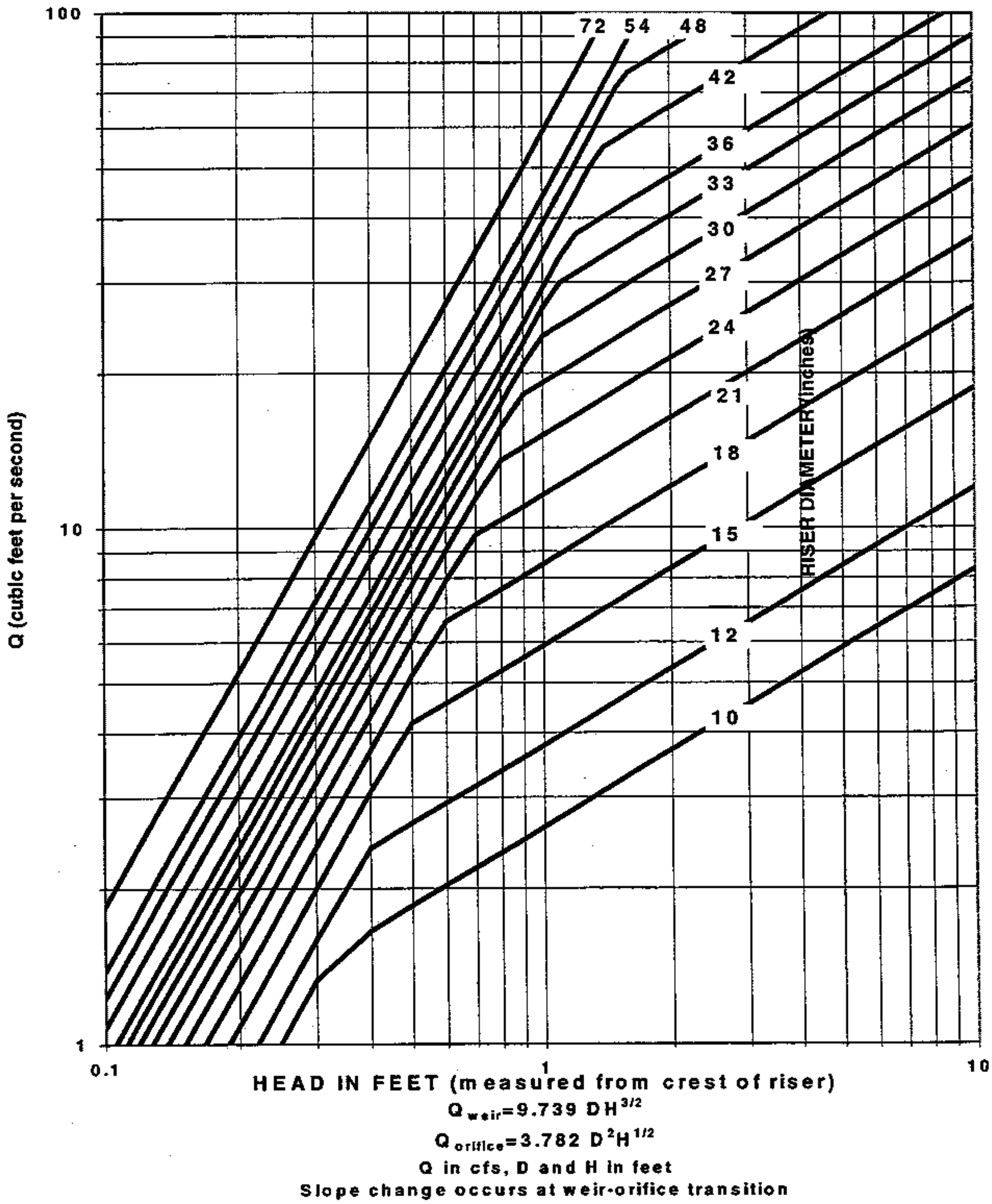
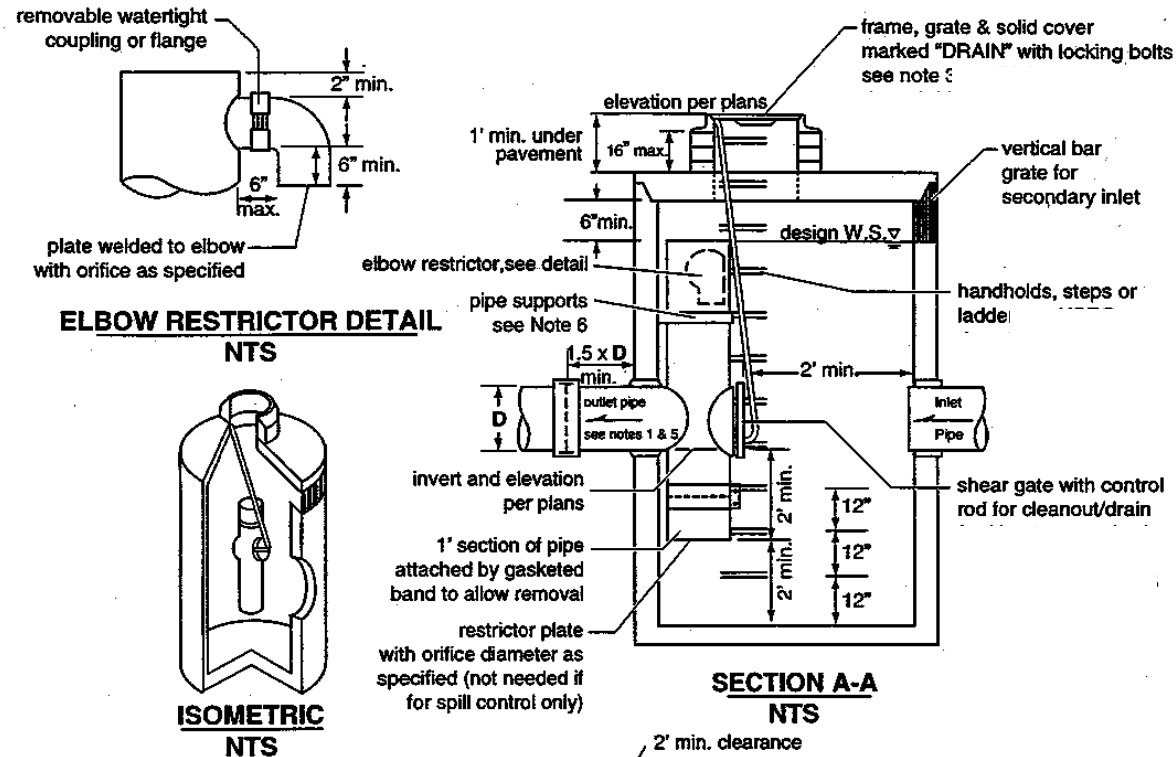
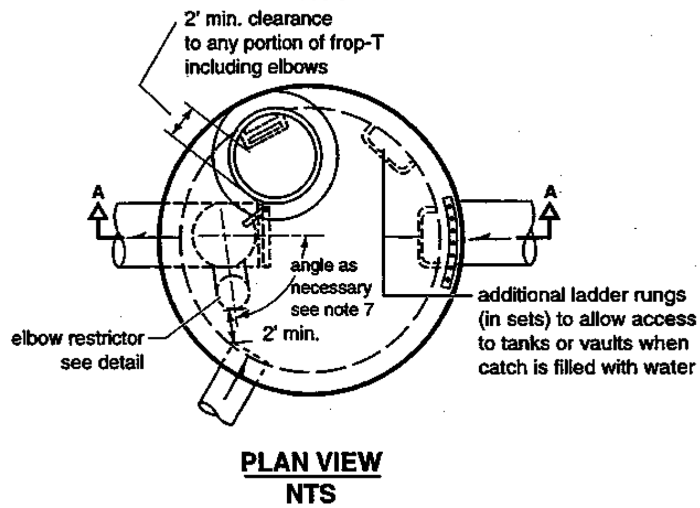


Figure A-5. Riser Inflow Curves.





NOTES:

1. Use a minimum of a 54" diameter type 2 catch basin.
2. Outlet Capacity: 100-Year developed peak flow.
3. Metal Parts: Corrosion resistant. Non-Galvanized parts perferred. Galvanized pipe parts to have asphalt treatment 1.
4. Frame and ladder or steps offset so:
   A. Cleanout gate is visible from top.
   B. Climb-down space is clear of riser and cleanout gate.
   C. Frame is clear of curb.
5. If metal outlet pipe connects to cement concrete pipe: outlet pipe to have smooth O.D. equal to concrete pipe I.D. less 1/4".
6. Provide at least one 3" X .090 inches support bracket anchored to concrete wall. (maximum 3'-0" vertical spacing)
7. Locate elbow restrictor(s) as necessary to provide minimum clearance as shown.
8. Locate additional ladder rungs in structures used as access to tanks or vaults to allow access when catch basin is filled with water.

Figure A-6. Flow Restrictor (TEE).

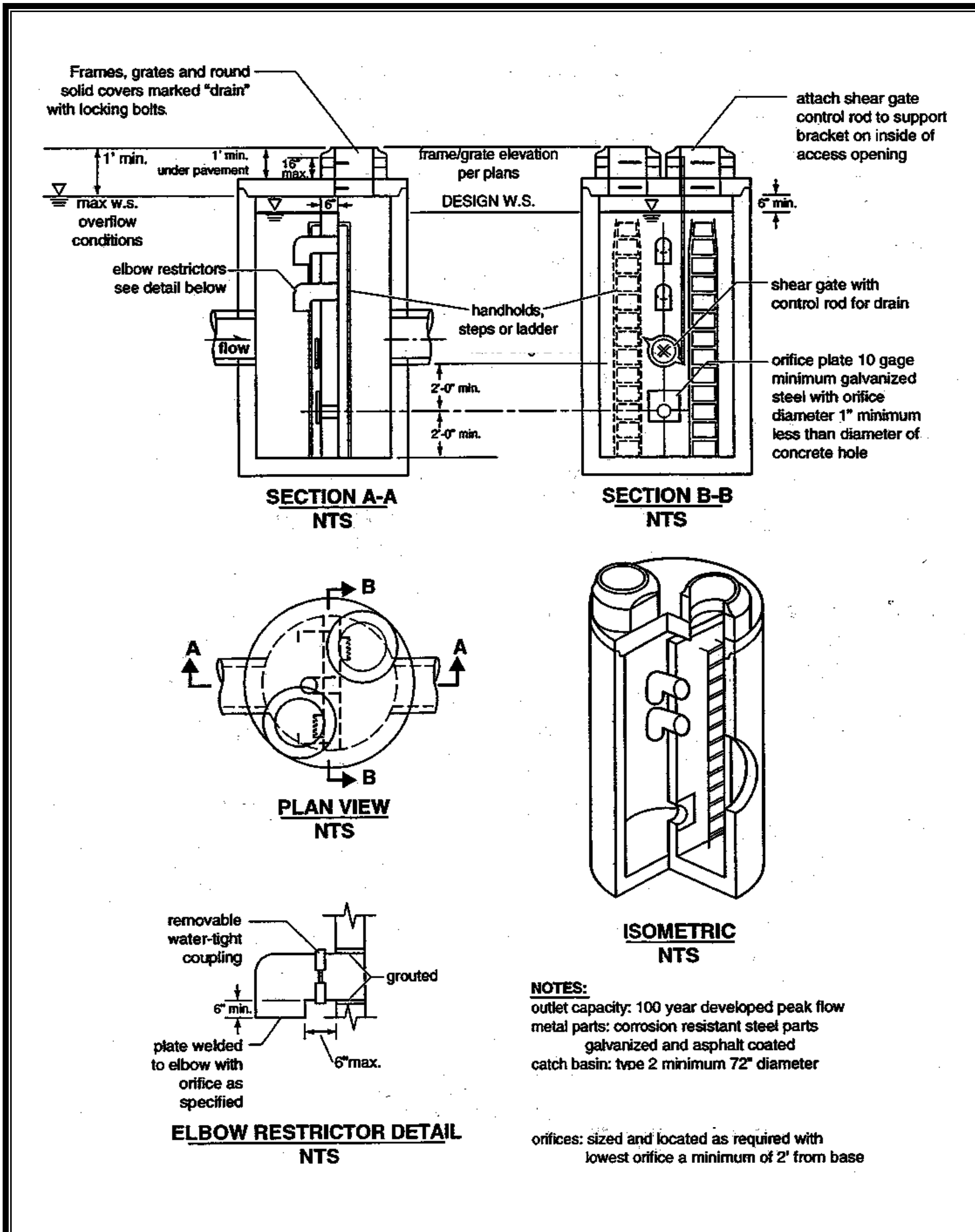
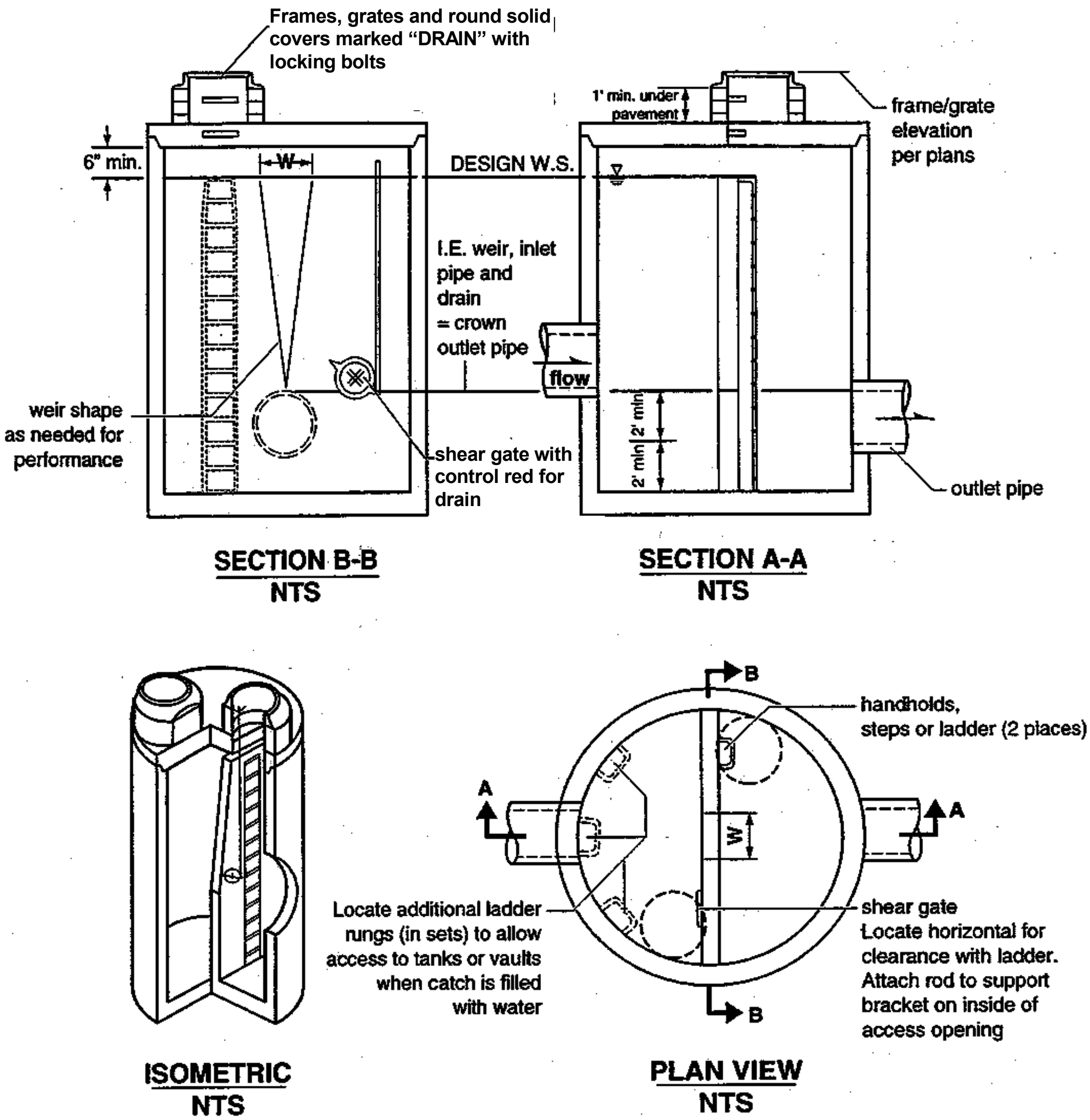


Figure A-7. Flow Restrictor (Baffle).



NOTES:

Outlet Capacity: 100-year developed peak flow.
Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.
Catch Basin: type 2 Min. 72" diameter

Baffle Wall: to be designed with concrete reinforcing as required.
Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

Figure A-8. Flow Restrictor (Weir).

Riser and Weir Restrictor

- Properly designed weirs may be used as flow restrictors (see Figure A-8). However, they must be designed to provide for primary overflow of the developed 100-year peak flow discharging to the detention facility.
- The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design must still provide for primary overflow of the developed 100-year peak flow assuming all orifices are plugged. Figure A-5 can be used to calculate the head in feet above a riser of given diameter and flow.

Information Plate

It is recommended that a brass or stainless steel plate be permanently attached inside each control structure with the following information engraved on it:

- Name and file number of project
- Name and company of (1) developer, (2) engineer, and (3) contractor
- Date constructed
- Date of manual used for design
- Outflow performance criteria
- Release mechanism size, type, and invert elevation
- List of stage, discharge, and volume at 1-foot increments
- Elevation of overflow
- Recommended frequency of maintenance.

Bypass and Diversion Structures

Bypass and diversion structures are used to isolate flows when only part of the contributing flows are being directed to water quality.

Applicability

Bypass and diversion structures apply to any BMPs that are designed to be "offline", where only part of the contributing stormwater flow is routed to the treatment BMP.

The structures included in this appendix are especially suited to the following BMPs:

- BMP BF.01 Basic Biofiltration Swale
- BMP MF.01 Sand Filter Basin
- BMP MF.02 Sand Filter Vault.

Hydrologic and Hydraulic Design Considerations

Offline sand filters placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 15-minute water quality flow rate, as predicted by an approved continuous runoff model, to the treatment BMP. The sand filter must be sized to filter all the runoff sent to it (no overflows from the treatment facility should occur).

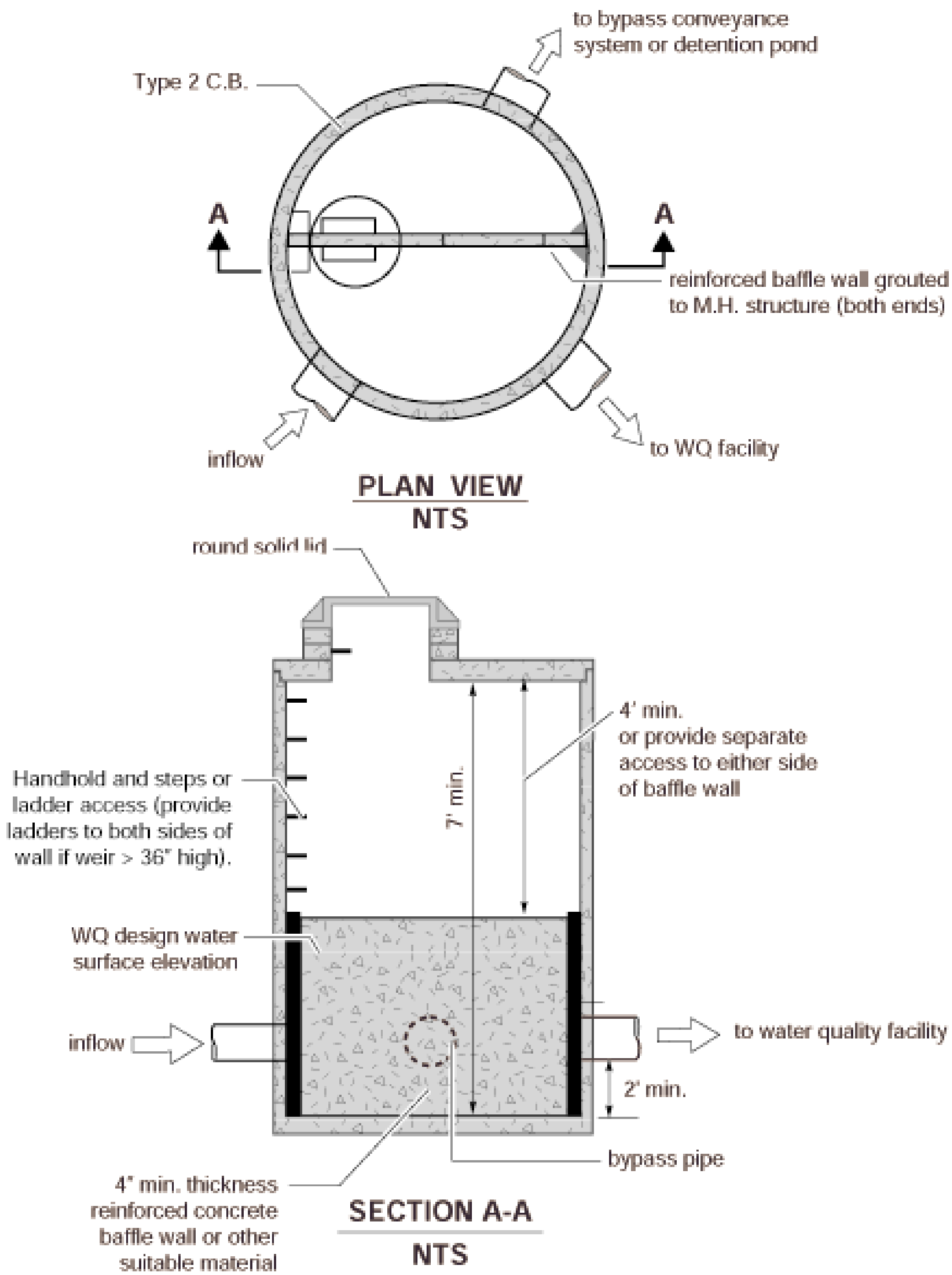
Note: WWHM allows any bypasses and the runoff filtered through the sand to be directed to the downstream detention facility.

Offline sand filters placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 2-year recurrence interval flow from the detention pond (as predicted by an approved continuous runoff model) to the treatment facility. The treatment facility must be sized to filter all the runoff sent to it (no overflows from the treatment facility should occur).

Design Criteria

Figures A-9 through A-11 provide examples of flow splitters and diversion structures.

Where flow restrictor manholes are to be used, they are to be designed in a manner similar to that shown in Appendix A, Figures A-3 and A-4. Manholes used to house flow restrictor assemblies shall have a minimum diameter of 54 inches. Assemblies shall be equipped with a chain-operated lift gate that can be opened in emergency situations. Flow restrictor devices may have multiple orifices as described in Chapter 4, or may use thin-plate slotted weirs in place of orifices.



Note: The water quality discharge pipe may require an orifice plate be installed on the outlet to control the height of the design water surface (weir height). The design water surface should be set to provide a minimun headwater/diameter ratio of 2.0 on the outlet pipe.

Figure A-9. Flow Splitter Option A.

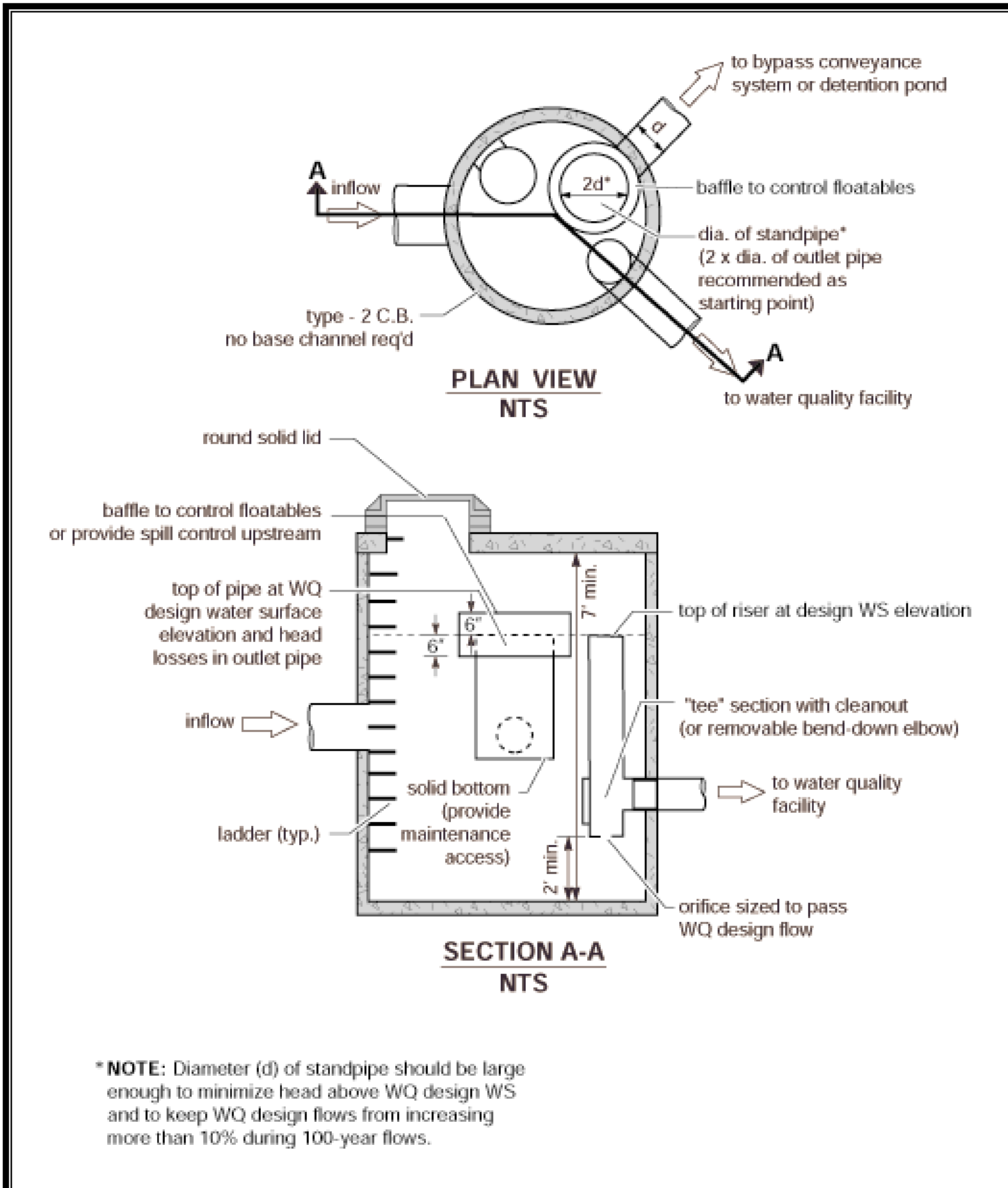
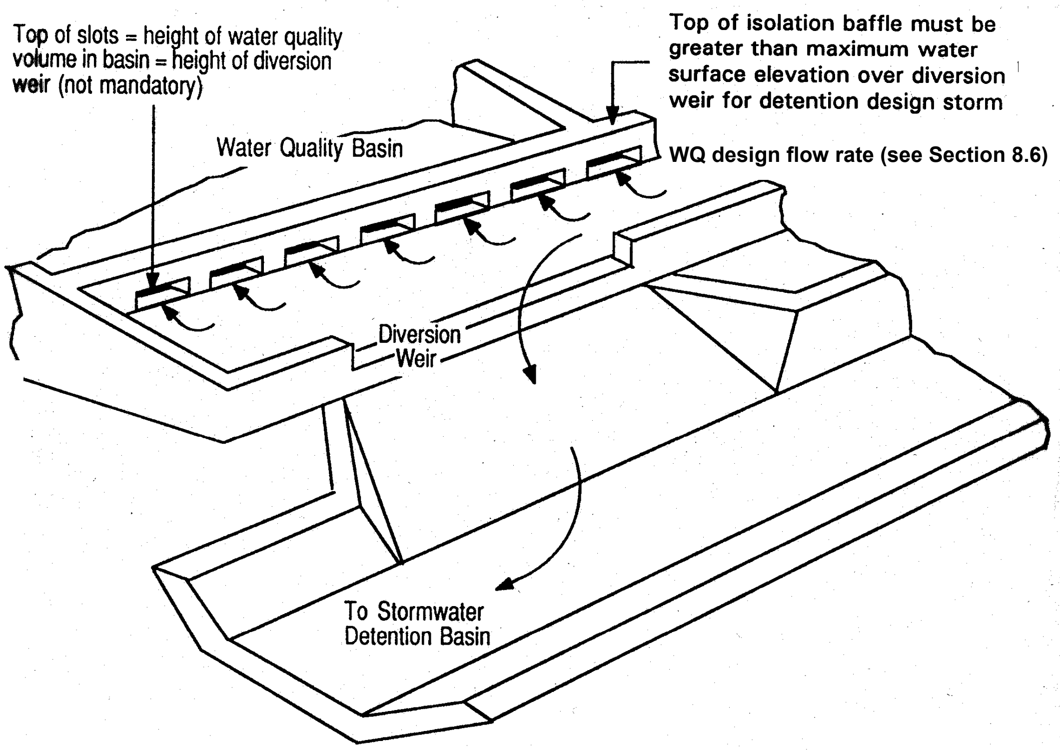


Figure A-10. Flow Splitter Option B.



Source: City of Austin

Figure A-11. Example Isolation/Diversion Structure.

Flow Spreading Options

Flow spreaders function to uniformly spread flows across the inflow portion of several water quality facilities (e.g., sand filter, biofiltration swale, or filter strip). There are five flow spreader options described in this section:

- Option A – Anchored plate
- Option B – Concrete sump box
- Option C – Notched curb spreader
- Option D – Through-curb ports
- Option E – Interrupted curb.

Options A through C can be used for spreading flows that are concentrated, and when spreading is required by facility design criteria. Options A through C can also be used for unconcentrated flows, and in some cases must be used, such as to correct for moderate grade changes along a filter strip.

Options D and E are only for flows that are already unconcentrated and enter a filter strip or continuous inflow biofiltration swale. Other flow spreader options are possible with acceptance of the Administrator or designee.

General Design Criteria

- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.
- For higher inflows (greater than 5 cfs for the 100-year storm), a Type 1 catch basin shall be positioned in the spreader and the inflow pipe should enter the catch basin with flows exiting through the top grate. The top of the grate shall be lower than the level spreader plate, or if a notched spreader is used, lower than the bottom of the v-notches.

Option A – Anchored Plate (Figure A-12)

- An anchored plate flow spreader shall be preceded by a sump with a minimum depth of 8 inches and minimum width of 24 inches. If not otherwise stabilized, the sump area shall be lined to reduce erosion and provide energy dissipation.

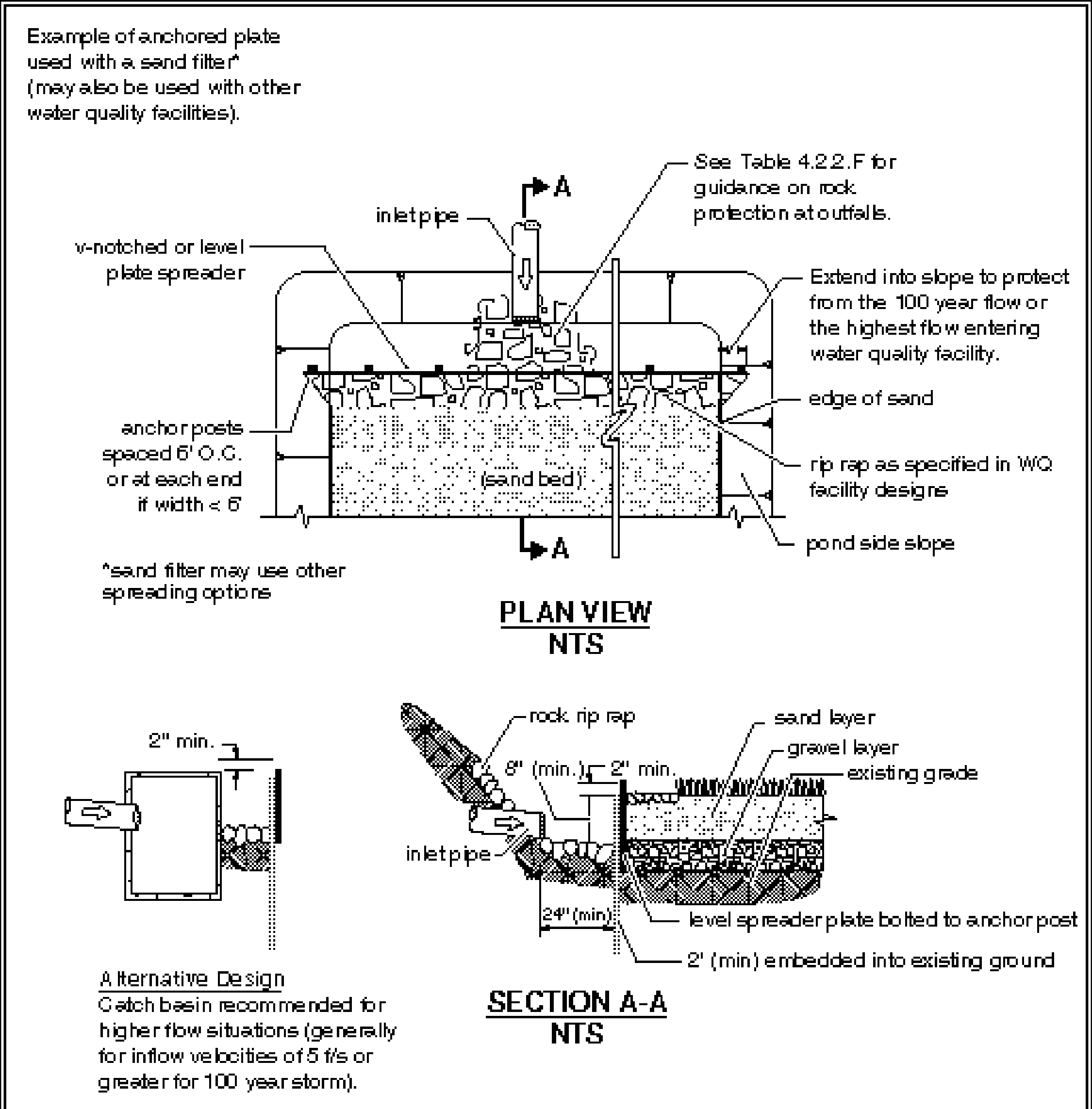


Figure A-12. Flow Spreader Option A: Anchored Plate.

- The top surface of the flow spreader plate shall be level, projecting at least 2 inches above the ground surface of the water quality facility, or V-notched with notches 6 to 10 inches on center and 1 to 6 inches deep (use shallower notches with closer spacing). Alternative designs may also be used.

- A flow spreader plate shall extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The horizontal extent shall be such that the bank is protected for all flows up to the 100-year flow or the maximum flow that will enter the runoff treatment facility.

- Flow spreader plates shall be securely fixed in place.

- Flow spreader plates may be made of either wood, metal, fiberglass reinforced plastic, or other durable material. If wood, pressure treated 4- by 10-inch lumber or landscape timbers are acceptable.

- Anchor posts shall be 4-inch square concrete, tubular stainless steel, or other material resistant to decay.

Option B – Concrete Sump Box (Figure A-13)

- The wall of the downstream side of a rectangular concrete sump box shall extend a minimum of 2 inches above the treatment bed. This serves as a weir to spread the flows uniformly across the bed.

- The downstream wall of a sump box shall have “wing walls” at both ends. Side walls and returns shall be slightly higher than the weir so that erosion of the side slope is minimized.

- Concrete for a sump box can be either cast-in-place or precast, but the bottom of the sump shall be reinforced with wire mesh for cast-in-place sumps.

- Sump boxes shall be placed over bases that consists of 4 inches of crushed rock, 5/8-inch minus to help assure the sump remains level.

Option C – Notched Curb Spreader (Figure A-14)

Notched curb spreader sections shall be made of extruded concrete laid side-by-side and level. Typically five “teeth” per 4 foot section provide good spacing. The space between adjacent “teeth” forms a v-notch.

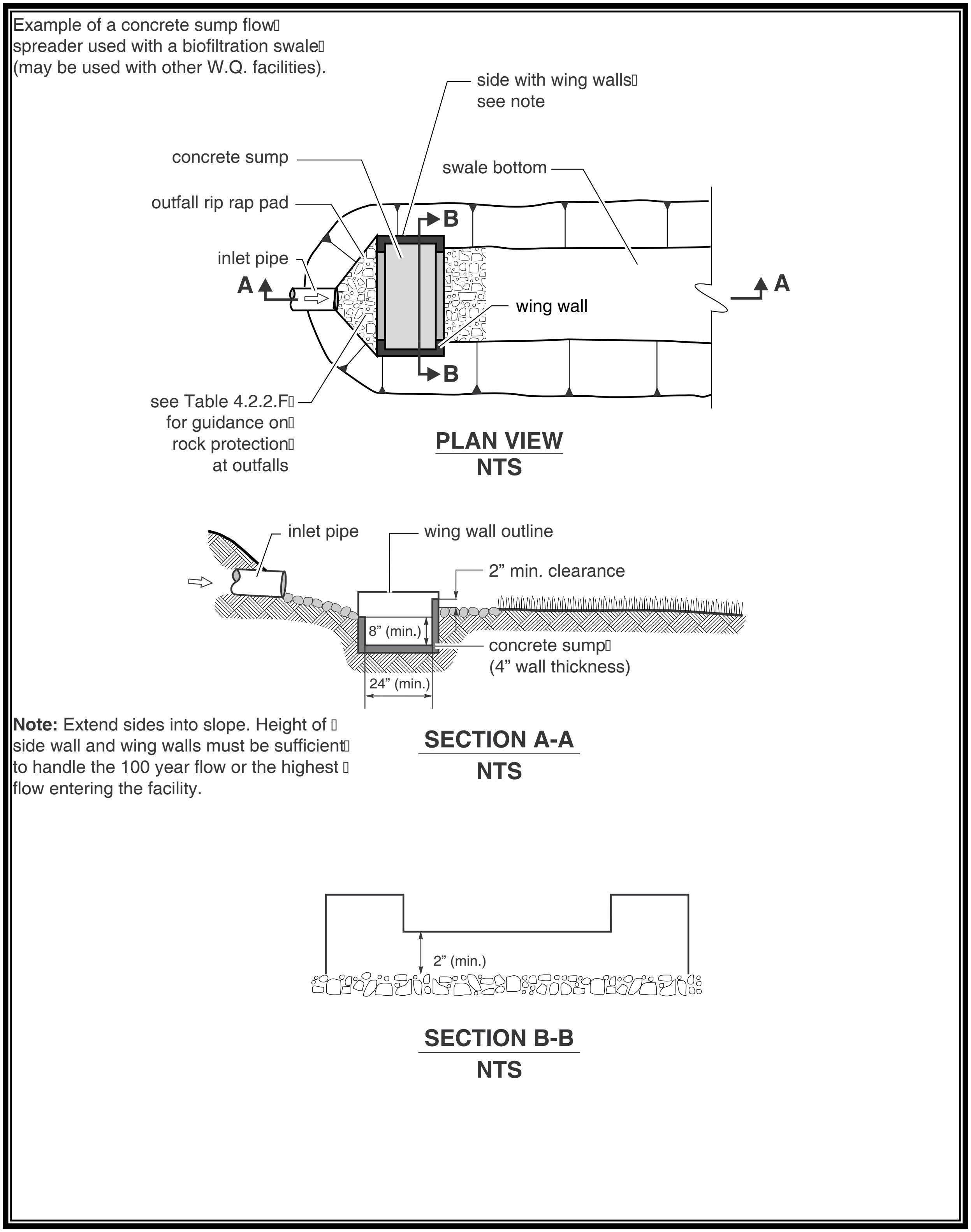


Figure A-13. Flow Spreader Option B: Concrete Sump Box.

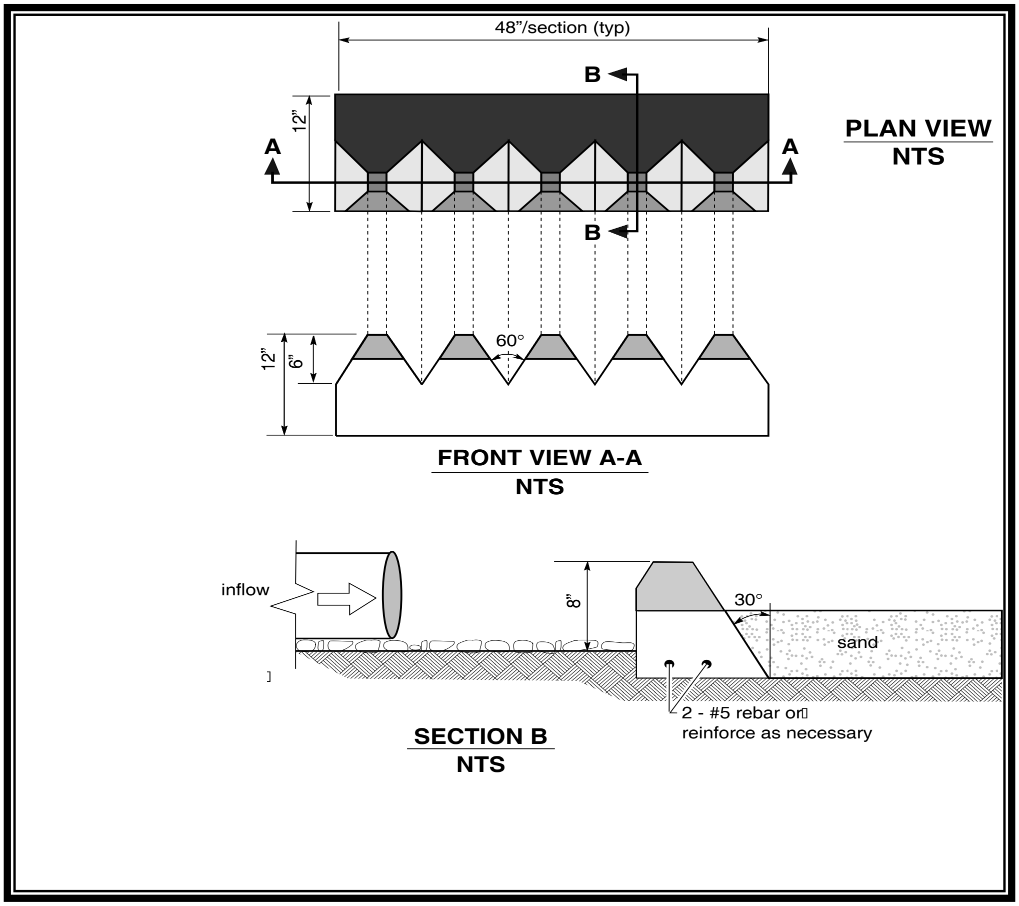


Figure A-14. Flow Spreader Option C: Notched Curb Spreader.

Option D –Through-Curb Ports (Figure A-15)

Unconcentrated flows from paved areas entering filter strips or continuous inflow biofiltration swales can use curb ports or interrupted curbs (Option E) to allow flows to enter the strip or swale. Curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the runoff treatment facility.

Openings in the curb shall be at regular intervals but at least every 6 feet (minimum). The width of each curb port opening shall be a minimum of 11 inches. Approximately 15 percent or more of the curb section length shall be in open ports, and no port shall discharge more than about 10 percent of the flow.

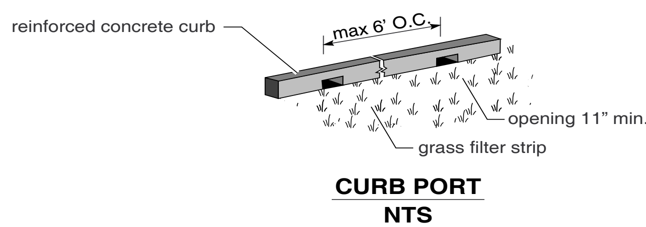


Figure A-15. Flow Spreader Option D: Through-Curb Port.

Option E – Interrupted Curb (No Figure)

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on facility) of the treatment area. At a minimum, gaps shall be every 6 feet to allow distribution of flows into the treatment facility before they become too concentrated. The opening shall be a minimum of 11 inches. As a general rule, no opening shall discharge more than 10 percent of the overall flow entering the facility.

Appendix V-B – Facility Liners and Geotextiles

Liners are intended to reduce the likelihood that pollutants in stormwater will reach groundwater when runoff treatment facilities are constructed.

Low permeability liners reduce infiltration to a very slow rate, generally less than 0.02 inches per hour (1.4×10^{-5} centimeters squared). These types of liners are used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff. Low permeability liners may be fashioned from compacted till, clay, geomembrane, or concrete.

Applicability

Liners are used when there is a need to protect underlying soils from pollutants or retain permanent water for wet BMPs. Geotextiles are used in many BMPs and are not listed here.

This appendix applies to the following BMPs:

- BMP LID.04 Downspout Infiltration Systems
- BMP BF.01 Basic Biofiltration Swale
- BMP WP.05 Presettling Basins
- BMP WP.01 Stormwater Treatment Wetlands
- BMP WP.02 Wet Ponds
- BMP WP.04 Combined Detention and Wet Pool Facilities
- MF.01 Sand Filter Basin
- MF.03 Linear Sand Filter.

Liners Design Criteria

- Table B-1 shows the type of liner required for use with various runoff treatment facilities. Other liner configurations may be used with prior acceptance from the County.
- Liners shall be evenly placed over the bottom and/or sides of the treatment area of the facility as indicated in Table B-1. Areas above the treatment volumes that are required to pass flows greater than the water quality treatment flow (or volume) need not be lined. However, the lining must be extended to the top of the

interior side slope and anchored if it cannot be permanently secured by other means.

Table B-1. Lining Types Required for Runoff Treatment Facilities

Water Quality Facility	Area to be Lined	Type of Liner Required
Presettling basin	Bottom and sides	Treatment liner or Low permeability liner (If the basin will intercept the seasonal high groundwater table, a treatment liner may be recommended.)
Wet pond	First cell: bottom and sides to water quality design water surface -- Second cell: bottom and sides to water quality design water surface	Treatment liner or Low permeability liner -- Treatment liner
Combined detention/water quality facility	First cell: bottom and sides to water quality design water surface -- Second cell: bottom and sides to water quality design water surface	Treatment liner or Low permeability liner -- Treatment liner
Stormwater wetland	Bottom and sides, both cells	Low permeability liner
Sand filtration basin	Basin sides only	Treatment liner
Sand filter vault	Not applicable	No liner needed
Linear sand filter	Not applicable if in vault Bottom and sides of presettling cell if not in vault	No liner needed Treatment liner or Low permeability
Media filter (in vault)	Not applicable	No liner needed
Wet vault	Not applicable	No liner needed

Low Permeability Liners

This section presents the design criteria for each of the following four low permeability liner options: compacted till liners, clay liners, geomembrane liners, and concrete liners.

- For low permeability liners, the following criteria apply:
    - Where the seasonal high groundwater elevation is likely to contact a low permeability liner, liner buoyancy may be a concern. In these instances, use of a low permeability liner shall be evaluated and recommended by a geotechnical engineer.
    - Where grass must be planted over a low permeability liner per the facility design, a minimum of 6 inches of good topsoil or

compost-amended native soil (2 inches compost tilled into 6 inches of native till soil) must be placed over the liner in the area to be planted. Twelve inches of cover is preferred.

Compacted Till Liners

- Liner thickness shall be 18 inches after compaction.
- Soil shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to retard the infiltration rate to 2.4×10^{-5} inches per minute (1×10^{-6} centimeters squared) may also be used instead of the thickness and density criteria above.
- Soil should be placed in 6-inch lifts.
- Soils may be used that meet the gradation in Table B-2 below:

Table B-2. Compacted Till Liners

Sieve Size	Percent Passing
6-inch	100
4-inch	90
#4	70 - 100
#200	20

Clay Liners

- Liner thickness shall be 12 inches.
- Clay shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to retard the infiltration rate to 2.4×10^{-5} inches per minute (1×10^{-6} centimeters squared) may also be used instead of the above criteria.
- Plasticity index shall not be less than 15 percent (ASTM D-423, D-424).
- Liquid limit of clay shall not be less than 30 percent (ASTM D-2216).
- Clay particles passing shall not be less than 30 percent (ASTM D-422).

- The slope of clay liners must be restricted to 3H:1V for all areas requiring soil cover; otherwise, the soil layer must be stabilized by another method so that soil slippage into the facility does not occur. Any alternative soil stabilization method must take maintenance access into consideration.
- Where clay liners form the sides of ponds, the interior side slope shall not be steeper than 3H: 1V, irrespective of fencing. This restriction is to ensure that anyone falling into the pond may safely climb out.

Geomembrane Liners

- Geomembrane liners shall be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils shall be used in areas of maintenance access or where heavy machinery must be operated over the membrane.
- The geomembrane fabric shall be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane determined to have a high survivability per the WSDOT standard specifications, specifically Section 9-33 Construction Geotextile (2006 or the latest version as amended). Equivalent methods for protection of the geomembrane liner will be considered. Equivalency will be judged on the basis of ability to protect the geomembrane from puncture, tearing, and abrasion.
- Geomembranes shall be bedded according to the manufacturer's recommendations.
- Liners must be covered with 12 inches of top dressing forming the bottom and sides of the water quality facility, except for linear sand filters. Top dressing shall consist of 6 inches of crushed rock covered with 6 inches of native soil. The rock layer is to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, 12 inches of native soil may be used if orange plastic “safety fencing” or another highly visible, continuous marker is embedded 6 inches above the membrane.
- If possible, liners should be of a contrasting color so that maintenance workers are aware of any areas where a liner may have become exposed when maintaining the facility.
- Geomembrane liners shall not be used on slopes steeper than 5H:1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

Concrete Liners

- Concrete liners may also be used for sedimentation chambers and for sedimentation and filtration basins less than 1,000 square feet in area. Concrete shall be 5-inch thick Class 3000 or better and shall be reinforced by steel wire mesh. The steel wire mesh shall be six (6) gage wire or larger and 6 inch by 6 inch mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete shall have a minimum 6 inch compacted aggregate base consisting of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch. Where visible, the concrete shall be inspected annually and all cracks shall be sealed.

- Portland cement liners are allowed irrespective of facility size, and shotcrete may be used on slopes. However, specifications must be developed by a professional engineer who certifies the liner against cracking or losing water retention ability under expected conditions of operation, including facility maintenance operations. Weight of maintenance equipment can be up to 80,000 pounds when fully loaded.

- Asphalt concrete may not be used for liners due to its permeability to many organic pollutants.

- If grass is to be grown over a concrete liner, slopes must be no steeper than 5H: 1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

Geotextiles

Applications

1. For sand filter drain strip between the sand and the drain rock or gravel layers specify Geotextile Properties for Underground Drainage, moderate survivability, Class A, from Tables 1 and 2 in the Geotextile Specifications.

2. For sand filter matting located immediately above the impermeable liner and below the drains, the function of the geotextile is to protect the impermeable liner by acting as a cushion. The specification provided below in Table 3 shall be used to specify survivability properties for the liner protection application. Table 2, Class C shall be used for filtration properties. Only nonwoven geotextiles are appropriate for the liner protection application.

3. For an infiltration drain specify Geotextile for Underground Drainage, low survivability, Class C, from Tables 1 and 2 in the Geotextile Specifications.

4. For a sand bed cover a geotextile fabric is placed exposed on top of the sand layer to trap debris brought in by the storm water and to protect the sand, facilitating easy cleaning of the surface of the sand layer. However, a geotextile is not the best product for this application. A polyethylene or polypropylene geonet would be better. The geonet material shall have high UV resistance (90% or more strength retained after 500 hours in the weatherometer, ASTM D4355), and high permittivity (ASTM D4491, 0.8 sec. -1 or more) and percent open area (CWO-22125, 10% or more). Tensile strength shall be on the order of 200 lbs grab (ASTM D4632) or more.

Table B-3. Geotextile Properties for Underground Drainage

Geotextile Property Requirements[1]			
		Low Survivability	**Moderate Survivability**
Geotextile Property	**Test Method**	**Woven/Nonewoven**	**Woven/Nonwoven**
Grab Tensile Strength, min. in machine and x-machine diretion.	ASTM D4632	189 lbs/115 lbs min.	250 lbs/160 lbs min.
Grab Failure Strain, in machine and x-machine direction.	ASTM D4632	<50% / >50%	<50%/>50%
Seam Breaking Strength (if seams are present)	ASTM D4632 and ASTM D4884 (adapted for grab test)	160 lbs/100 lbs min.	220 lbs/140 lbs min.
Puncture Resistance	ASTM D4833	67 lbs/40 lbs min.	80 lbs/50 lbs min.
Tear Strength, min. in machine and x-machine direction.	ASTM D4533	67 lbs/40 lbs min.	80 lbs/50 lbs min.
Ultraviolet (UV) Radiation stability	ASTM D4355	50% strength retained min., after 500 hrs. in weatherometer	50% strength retained min., after 500 hrs. in weatherometer

1 All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

Table B-4. Geotextile for Underground Drainage Filtration Properties

Geotextile Property Requirements [1]				
Geotextile Property	**Test Method**	**Class A**	**Class B**	**Class C**
AOS[2]	ASTMD4751	0.43 mm max (#40 sieve)	0.25 mm max (#60 sieve)	0.18 mm max. (#80 sieve)
Water Permittivity	ASTMD4491	0.5 sec-1 min	0.4 sec -1 min.	0.3 sec -1 min.

[1] All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

[2] Apparent Opening Size (measure of diameter of the pores in the geotextile).

Table B-5. Geotextile Strength Properties for Impermeable Liner Protection

Geotextile Property	Test Method	Geotextile Property Requirements [1]
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	250 lbs min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	>50%
Seam Breaking Strength (if seams are present)	ASTM D43632 and ASTM D4884 (adapted for grab test)	220 lbs min.
Puncture Resistance	ASTM D4833	125 lbs min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	90 lbs min.
Ultraviolet (UV) Radiation	ASTM D4355	50% strength stability retained min., after 500 hrs in weatherometer

[1] All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

Reference for Tables B-3 and B-4: Section 9-33.2 "Geotextile Properties," 1998 Standard Specifications for Road, Bridge, and Municipal Construction

Appendix V-C – Maintenance Guidelines

This appendix provides facility-specific maintenance standards. The standards are intended to provide conditions for determining, through inspection, if maintenance actions are required. Failure to meet these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these standards. However, the inspection and maintenance schedules must be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action.

Instructions for Use of Maintenance Checklists

The following pages contain maintenance tables for most of the BMPs included in Volume V. Where private developers, rather than Thurston County staff, are responsible for facility maintenance, they should plan to complete a checklist for all system components on the following schedule:

- (M) Monthly from October through April.
- Annually, once in late summer (preferably September)
- (S) Storm-based, after any major storm (use 1 inch in 24 hours as a guideline).

The tables contained in this appendix may be used as checklists. Maintenance personnel may use photocopies of these pages and check off items inspected and problems noted during each inspection. Actions taken and corrective action recommended should also be noted.

Table C-1. Maintenance Checklist for Bioretention Facilities (BMP LID.08)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
S	General		Erosion	Look for signs of erosion in flow entrance, ponding area, and surface overflow. If erosion has occurred, reassess flow volumes, cell sizing, velocities, and flow dissipation.	Replace soil, plant material and/or mulch layer. If needed, cell geometry and erosion protection measures have been modified to prevent future erosion problems.
S			Drawdown	Look for standing water beyond 48-hours after a storm event. If standing water lingers beyond 48 hours risk of mosquito and other pests increases and ability of facility to handle larger storms is restricted.	Facility should drawdown after a storm event within 48-hours. If needed rehabilitate treatment soils and clean debris from surface of soils to restore infiltration capacity. Scarify surface soils to a depth of 2-6 inches & add mulch.
A	Plants		Dead or unhealthy plants	Dead plants, sparse vegetation. If a specific plant type has a high mortality rate, assess cause and replace with appropriate species. Consider analyzing soils for fertility and adding soil amendment if needed.	Prune plants as needed. Remove dead plant material. Replace all dead plants.
M			Weeds	Weeds or invasive plant species present.	Weeds are removed.
A			Mulch	Gaps in depth or coverage of mulch.	Place additional mulch so that there is 2 to 3 inch depth. Where heavy metal deposition is likely (e.g., contributing areas that include parking lots and roads), all mulch shall be replaced annually.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-2. Maintenance Checklist for Detention Tanks (BMP D.01), Detention Vaults (BMP D.02), and Wet Vaults (BMP WP.03)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	Storage Area		Plugged Air Vents	One-half of the cross-section of a vent is blocked at any point or the vent is damaged. Plugged vent can cause storage area to collapse.	Vents open and functioning.
M			Debris and Sediment	Accumulated sediment depth exceeds 10 percent of the diameter of the storage area for one-half length of storage vault or any point depth exceeds 15 percent of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than one-half length of tank.)	All sediment and debris removed from storage area.
A			Joints Between Tank Section	Any crack allowing material to leak into facility.	All joint between tank sections are sealed.
A			Tank Bent Out of Shape	Any part of tank is noticeably bent out of shape.	Tank repaired or replaced to design. Contact a professional engineer for evaluation.
A			Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2 inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications and is structurally sound.
A				Cracks wider than 1/2 inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls	No cracks more than 1/4 inch wide at the joint of the inlet/outlet pipe.
M, S	Crest Gage		Crest Gage Missing/Broken	Crest gage is not functioning properly, has been vandalized, or is missing.	Repair/replace

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A	Manhole		Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
A			Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than one-half inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.
A			Cover Difficult to Remove	One maintenance person cannot remove lid after applying 80 Pounds of lift. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
A			Ladder Rungs Unsafe	Maintenance person judges that ladder is unsafe due to missing rings, misalignment, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Tanks and vaults are a confined space. Visual inspections should be performed aboveground. If entry is required it should be performed by qualified personnel.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-3A. Maintenance Checklist for Detention Ponds (BMP D.01), and Wetponds (BMP WP.02)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M,S	General		Trash and Debris buildup in pond.	Dumping of yard wastes such as grass clippings and branches into basin. Unsightly accumulation of non-degradable materials such as glass, plastic, metal, foam, and coated paper.	Remove trash and debris and dispose as prescribed by Thurston County Department of Resource Stewardship.
M,S			Trash rack plugged or missing	Bar screen over outlet more than 25% covered by debris or missing.	Replace screen. Remove trash and debris and dispose as prescribed by City Waste Management Section.
M			Poisonous Vegetation	Any poisonous vegetation which may constitute a hazard to the public. Examples of poisonous vegetation include: tansy ragwort, poison oak, stinging nettles, devilsclub.	Remove poisonous vegetation. Do not spray chemicals on vegetation without obtaining guidance from the County.
M,S			Fire hazard or pollution	Presence of chemicals such as natural gas, oil, and gasoline, obnoxious color, odor, or sludge noted.	Find sources of pollution and eliminate them. Water is free from noticeable color, odor, or contamination.
M			Vegetation not growing or is overgrown	For grassy ponds, grass cover is sparse and weedy or is overgrown.	For grassy ponds, selectively thatch, aerate, and reseed ponds. Grass cutting unnecessary unless dictated by aesthetics. Contact the Thurston County Noxious Weed program for direction on invasive species such as purple loosestrife and reed canary grass. Pond bottoms shall have uniform dense coverage of desired plant species.
M			Rodent Holes	If the facility is constructed with a dam or berm, look for rodent holes or any evidence of water piping through the dam or berm.	Rodents destroyed and dam or berm repaired. Contact the Thurston County Public Health and Social Services Department for guidance.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M			Insects	When insects such as wasps and hornets interfere with maintenance activities, or when mosquitoes become a nuisance.	Insects destroyed or removed from site. Contact Cooperative Extension Service for guidance.
A			Tree Growth	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, or equipment movements). If trees are not interfering with access, leave trees alone.	Trees do not hinder maintenance activities. Selectively cultivate trees such as alders for firewood. Remove species that are not part of recorded planting plan.
M	Side Slopes of Pond		Erosion on berms or at entrance/exit	Check around inlets and outlets for signs of erosion. Check berms for signs of sliding or settling. Action is needed where eroded damage over 2 inches deep and where there is potential for continued erosion.	Find causes of erosion and eliminate them. Then slopes should be stabilized by using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
M	Storage Area		Sediment buildup in pond	Accumulated sediment that exceeds 10 percent of the designed pond depth. Buried or partially buried outlet structure probably indicates significant sediment deposits.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
A	Pond Dikes		Settlements	Any part of dike which has settled 4 inches lower than the design elevation.	Dike is built back to the design elevation.
A	Emergency Overflow/ Spillway		Rock Missing	Only one layer of rock exists above native soil in area 5 square feet or larger, or any exposure of native soil.	Replace rocks to design standards.
A	Wet Pond		Permanent Water Volume	Check that pond has a permanent water volume and does not drain between storm events.	A permanent water volume is necessary to provide water quality treatment. If no water volume, pond lining needs to be evaluated.
One time	Emergency Overflow/ Spillway		Overflow Missing	Side of pond has no area with large rocks to handle emergency overflows.	Contact County for guidance.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-3B. Maintenance Checklist for Stormwater Wetland (BMP WP.01)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M,S	General		Trash and Debris buildup in pond or wetland.	Dumping of yard wastes such as grass clippings and branches into basin. Unsightly accumulation of non-degradable materials such as glass, plastic, metal, foam, and coated paper.	Remove trash and debris and dispose as prescribed by Thurston County Department of Resource Stewardship.
M,S			Trash rack plugged or missing	Bar screen over outlet more than 25% covered by debris or missing.	Replace screen. Remove trash and debris and dispose as prescribed by City Waste Management Section.
M			Poisonous Vegetation	Any poisonous vegetation which may constitute a hazard to the public. Examples of poisonous vegetation include: tansy ragwort, poison oak, poison ivy, stinging nettles, devilsclub.	Remove poisonous vegetation. Do not spray chemicals on vegetation without obtaining guidance from the County. Contact Thurston County Noxious Weeds program.
M,S			Fire hazard or pollution	Presence of chemicals such as natural gas, oil, and gasoline, obnoxious color, odor, or sludge noted.	Find sources of pollution and eliminate them. Water is free from noticeable color, odor, or contamination.
M			Vegetation not growing or is overgrown	Plants are sparse or invasive species are present.	Hand-plant nursery-grown wetland plants in baser areas. Contact the Thurston County Noxious Weed program for direction on invasive species such as purple loosestrife and reed canary grass. Pond bottoms shall have uniform dense coverage of desired plant species.
M			Rodent Holes	If the facility is constructed with a dam or berm, look for rodent holes or any evidence of water piping through the dam or berm.	Rodents destroyed and dam or berm repaired. Contact the Thurston County Public Health and Social Services Department for guidance.
M			Insects	When insects such as wasps and hornets interfere with maintenance activities, or when mosquitoes become a nuisance.	Insects destroyed or removed from site. Contact Cooperative Extension Service for guidance.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A			Tree Growth	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, or equipment movements). If trees are not interfering with access, leave trees alone.	Trees do not hinder maintenance activities. Selectively cultivate trees such as alders for firewood. Remove species that are not part of recorded planting plan.
M	Side Slopes of Pond		Erosion on berms or at entrance/exit	Check around inlets and outlets for signs of erosion. Check berms for signs of sliding or settling. Action is needed where eroded damage over 2 inches deep and where there is potential for continued erosion.	Find causes of erosion and eliminate them. Then slopes should be stabilized by using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
A	Internal berm or embankment		Settlements	Any part of dike which has settled 4 inches lower than the design elevation.	Dike is built back to the design elevation.
			Irregular surface on internal berm	Top of berm not uniform and level.	Top of berm graded flat to design elevation.
A	Emergency Overflow/ Spillway		Rock Missing	Only one layer of rock exists above native soil in area 5 square feet or larger, or any exposure of native soil.	Replace rocks to design standards.
One time			Overflow Missing	Side of pond has no area with large rocks to handle emergency overflows.	Contact County for guidance.
A	Pond Areas		Sediment accumulation (first cell / forebay)	Sediment accumulations in pond bottom that exceeds the depth of sediment storage (1 foot) plus 6 inches.	Sediment storage contains no sediment.
A			Sediment accumulation (wetland cell)	Accumulated sediment that exceeds 10% of the designed pond depth.	Sediment cleaned out to designed pond shape and depth.
A			Liner damaged (if applicable)	Liner is visible or pond does not hold water as designed.	Liner repaired or replaced.
A			Water level (first cell / forebay)	Cell does not hold 3 feet of water year round.	3 feet of water retained year round.
A			Water level (wetland cell)	Cell does not retain water for at least 10 months of the year or wetland plants are not surviving.	Water retained at least 10 months of the year or wetland plants are surviving.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A			Algae mats (first cell / forebay)	Algae mats develop over more than 10% of the water surface should be removed.	Algae mats removed (usually in the late summer before Fall rains.
A			Vegetation	Vegetation dead, dying, or overgrown (cattails) or not meeting original planting specifications.	Plants in wetland cell surviving and not interfering with wetland function.
A	Gravity Drain		Inoperable valve	Valve will not open and close	Valve opens and closes normally.
A			Valve won't seal	Valve does not seal completely.	Valve completely seals closed.
A	Inlet/Outlet pipe		Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
A			Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
A			Damaged	Cracks wider than ½ inch at the joint of the inlet / outlet pipe or any evidence of soil entering at the joints of the inlet / outlet pipes.	No cracks more than ¼ inch wide at the joint of the inlet/outlet pipe.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-4. Maintenance Checklist for Infiltration Basins (BMP IN.01), Infiltration Trenches (BMP IN.02), and Bioinfiltration Swale (BMP IN.03)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M,S	General		Trash and Debris buildup in pond	Dumping of yard wastes such as grass clippings and branches into basin. Unsightly accumulation of non-degradable materials such as glass, plastic, metal, foam, and coated paper.	Remove trash and debris and dispose as prescribed by Thurston County Department of Resource Stewardship.
M			Poisonous Vegetation	Any poisonous vegetation which may constitute a hazard to the public. Examples of poisonous vegetation include: tansy ragwort, poison oak, stinging nettles, devilsclub.	Remove poisonous vegetation. Do not spray chemicals on vegetation without obtaining guidance from the County.
A			Tree Growth	Tree growth in pond or swale bottoms, side slopes and maintenance access areas.	Trees removed from facility bottom, side slopes and maintenance access areas. Remove species that are not part of recorded planting plan.
M,S			Fire Hazard or Pollution	Presence of chemicals such as natural gas, oil, and gasoline, obnoxious color, odor, or sludge noted.	Find sources of pollution and eliminate them. Water is free from noticeable color, odor, or contamination.
M			Vegetation not growing or is overgrown	Grass cover is sparse and weedy or is overgrown. Plants are sparse or invasive species are present.	Selectively thatch, aerate, and reseed ponds. Grass cutting unnecessary unless dictated by aesthetics. Contact the Thurston County Noxious Weed program for direction on invasive species such as purple loosestrife and reed canary grass. Pond bottoms shall have uniform dense coverage of desired plant species.
M			Rodent Holes	If the facility is constructed with a dam or berm, look for rodent holes or any evidence of water piping through the dam or berm.	Rodents destroyed and dam or berm repaired. Contact the Thurston County Public Health and Social Services Department for guidance.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M			Insects	When insects such as wasps and hornets interfere with maintenance activities, or when mosquitoes become a nuisance.	Insects destroyed or removed from site. Contact Cooperative Extension Service for guidance.
A	Storage Area		Sediment buildup in system	A soil texture test indicates facility is not working at its designed capabilities or was incorrectly designed.	Sediment is removed and/or facility is cleaned so that infiltration system works according to design. A sediment trapping area is installed to reduce sediment transport into infiltration area.
A			Storage area drains slowly (more than 48 hours) or overflows	A soil texture test indicates facility is not working at its designed capabilities or was incorrectly designed.	Additional volume is added through excavation to provide needed storage. Soil is aerated and rototilled to improve drainage. Contact the County for information on its requirements regarding excavation.
M			Sediment trapping area	Any sediment and debris filling area to 10 percent of depth from sump bottom to bottom of outlet pipe or obstructing flow into the connector pipe.	Clean out sump to design depth.
One time			Sediment trapping area not present	Stormwater enters infiltration area directly without treatment.	Add a trapping area by constructing a sump for settling of solids. Segregate settling area from rest of facility. Contact County for more guidance.
M	Rock filters		Sediment and debris	By visual inspection little or no water flows through filter during heavy rain storms.	Replace gravel in rock filter.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-5. Maintenance Checklist for Media Filter Drain (BMP MF.04)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	No Vegetation Zone adjacent to pavement		Erosion, Scour, or Vehicular Damage	No vegetation zone uneven or clogged so that flows are not uniformly distributed.	Level the area and clean so that flows are spread evenly.
M			Sediment Accumulation on Edge of Pavement	Flows no longer sheeting off of roadway. Sediment accumulation on pavement edge exceeds top of pavement elevation.	Remove sediment deposits such that flows can sheet off of roadway.
M	Vegetated Filter		Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through Media Filter Drain.
M			Excessive Vegetation or Undesirable Species	When the grass becomes excessively tall; when nuisance weeds and other vegetation starts to take over or shades out desirable vegetation growth characteristics.	Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height that encourages dense even herbaceous growth.
M			Erosion, Scour, or Vehicular Damage	Eroded or scoured areas due to flow channelization, high flows or vehicular damage.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with suitable topsoil. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re- seeded. For smaller bare areas, overseed when bare spots are evident.
M	Media Bed		Erosion, Scour, or Vehicular Damage	Eroded or scoured areas due to flow channelization, high flows or vehicular damage.	For ruts or areas less than 12 inches wide, repair the damaged area by filling with suitable media. If bare areas are large, generally greater than 12 inches wide, the media bed should be re-graded.
M			Sediment Accumulation on Media Bed	Sediment depth inhibits free infiltration of water.	Remove sediment deposits, re-level so slope is even and flows pass freely through Media Bed.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	Underdrains		Sediment	Depth of sediment within perforated pipe exceeds 1/2 inch.	Flush underdrains through access ports and collect flushed sediment.
M	General		Trash and Debris Accumulation	Trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one 32 gallon garbage can). In general, there should be no visual evidence of dumping. If less than threshold all trash and debris will be removed as part of next scheduled maintenance.	Remove trash and debris.
M			Flows are Bypassing Media Filter Drain	Evidence of significant flows downslope (rills, sediment, vegetation damage, etc.) of Media Filter Drain.	Remove sediment deposits, re-level so slope is even and flows pass evenly through Media Filter Drain. If Media Filter Drain is completely clogged it may require a more extensive repair or replacement.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-6. Maintenance Checklist for Sand Filter Basins (BMP MF.01)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Sediment Accumulation on top layer	Sediment depth exceeds 1/2 inch.	No sediment deposit on grass layer of sand filter that would impede permeability of the filter section.
M			Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	Trash and debris removed from sand filter bed.
M			Sediment/ Debris in Clean-Outs	When the clean-outs become full or partially plugged with sediment and/or debris.	Sediment removed from clean-outs.
M			Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24 hours, and/or flow through the overflow pipes occurs frequently.	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material). Other options include removal of thatch, aerating the filter surface, tilling the filter surface, replacing the top 4 inches of filter media, and inspecting geotextiles for clogging.
M			Prolonged Flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities (consider 4-8 hour drawdown tests).	Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.
M			Short Circuiting	Drawdown greater than 12 inches per hour. When flows become concentrated over one section of the sand filter rather than dispersed (consider 4-8 hour drawdown tests).	Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M			Erosion Damage to Slopes	Erosion over 2 inches deep where cause of damage is prevalent or potential for continued erosion is evident.	Slopes stabilized using proper erosion control measures.
A			Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
M			Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter. Rills and gullies on the surface of the filter can indicate improper function of the inlet flow spreader.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.
M			Damaged Pipes	Any part of the piping that is crushed or deformed more than 20 percent or any other failure to the piping.	Pipe repaired or replaced.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-7. Maintenance Checklist for Sand Filter Vault (BMP MF.02) and Linear Sand Filter (MF.03)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	Below Ground Vault		Sediment Accumulation on Sand Media Section	Sediment depth exceeds 1/2 inch.	No sediment deposits on sand filter section that which would impede permeability of the filter section.
M	Below Ground Vault		Sediment Accumulation in Presettling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment deposits in first chamber of vault.
M	Below Ground Vault		Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
M	Below Ground Vault		Sediment in Drain Pipes/Cleanouts	When drain pipes, cleanouts become full with sediment and/or debris.	Sediment and debris removed.
M	Below Ground Vault		Clogged Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, and/or flow through the overflow pipes occurs frequently (consider 4-8 hour drawdown tests).	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material). Other options include removal of thatch, aerating the filter surface, tilling the filter surface, and replacing the top 4 inches of filter media.
M	Below Ground Vault		Short Circuiting	Drawdown greater than 12 inches per hour. When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area (consider 4-8 hour drawdown tests).	Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.
A	Below Ground Vault		Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
M	Below Ground Vault		Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	Below Ground Vault		Ventilation	Ventilation area blocked or plugged	Blocking material removed or cleared from ventilation area. A specified percentage of the vault surface area must provide ventilation to the vault interior (see design specifications).
A	Below Ground Vault		Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover. Maintenance person cannot remove cover using normal lifting pressure.	Cover repaired to proper working specifications or replaced.
A	Below Ground Vault		Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab.	Cracks wider than 1/2 inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
A	Below Ground Vault		Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab.	Cracks wider than 1/2 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4 inch at the joint of the inlet/outlet pipe.
A	Below Ground Vault		Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
A	Below Ground Vault		Access Ladder	Damaged ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Sand filter vaults are confined spaces. Visual inspections should be performed aboveground. If entry is required it should be performed by qualified personnel.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-8. Maintenance Checklist for Compost Amended Soil for Post-Construction Soil Quality and Depth (BMP LID.02) and Compost-Amended Vegetated Filter Strip (BMP BF.06)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A	General		Soil media (maintain high organic soil content	Vegetation not fully covering ground surface.	Re-mulch landscape beds with 2-3 inches of mulch until the vegetation fully closes over the ground surface
Ongoing				None. Preventative maintenance.	Return leaf fall and shredded woody materials from the landscape to the site as mulch.
Ongoing				None. Preventative maintenance.	On turf areas, “grasscycle” (mulch-mow or leave the clippings) to build turf health
Ongoing				None. Preventative maintenance.	Avoiding broadcast use of pesticides (bug and weed killers) like “weed & feed,” which damage the soil life.
A				None. Preventative maintenance.	Where fertilization is needed (mainly turf and annual flower beds), a moderate fertilization program which relies on natural organic fertilizers (like compost) or slow release synthetic balanced fertilizers.
A			Compaction	Soils become waterlogged, do not appear to be infiltrating.	To remediate, aerate soil, till or further amend soil. If drainage is still slow, consider investigating alternative causes (e.g., high wet-season groundwater levels, low permeability soils). Also consider land use and protection from compacting activities. If areas are turf, aerate compacted areas and top dress them with 1/4 to 1/2 inch of compost to renovate them.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A			Erosion/scouring	Areas of potential erosion are visible.	Take steps to repair or prevent erosion. Identify and address the causes of erosion.
A			Grass/vegetation	Less than 75% of planted vegetation is healthy with a generally good appearance.	Take appropriate maintenance actions (e.g., remove/replace plants)
M			Noxious weeds	Listed noxious vegetation is present. See Pierce County noxious weed list.	By law, noxious weeds must be removed and disposed immediately. It is strongly encouraged that herbicides and pesticides not be used in order to protect water quality.
Q			Weeds	Weeds are present.	Remove and dispose of weed material. It is strongly encouraged that herbicides and pesticides not be used in order to protect water quality.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms.
Q = Quarterly

Table C-9. Maintenance Checklist for Basic Biofiltration Swales (BF.01) and Continuous Inflow Biofiltration Swales (BF.03)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Sediment Accumulation on Grass	Sediment depth exceeds 2 Inches or inhibits vegetation growth in 10 percent or more of swale.	Remove sediment deposits on grass treatment area of the bioswale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased.
M	General		Standing Water	When water stands in the swale between storms and does not drain freely.	Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains or convert to a wet biofiltration swale.
M	General		Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
M	General		Constant Baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom.	Add a low-flow pea-gravel drain the length of the swale or by-pass the baseflow around the swale.
M	General		Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10 percent of the swale bottom.	Determine why grass growth is poor and correct that condition. Re-plant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. Or re-seed into loosened, fertile soil.
M	General		Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and other vegetation starts to take over.	Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
A			Vegetation	Trees growing in swale bottom or side slopes. Other invasive vegetation interfering with function of swale (scot's bloom).	Trees removed from swale bottom and slopes. Trees removed that are not part of planting plan. Invasive plants removed.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Excessive Shading	Grass growth is poor because sunlight does not reach swale.	If possible, trim back over-hanging limbs and remove brushy vegetation on adjacent slopes.
M	General		Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
M	General		Trash and Debris Accumulation	Trash and debris accumulated in the bioswale.	Remove leaves, litter, and oily materials, and re-seed or resod, and regrade, as needed. Clean curb cuts and level spreaders as needed.
M	General		Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-10. Maintenance Checklist for Wet Biofiltration Swales

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Sediment Accumulation	Sediment depth exceeds 2 inches in 10 percent of the swale treatment area.	Remove sediment deposits in treatment area.
M			Water Depth	Water not retained to a depth of about 4 inches during the wet season.	Build up or repair outlet berm so that water is retained in the wet swale.
M			Wetland Vegetation	Vegetation becomes sparse and does not provide adequate filtration, OR vegetation is crowded out by very dense clumps of cattail, which do not allow water to flow through the clumps.	Determine cause of lack of vigor of vegetation and correct. Replant as needed. For excessive cattail growth, cut cattail shoots back and compost offsite. Note: normally wetland vegetation does not need to be harvested unless die-back is causing oxygen depletion in downstream waters.
M			Inlet/Outlet	Inlet/outlet area clogged with sediment and/or debris.	Remove clogging or blockage in the inlet and outlet areas.
M			Trash and Debris Accumulation	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one 32 gallon garbage can). In general, there should be no visual evidence of dumping. If less than threshold all trash and debris will be removed as part of next scheduled maintenance.	Remove trash and debris from wet swale.
M			Erosion/ Scouring	Swale has eroded or scoured due to flow channelization, or higher flows.	Check design flows to assure swale is large enough to handle flows. By-pass excess flows or enlarge swale. Replant eroded areas with fibrous-rooted plants such as Juncus effusus (soft rush) in wet areas or snowberry (*Symphoricarpos albus*) in dryer areas.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-11. Maintenance Checklist for Basic Filter Strip (BMP BF.04) and Narrow Area Filter Strip (BMP BF.05)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through strip.
M	General		Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and other vegetation starts to take over.	Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height between 3-4 inches.
A			Trees	Trees growing in swale bottom or side slopes.	Trees removed from swale bottom and slopes. Trees removed that are not part of planting plan.
M	General		Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	Remove trash and Debris from filter.
M	General		Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re- seeded. For smaller bare areas, overseed when bare spots are evident.
M	General		Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-12. Maintenance Checklist for Control Structure/ Flow Restrictor (Structure that Controls Rate at which Water Exits Facility)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	Structure		Trash & debris (includes sediment)	Distance between debris buildup and bottom of orifice plate is less than 1-1/2 feet.	All trash and debris removed.
A			Structural damage	Structure is not securely attached to manhole wall and outlet pipe structure should support at least 1,000 pounds of up or down pressure.	Structure securely attached to wall and outlet pipe.
A				Structure is not upright position (allow up to 10% from plumb).	Structure in correct position.
A				Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are watertight; structure repaired or replaced and works as designed.
M				Any holes – other than designed holes – in the structure.	Structure has no holes other than designed holes.
M,S	Cleanout gate		Damaged or missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
A				Gate cannot be moved up and down by one maintenance person.	
M,S				Chain leading to gate is missing or damaged.	
A				Gate is rusted over 50% of its surface.	
M,S			Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	
M,S	Overflow pipe		Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-13. Maintenance Checklist for Catch Basins and Inlets

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M,S	General		Trash and Debris	Trash, debris, and sediment in or on basin	No trash or debris located immediately in front of catch basin opening. Grate is kept clean and allows water to enter.
M				Sediment or debris (in the basin) that exceeds 1/3 the depth (1-ft minimum storage remaining) from the bottom of basin to invert of the lowest pipe into or out of the basin.	No sediment or debris in the catch basin. Catch basin is dug out and clean.
M,S				Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.	Inlet and outlet pipes free of trash or debris.
M			Structural Damage to Frame and/or Top Slab	Corner of frame extends more than 3/4 inch past curb face into the street (if applicable).	Frame is even with curb.
M				Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (intent is to make sure no material is running into basin).	Top slab is free of holes and cracks.
M				Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached.	Frame is sitting flush on the riser rings or top slab and firmly attached.
A			Cracks in Basin Walls/ Bottom	Cracks wider than 1/2 inch and longer than 3 feet, any evidence of soil particles entering catch basin through cracks, or maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards. Contact a professional engineer for evaluation.
A				Cracks wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	No cracks more than 1/4 inch wide at the joint of inlet/outlet pipe.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A			Settlement/ Misalignment	Basin has settled more than 1 inch or has rotated more than 2 inches out of alignment.	Basin replaced or repaired to design standards. Contact a professional engineer for evaluation.
A			Illicit discharges to Catch Basin	Look for connections from adjacent businesses, residences that are not part of drainage plan. If detected identify source of connection and notify Thurston County.	No connections to Catch Basins are allowed that are not part of the approved plans or authorized by permit from Thurston County.
M			Vegetation	Vegetation growing across and blocking more than 10 percent of the basin opening.	No vegetation blocking opening to basin.
M			Vegetation	Vegetation growing in inlet/outlet pipe joints that is more than 6 inches tall and less than 6 inches apart.	No vegetation or root growth present.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-14. Maintenance Checklist for Energy Dissipators

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A	Rock pad		Missing or moved rock	Only one layer of rock exists above native soil in area 5 square feet or larger, or any exposure of native soil.	Replace rocks to design standard.
A	Rock pad		Vegetation	Vegetation growth in and around dispersion pad area prevents proper inspection or interferes with flows.	Remove vegetation growth and plants that are not part of approved planting plan.
A	Rock-filled trench for discharge from pond		Missing or moved rock	Trench is not full of rock.	Add large rock (~30 lbs each) so that rock is visible above edge of trench.
M	Dispersion trench		Pipe plugged with sediment	Accumulated sediment that exceeds 20% of the design depth.	Pipe cleaned/flushed.
M			Perforations plugged	Over 1/2 of perforations in pipe are plugged with debris and sediment.	Clean or replace perforated pipe.
M,S			Not discharging water properly	Visual evidence of water discharging at concentrated points along trench (under normal conditions, there should be a “sheet flow” of water along trench.) Intent is to prevent erosion damage.	Trench must be rebuilt or redesigned to standards. Pipe is provably plugged or damaged and needs replacement.
M,S			Water flows out top of “distributor” catch basin	Maintenance person observes water flowing out during any storm less than the design storm or it is causing or appears likely to cause damage.	Facility must be rebuilt or redesigned to standards. Pipe is probably plugged or damaged and needs replacement.
M,S			Receiving area over-saturated	Water in receiving area is causing or has potential of causing landslide.	Stabilize slope with grass or other vegetation, or rock if condition is severe.
A	Gabions		Damaged mesh	Mesh of gabion broken, twisted or deformed so structure is weakened or rock may fall out.	Mesh is intact, no rock missing.
A			Corrosion	Gabion mesh shows corrosion through more than ¼ of its gage	All gabion mesh capable of containing rock and retaining designed form.
A			Collapsed or deformed baskets	Gabion basket shape deformed due to any cause.	All gabion baskets intact, structure stands as designed.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A			Missing rock	Any rock missing that could cause gabion to loose structural integrity	No rock missing.
A	Manhole/Chamber		Worn or damaged post, baffles or side of chamber	Structure dissipating flow deteriorates to ½ of original size or any concentrated worn spot exceeding one square foot which would make structure unsound.	Structure is in no danger of failing.
A			Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½-inch or any evidence of soil entering the structure through cracks. Or maintenance inspection personnel determine that the structure is not structurally sound.	Manhole/chamber is sealed and structurally sound.
A			Damaged pipe joints.	Cracks wider than ½-inch at the joint of the inlet/outlet pipes or any evidence of soil entering the structure at the joint of the inlet/outlet pipes.	No soil or water enters and no water discharges at the joint of inlet/outlet pipes.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-15. Maintenance Checklist for Fencing

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Missing or broken parts/dead shrubbery	Any defect in the fence or screen that permits easy entry to a facility.	Fence is mended or shrubs replaced to form a solid barrier to entry.
M,S			Erosion	Erosion has resulted in an opening under a fence that allows entry by people or pets.	Replace soil under fence so that no opening exceeds 4 inches in height.
M			Unruly Vegetation	Shrubbery is growing out of control or is infested with weeds.	Shrubbery is trimmed and weeded to provide appealing aesthetics. Do not use chemicals to control weeds.
A	Wire Fences		Damaged Parts	Posts out of plumb more than 6 inches.	Posts plumb to within 1.5 inches of plumb.
A				Top rails bent more than 6 inches.	Top rail free of bends greater than 1 inch.
A				Any part of fence (including posts, top rails, and fabric) more than 1 foot out of design alignment.	Fence is aligned and meets design standards.
A				Missing or loose tension wire.	Tension wire in place and holding fabric.
A				Missing or loose barbed wire that is sagging more than 2.5 inches between posts.	Barbed wire in place with less than 3/4 inch sag between posts.
A				Extension arm missing, broken, or bent out of shape more than 1.5 inches.	Extension arm in place with no bends larger than 3/4 inch.
A			Deteriorated Paint or Protective Coating	Part or parts that have a rusting or scaling condition that has affected structural adequacy.	Structurally adequate posts or parts with a uniform protective coating.
M			Openings in Fabric	Openings in fabric are such that an 8-inch diameter ball could fit through.	No openings in fabric.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-16. Maintenance Checklist for Gates

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Damaged or Missing Components	Gate is broken, jammed, or missing.	Pond has a functioning gate to allow entry of people and maintenance equipment such as mowers and backhoe. If a lock is used, make sure the county field staff have a key.
M				Broken or missing hinges such that gate cannot be easily opened and closed by one maintenance person.	Hinges intact and lubed. Gate is working freely.
A				Gate is out of plumb more than 6 inches and more than 1 foot out of design alignment.	Gate is aligned and vertical.
A				Missing stretcher bar, stretcher bands, and ties.	Stretcher bar, bands, and ties in place.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-17. Maintenance Checklist for Access Roads/Easements

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
One Time	General		No access road exists	If ponds or other drainage system features needing maintenance by motorized equipment are present, either an access road or access from public streets is required.	Determine whether an easement to drainage feature exists. If yes, obtain County permits and construct gravel (or equal) access road. If not report lack of easement to County attention.
M			Block roadway	Debris which could damage vehicle tires (glass or metal)	Roadway free of debris which could damage tires.
A				Any obstructions which reduce clearance above road surface to less than 14 feet.	Roadway overhead clear to 14 feet high.
A				Any obstructions restricting access to less than 15 feet width.	Obstruction removed to allow at least a 15 foot wide access.
A	Easement Markers		Easement Not Clearly Identified	Check that easement markers are in place identifying limits of easement	Easement markers installed at 100-ft intervals and changes in direction along easement lines.
A,S	Road surface		Settlement, potholes, mush spots, ruts	When any surface exceeds 6-inches in depth and 6 square feet in area. In general, any surface defect which hinders or prevents maintenance access.	Road surface uniformly smooth with no evidence of settlement, potholes, mush spots, or ruts. Occasionally application of additional gravel or pit run rock will be needed.
M			Vegetation in road surface	Woody growth that could block vehicular access. Excessive weed cover.	Remove woody growth at early stage to prevent blockage. Cut back weeds if they begin to encroach on road surface.
M,S	Shoulders and ditches		Erosion damage	Erosion within 1 foot of the roadway more than 8 inches wide and 6 inches deep	Shoulder free of erosion and matching the surrounding road.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

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Table C-18. Conveyance Pipes and Ditches

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M,S	Pipes		Sediment & Debris	Accumulated sediment that exceeds 20% of the diameter of the pipe.	Pipe cleaned of all sediment and debris.
M			Vegetation	Vegetation that reduces free movement of water through pipes.	All vegetation removed so water flows freely through pipes.
A			Damaged (rusted, bent, or crushed)	Protective coating is damaged, rust is causing more than 50% deterioration to any part of pipe.	Pipe repaired or replaced.
M				Any dent that significantly impedes flow (i.e. decreases the cross section area of pipe by more than 20%)	Pipe repaired or replaced
M				Pipe has major cracks or tears allowing groundwater leakage.	Pipe repaired or replaced.
M,S	Open ditches		Trash & debris	Dumping of yard wastes such as grass clippings and branches into basin. Unsightly accumulation of non-degradable materials such as glass, plastic, metal, foam and coated paper.	Remove trash and debris and dispose as prescribed by solid waste regulations.
M			Sediment buildup	Accumulated sediment that exceeds 20% of the design depth.	Ditch cleared of all sediment and debris so that it matches design.
A			Vegetation	Vegetation (e.g. weedy shrubs or saplings) that reduces free movements of water through ditches.	Water flows freely through ditches. Grass vegetation should be left alone.
M			Erosion on	Check around inlets and outlets for signs of erosion. Check berms for signs of sliding or settling. Action is needed where eroded damage over 2 inches deep and where there is potential for continued erosion.	Find causes of erosion and eliminate them. Then slopes should be stabilized by using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
A			Rock lining out of place or missing (if applicable)	Maintenance person can see native soil beneath the rock lining.	Replace rocks to design standard.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
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Table C-19. Debris Barriers (E.G. Trash Racks)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M,S	Site		Trash and debris	Trash and debris plugging more than 20% of the area of the barrier.	Barrier clear to receive capacity flow.
A			Sediment accumulation	Sediment accumulation of greater than 20% of the area of the barrier	Barrier clear to receive capacity flow
A	Structure		Cracked, broken or loose	Structure with bars attached to is damaged – pipe is loose or cracked or concrete structure is cracked, broken or loose.	Structure barrier attached to is sound.
A	Bars		Bar spacing	Bar spacing exceeds 6-inches	Bars have at most 6-inches spacing
A			Damaged or missing bars	Bars are bent out of shape more than 3 inches.	Bars in place with no bends more than ¾ inch.
A				Bars are missing or entire barrier missing.	Bars in place according to design.
A				Bars are loose and rust is causing 50% deterioration to any part of barrier.	Repair or replace barrier to design standards.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-20. Maintenance Checklist for Grounds (Landscaping)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Weeds (non poinsonous)	Weeds growing in more than 20% of the landscaped area (trees and shrubs only)	Weeds present in less than 5% of the landscaped area.
M			Safety hazard	Any presence of poison ivy, poison oak or other poisonous vegetation or insect nests.	No poisonous vegetation or inspect nests present in landscaped area.
M,S			Trash or litter	Trash/debris exceeds 5 cubic feet (this is about equal to the amount of trash in one standard garbage can) per 1,000 square feet. In general there should be no evidence of visual dumping.	Remove/dispose of waste in accordance with solid waste regulations.
M,S			Erosion of ground surface	Noticeable rills are seen in landscaped areas.	Causes of erosion are identified and steps taken to slow down/spread out the water. Eroded areas are filled, contoured, and seeded.
A	Trees and shrubs		Damage	Limbs or parts of trees or shrubs that are split or broken which affect more than 25% of the total foliage of the tree or shrub.	Trim trees/shrubs to restore shape. Replace trees/shrubs with severe damage.
M				Tree or shrubs that have been blown down or knocked over.	Replant tree, inspecting for injury to stem or roots. Replace if severely damaged.
A				Tree or shrubs which are not adequately supported or are leaning over, causing exposure of the roots.	Place stakes and rubber-coated ties around young trees/shrubs for support.
M,S	Shoulders and ditches		Erosion damage	Erosion within 1 foot of the roadway more than 8 inches wide and 6 inches deep	Shoulder free of erosion and matching the surrounding road.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
S = After major storms

Table C-21. Maintenance Checklist for Dispersion BMPs (BMP LID.05,06,07,11,12,13)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	General		Vegetation management	Any presence invasive plants, poison ivy, poison oak or other poisonous vegetation or insect nests.	No poisonous vegetation or inspect nests present in landscaped area.
M			Disturbance	Area designated for dispersion is no encroached upon vegetation is healthy and functioning.	Restore disturbed native vegetation areas (see BMP LID.01). Remove encroachments.
M,S			Trash or litter	In general there should be no evidence of visual dumping.	Remove/dispose of waste in accordance with solid waste regulations.
M,S			Erosion of ground surface	Noticeable rills or channeling is seen in dispersion areas.	Causes of erosion are identified and steps taken to slow down/spread out the water. Eroded areas are filled, contoured, and seeded.
A	Drainage		Bypass flow	Dispersed flow concentrates and isn't spread evening through dispersion area.	No evidence of dispersed flow bypassing dispersion area.
M			Inlets & Outlets	Dispersion pads and spreaders functioning correctly. See outfall maintenance checklist.	Dispersion device functions as designed.
A	Controls		Signage & fencing	Signs removed, fencing damaged or missing.	Restore fencing & signage per design.
M,S	Sedimentation		Sediment buildup	Sediment buildup around outlet of dispersion device.	Hand remove sediment buildup and replant disturbed area.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

Key:
A = Annual (March or April preferred)
M = Monthly (see schedule)
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Table C-22. Maintenance Checklist for Vegetated Roof (BMP LID.10)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A	Soil/Growth Medium		Growth Medium	Water does not permeate growth media (runs off surface)	Aerate or replace media
M			Fallen leaves/ debris	Fallen leaves or debris are present.	Remove/dispose.
M,S			Erosion/scouring	Areas of potential erosion are visible.	Take steps to repair or prevent erosion. Stabilize with additional soil substrate growth medium and additional plants.
A	System Structural Components		General	Structural components are present.	Inspect structural components for deterioration or failure. Repair/replace as necessary.
M			Inlet Pipe	Sediment, vegetation, or debris blocks 35% or more of inlet structure.	Clear blockage, identify and correct any problems that led to blockage.
M				Inlet pipe is in poor condition.	Repair/replace
M				Inlet pipe is clogged	Remove roots or debris.
A	Vegetation		Coverage	Vegetative coverage falls below 75% (unless design specifications stipulate less than 75% coverage)	Install more vegetation.
M			Noxious weeds	Listed noxious vegetation is present. See Thurston County noxious weed list.	By law, noxious weeds must be removed and disposed of immediately. Herbicides and pesticides shall not be used in order to protect water quality.
M			Weeds	Weeds are present	Remove and dispose of weed material. Herbicides and pesticides shall not be used in order to protect water quality.
A			Plants	Dead vegetation is present	Remove dead vegetation when covering greater than 10% of basin area. Replace dead vegetation annually or immediately if necessary to control erosion.
Startup	Irrigation		Irrigation system (if any)	Irrigation system present.	Follow manufacturer's instructions for O&M
Weekly at startup			Plant watering	Plant establishment period (1-3 years)	Water weekly during periods of no rain to ensure plant establishment.
On-going				Longer term period (3+ years)	Water during drought conditions or more often if necessary to maintain plant cover.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
As needed	Spill Prevention and Response		Spill prevention	Storage or use of potential contaminants in the vicinity of the facility.	Exercise spill prevention measures whenever handling or storing potential contaminants.
As needed			Spill response	Release of pollutants. Call to report any spill to the Washington Dept. of Emergency Management. 1-800-258-5990	Cleanup spills as soon as possible to prevent contamination of stormwater.
Startup	Training and documentation		Training/written guidance	Training/written guidance is required for proper O&M	Provide property owners and tenants with proper training and a copy of the O&M Manual and Maintenance Plan.
On-going	Safety		Access and Safety	Egress and ingress routes	Maintain egress and ingress routes to design standards and fire codes.
M	Aesthetics		Aesthetics	Damage / vandalism / debris accumulation	Restore facility to original aesthetic conditions.
A			Grass / vegetation	Less than 75% of planted vegetation is healthy with a generally good appearance.	Take appropriate maintenance actions (e.g. remove / replace plants, amend soils, etc.)
A	Pest Control		Mosquitoes	Standing water remains for more than three days following a storm	Remove standing water. Identify cause of the standing water and take appropriate action to address the problem (improve drainage).

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

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Table C-23. Porous Pavement (BMP LID.09)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A	Surface		Porous asphalt or cement concrete	Maintenance to prevent clogging with fine sediment.	Use convential street sweepers equipped with vacuums.
Ongoing					Prohibit use of sand and sealant application and protect from construction runoff.
A				Major cracks or trip hazards	Fill with patching mixes. Large cracks and settlement may require cutting and replacing the pavement section.
As required				Utility cuts	Any damage or change due to utility cuts must be replaced in kind.
A			Fallen leaves / debris	Fallen leaves or debris	Remove / dispose
As required			Interlocking concrete paver blocks	Interlocking paving block missing or damaged	Replace paver block
As required				Settlement of surface	May require resetting
A				Sediment or debris accumulation between paver blocks	Remove / dispose.
A				Loss of void material between paver blocks	Refill per manufacturer's recommendations.
On going				Varied conditions	Perform O&M per manufacturer's recommendations.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

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Table C-24. Baffle Oil/Water Separator (BMP OW.01)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	Site		Trash and debris	Any trash or debris which impairs the function of the facility.	Trash and debris removed from facility.
M			Contaminants and pollution	Floating oil in excess of 1 inch in first chamber, any oil in other chambers or other contaminants of any type in any chamber.	No contaminants present other than a surface oil film.
A	Vault treatment area		Sediment accumulation	Sediment accumulation exceeding 6 inches in the vault.	No sediment in the vault.
M			Discharge water not clear.	Inspection of discharge water shows obvious signs of poor water quality – effluent discharge from vault shows thick visible sheen.	Effluent discharge is clear.
A			Trash or debris accumulation	Any trash and debris accumulation in vault (floatables and non-floatables).	Vault is clear of trash and debris.
M			Oil accumulation	Oil accumulations that exceed 1 inch, at the surface of the water in the oil/water separator chamber.	No visible oil depth on water.
A	Vault structure		Damage to wall, frame, bottom and/or top slab.	Cracks wider than ½ inch or evidence of soil particles entering the structure through the cracks, or maintenance / inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications.
A			Baffles damaged	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance inspection personnel.	Repair or replace baffles to specifications.
A	Gravity drain		Inoperable valve	Valve will not open and close	Valve opens and closes normally.
A			Valve won't seal	Valve does not seal completely.	Valve completely seals closed.
A	Inlet/outlet pipe		Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipe clear of sediment.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
A			Trash and debris	Trash and debris accumulated in inlet / outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes.
A			Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes or any evidence of soil entering the joints of the inlet / outlet pipes.	No cracks more thatn ¼ inch wide at the joint of the inlet/outlet pipe.
M	Access manhole		Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open manhole requires immediate maintenance.**	Manhole access covered.
M			Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
M			Cover/lid difficult to remove.	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed an reinstalled by one maintenance person.
A			Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
M	Large access doors / plate		Damaged or difficult to open.	Large access doors or plates cannot be opened / removed using normal equipment.	Replace or repair access door so it can be opened as designed.
M			Gap doesn't cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
M			Lifting Rings missing, rusted.	Lifting rings not capable of lifting weight of door or cover/lid.	Lifting rings sufficient to lift or remove cover/lid.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

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Table C-25. Coalescing Plate Oil/Water Separator (BMP OW.02)

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
M	Site		Trash and debris	Any trash or debris which impairs the function of the facility.	Trash and debris removed from facility.
M			Contaminants and pollution	Floating oil in excess of 1 inch in first chamber, any oil in other chambers or other contaminants of any type in any chamber.	No contaminants present other than a surface oil film.
A	Vault treatment area		Sediment accumulation in forebay	Sediment accumulation exceeding 6 inches in the forebay.	No sediment in the forebay.
M			Discharge water not clear.	Inspection of discharge water shows obvious signs of poor water quality – effluent discharge from vault shows thick visible sheen.	Repair function of plates so effluent is clear.
A			Trash or debris accumulation	Any trash and debris accumulation in vault (floatables and non-floatables).	Vault is clear of trash and debris.
M			Oil accumulation	Oil accumulations that exceed 1 inch, at the surface of the water in the coalescing plate chamber.	No visible oil depth on water and coalescing plates clear of oil.
	Coalescing Plates		Damaged	Plate media broken, deformed, cracked and/or showing signs of failure.	Replace that portion of media pack or entire plate pack depending on severity of failure.
			Sediment accumulation	Any sediment accumulation which interferes with the operation of the coalescing plates.	No sediment accumulation interfering with the coalescing plates.
A	Vault structure		Damage to wall, frame, bottom and/or top slab.	Cracks wider than ½ inch or evidence of soil particles entering the structure through the cracks, or maintenance / inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications.
A			Baffles damaged	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance inspection personnel.	Repair or replace baffles to specifications.

Frequency	Drainage Systems Feature	√	Problem	Conditions to Check For	Conditions that Shall Exist
	Ventilation pipes		Plugged	Any obstruction to the ventilation pipes.	Ventilation pipes are clear.
A	Shutoff valve		Damaged or inoperable	Shutoff valve cannot be opened or closed.	Shutoff valve operates normally.
A	Inlet/outlet pipe		Sediment accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipe clear of sediment.
A			Trash and debris	Trash and debris accumulated in inlet / outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes.
A			Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes or any evidence of soil entering the joints of the inlet / outlet pipes.	No cracks more thatn ¼ inch wide at the joint of the inlet/outlet pipe.
M	Access manhole		Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open manhole requires immediate maintenance.**	Manhole access covered.
M			Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
M			Cover/lid difficult to remove.	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed an reinstalled by one maintenance person.
A			Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
M	Large access doors / plate		Damaged or difficult to open.	Large access doors or plates cannot be opened / removed using normal equipment.	Replace or repair access door so it can be opened as designed.
M			Gaps, doesn't cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
M			Lifting Rings missing, rusted.	Lifting rings not capable of lifting weight of door or cover/lid.	Lifting rings sufficient to lift or remove cover/lid.

If you are unsure whether a problem exists, please contact Thurston County and ask for technical assistance.

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Appendix V-D – Access Roads and Ramps

Access roads provide access from main arterials to inspect or maintain BMPs. They are a critical part of BMP development but also create disturbances complicating facility design and construction. Use this appendix to ensure that safe, proper access is created.

Access ramps allow vactor trucks and other maintenance vehicles to drive into a detention pond or other open facility to remove sediment, inspect underdrain piping and outlets and perform other activities that require access to the bottom of the facility.

On large, deep ponds, truck access to the pond bottom via an access ramp is necessary for loading in the pond bottom. On small, deep ponds, the truck can remain on the ramp for loading. On small shallow ponds, a ramp to the bottom may not be required if the trackhoe can load a truck parked at the pond edge or on the internal berm of a wet pond or combined pond (trackhoes can negotiate interior pond side slopes).

Access Roads

Applicability

Access roads shall provide access to the control structure(s). Where the access road is to provide maintenance to a pond or basin, the access road shall provide access alongside the pond as necessary for vehicular maintenance access to each pond cell.

This appendix applies to the following BMPs:

- BMP IN.04 Infiltration Basins
- BMP D.01 Detention Ponds
- BMP D.02 Detention Tanks
- BMP D.04 Detention Vaults
- BMP WP.02 Wet Ponds
- BMP WP.05 Presettling Basins.

Design Criteria

The design guidelines for access road are given below.

Geometry

- Maximum grade shall be 15 percent.
- Outside turning radius will be a minimum of 40 feet.
- Access roads shall be a minimum of 15 feet in width.

Materials

- A paved apron must be provided where access roads connect to paved public roadways.
- Access roads may be constructed with an asphalt or gravel surface, or modular grid pavement. All surfaces must conform to the jurisdictional standards and manufacturer's specifications.

Fencing

- Vehicle access shall be limited by a double-posted gate if a pond is fenced or by bollards if the pond is not fenced. A minimum of one locking access road gate shall be provided that meets WSDOT Standard Plan L-3. Gates may be 14, 16, 18, or 20 feet in width. Bollards shall consist of two fixed bollards, on the outside of the access road and two removable bollards equally spaced between the fixed bollards (or all four removable if placed in the traveled way). Any fenced pipe stem access to a facility shall be fenced with a WSDOT Type 4 chain link fence with a 14 to 20 foot wide gate set at the same height, or bollards.
- Fence gates shall be located only on straight sections of road.

Site Design Elements

- Maintenance access road(s) will be provided to the control structure and other drainage structures associated with the pond (e.g., inlet or bypass structures).
- It is recommended that manhole and catch basin lids be in or at the edge of the access road and at least three feet from a property line.
- Pond access roads shall be located in the same tracts when the ponds themselves are in tracts. When ponds are located in open space, the pond access roads may be located in open space also, provided that they are constructed so as to be aesthetically compatible with the open space use.
- When the length of a pond access road to control structure or pond exceeds 75 feet, a vehicle turn-around must be provided, designed

to accommodate vehicles having a maximum length of 31 feet and having an inside wheel path radius of 40 feet. Access roads to control structures shall have a maximum slope of 12 percent.

Access Ramps

An access ramp is needed for removal of sediment with a trackhoe and truck.

Applicability

For all ponds cell bottoms which cannot be accessed from the access road by a trackhoe with a maximum reach of 20 feet, an access ramp shall be constructed extending to the bottom of the pond.

Design Criteria

Geometry

- The access ramp shall have a minimum width of 15 feet.
- The maximum grade for the access ramp is 15 percent if paved to access road standard, or 12 percent if constructed of alternate ramp surface (see below).
- The ramp must extend to the pond bottom if the pond bottom is greater than 1,500 square feet (measured without the ramp) and it may end at an elevation 4 feet above the pond bottom, if the pond bottom is less than 1,500 square feet (measured without the ramp).

Materials

An alternate ramp surface can be constructed with a maximum slope of 12 percent by laying a geotextile fabric over the native soil, placing quarry spalls (2”-4”) 6 inches thick, then providing a 2-inch thick crushed rock surface.

Structural Design Considerations

- The internal berm of a wet pond or combined detention and wet pond may be used for access if it is no more than 4 feet above the first wet pool cell, if the first wet pool cell is less than 1,500 square feet (measured without the ramp), and if it is designed to support a loaded truck, considering the berm is normally submerged and saturated.
- Access ramps must meet the requirements for design and construction of access roads specified above.

Appendix V-E – Site Design Elements

This appendix provides guidelines for various BMPs, including fencing requirements, proper signage use, right of way information, setback requirements, landscaping and planting requirements, and guidelines for naturalistic plantings. All of these factors will help provide an overall safe, effective and aesthetically pleasing BMP.

Fencing

Applicability

A fence is required around all public stormwater facility tracts. On private facilities fences need only be constructed for those slopes steeper than 3H:1V, at the emergency overflow water surface elevation, or higher. A fence is also needed where the impoundment is a wall greater than 30 inches in height. Other regulations such as the International Building Code may require fencing of vertical walls. If more than 10 percent of slopes are steeper 3H:1V, it is recommended that the entire pond be fenced.

This section applies to the following BMPs:

- BMP D.01 Detention Ponds
- BMP IN.01 Infiltration Basins
- BMP WP.02 Wet Ponds
- BMP WP.04 Combined Detention/Wet Pool Facilities.

Design Criteria

- Fencing of public drainage ponds shall consist of a minimum 6 foot high WSDOT Type 1 chain link fence, per State Standard Plan L-2. A minimum of one locking access road gate shall be provided that meets WSDOT Standard Plan L-3. Gates may be 14, 16, 18, or 20 feet in width. Fence material shall be No. 9 gauge galvanized steel fabric with bonded vinyl coating. Vinyl coating shall be green or black. All posts, cross bars, fasteners, and gates shall be painted or coated the same color as the vinyl clad fence.
- Any fencing shall be placed 1 foot inside the tract or easement boundary, or a minimum of 5 feet from the top slope catch point.
- Any pipe stem access to a basin shall be fenced with a WSDOT Type 4 chain link fence with a 14-foot gate.
- Pedestrian access gates (if needed) shall be 4 feet in width and meet WSDOT Standard Plan L-3.

- Vertical metal balusters or 9 gauge galvanized steel fabric with bonded vinyl coating can be used as fence material. For steel fabric fences, the following aesthetic features may be considered:
  - Vinyl coating that is compatible with the surrounding environment (e.g., green in open, grassy areas and black or brown in wooded areas). All posts, cross bars, and gates may be painted or coated the same color as the vinyl clad fence fabric.
  - Fence posts and rails that conform to WSDOT Standard Plan L-2 for Types 1, 3, or 4 chain link fence.
- Wood fences may be used in subdivisions where the fence will be maintained by homeowners associations or adjacent lot owners.
- Wood fences shall have pressure treated posts (ground contact rated) either set in 24-inch deep concrete footings or attached to footings by galvanized brackets. Rails and fence boards may be cedar, pressure-treated fir, or hemlock.

Signage

Applicability

Detention ponds, infiltration ponds, wet ponds, and combined ponds shall have a sign with educational information and emergency contact information (Figure E-1). Applicant shall submit sign design and proposed location for Administrator acceptance.

Figure E-1. Informational Sign for Wet Pond in Olympia, Washington.

This section applies to the following BMPs:

- BMP D.01 Detention Ponds
- BMP IN.01 Infiltration Basins
- BMP WP.02 Wet ponds
- BMP WP.04 Combined Detention/Wet pool Facilities.

Design Criteria

Signs shall be placed for maximum visibility from adjacent streets, sidewalks, and paths.

An example of sign specifications for a permanent surface water control pond is provided as follows:

Sample Specifications

Size:	48 inches by 24 inches
Material:	0.125-gauge aluminum
Face:	Non-reflective vinyl or 3 coats outdoor enamel (sprayed).
Lettering:	Silk screen enamel where possible, or vinyl letters.
Colors:	Beige background, teal letters.
Type face:	Helvetica condensed. Title: 3 inch; Sub-Title: 1½ inch; Text: 1 inch; Outer border: 1/8 inch border distance from edge: 1/4 inch; all text 1¾ inch from border.
Posts:	Pressure treated, beveled tops, 1½ inch higher than sign.
Installation:	Secure to chain link fence if available. Otherwise install on two 4"x4" posts, pressure treated, mounted atop gravel bed, installed in 30-inch concrete filled post holes (8-inch minimum diameter). Top of sign no higher than 42 inches from ground surface.
Placement:	Face sign in direction of primary visual or physical access. Do not block any access road. Do not place within 6 feet of structural facilities (e.g., manholes, spillways, pipe inlets).
Special Notes:	This facility is lined to protect groundwater (if a liner that restricts infiltration of stormwater exists).

A sample informational sign is presented in Figure E-1. For Homeowners Associations, the contact can be a residence address or P.O. Box.

Setbacks and Easements

Applicability

This section provides information on setbacks and easements for conveyance systems and stormwater BMPs from Volumes III and V.

Design Criteria

Natural Systems

The easements below apply to the following natural features:

- Stream channels
- Lake shores
- Wetlands
- Potholes
- Estuaries
- Gullies
- Ravines.

All natural systems shall be located within easements. Easements shall contain the natural features and shall allow Thurston County access to them for purposes of inspection, maintenance, flood control, water quality monitoring, and other activities permitted by law.

Conveyance Systems

The setbacks below apply to the following facilities (design criteria are provided in Volume III):

- Channels
- Pipes
- Outfalls.

All man-made drainage facilities and conveyances shall be located within easements. Easements shall contain the facilities and shall allow Thurston County access to them for purposes of inspection, maintenance, flood control, water quality monitoring, and other activities permitted by law.

Easements for Access

A minimum 15-foot wide access easement shall be provided to drainage facilities from a public street or right-of-way. Access easements shall be surfaced with a minimum 12-foot width of lattice block pavement, crushed rock, or other acceptable surface to allow year-round equipment access to the facility. The easement shall include easement boundary markers which shall be fiberglass utility markers with a reflective easement tag, located at each corner of the easement, at angle points and at least every 100-ft along the length of the easement. Contact Thurston County Water Resources for additional information on easement marker requirements.

Easements for Conveyance Systems

See Volume III for required easement widths and other requirements for conveyance systems.

Infiltration Facilities

The setbacks below apply to the following BMPs:

- LID.04 – Downspout Infiltration Systems
- LID.08 – Bioretention Facilities
- IN.01 – Infiltration Basins
- IN.02 – Infiltration Trenches
- IN.03 – Bio-Infiltration Swales
- IN.04 – Infiltration Vaults.

If the depth of the infiltration facility being considered is greater than the largest surface dimension, it is considered an injection well and is subject to the requirements of the Underground Injection Control Program, Chapter 173-218 WAC. See also Volume V, Section 3.1.3.

All infiltration facilities shall maintain minimum setback distances as follows:

Horizontal Clearances

- 10 feet – from open water maximum surface elevation or edge of infiltration facility to property lines and onsite structures
- 50 feet – from top of slopes steeper than 15 percent and greater than 10 feet high. The Administrator or designee may

require a geotechnical report to evaluate whether a slope exceeding 15 percent is a landslide hazard area. Increased setbacks or prohibition of infiltration facilities may result from this report. The geotechnical analysis and report shall address the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

- 10 feet – from open water maximum surface elevation or edge of infiltration facility to building sewer
- 50 feet – from septic tank, holding tank, containment vessel, pump chamber, and distribution box
- 100 feet – from edge of septic drainfield and drainfield reserve area.
- 100 feet – from drinking water wells and springs used for drinking water supplies.
- 300 feet – from landslide hazard area (as defined by Thurston County Code Title 17.15.600 – Geologic Hazard Areas) unless the slope stability impacts of such systems have been analyzed and mitigated by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.
- 100 feet – from building foundation or basement, where infiltration facilities are located upgradient from building. The Project Engineer shall perform calculations to ensure that the line of saturation, measured from the design storm elevation in the facility, at a gradient acceptable to the Administrator or designee, falls a minimum of 1 foot below the lowest floor elevation. Setbacks shall be increased as necessary to allow for saturation effects.
- 20 feet – from building foundation or basement, where infiltration facilities are located downgradient from building. The Project Engineer shall perform calculations to ensure that the line of saturation, measured from the design storm elevation in the facility, at a gradient acceptable to the Administrator or designee, falls a minimum of 1 foot below the

lowest floor elevation. Setbacks shall be increased as necessary to allow for saturation effects.

Vertical Clearances

- 1 foot – vertical clearance from the maximum water surface surface elevation of any open water pond/facility to built structures within 25 feet.

Ponds

The setbacks below apply to the following BMPs:

- D.01 – Detention Pond
- WP.01 – Stormwater Treatment Wetland
- WP.02 – Wet Pond
- WP.04 – Combined Detention/Wet Pool Facilities
- WP.05 – Presettling Basin.

All ponds shall maintain minimum setback distances as follows:

- 1 foot – positive vertical clearance from maximum water surface to structures within 25 feet
- 10 feet – from maximum water surface to property lines and onsite structures
- 10 feet – from maximum water surface to building sewer
- 10 feet – from maximum water level location to nearest tract property boundary lines
- 30 feet – from maximum water surface to septic tank or distribution box
- 30 feet – from maximum water surface to septic drainfields and drainfield reserve areas for single family onsite sewage disposal systems
- 100 feet – from maximum water surface to septic drainfields and drainfield reserve areas for community onsite sewage disposal systems

- 50 feet – from top of slopes steeper than 15 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

- 100 feet – from well to stormwater control and water quality facility, maximum water surface.

In addition, all underground stormwater facilities without infiltration (BMP D.02, D.03, WP.03, MF.02, MF.03, MF.05) shall be setback from any structure or property line a distance equal to the depth of the ground disturbed in setting the structure. These facilities shall also be within tracts or easements with widths equivalent to those listed for conveyance systems in Volume III.

Planting and Landscaping Requirements

Applicability

All disturbed or exposed soil must be planted and/or landscaped. Landscaping is encouraged for most stormwater tract areas (see below for areas not to be landscaped). Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, “naturalistic” stormwater facilities may be placed in open space tracts. Bioretention facilities also have specific planting requirements.

This appendix applies to the following BMPs:

- BMP IN.02 Bioretention Facilities or Rain Gardens

- BMP D.01 Detention Ponds

- BMP BF.01 Basic Bioinfiltration Swale

Other facilities may be subject to these requirements if they include landscaping.

Design Criteria

Exposed earth on pond interiors side slopes shall be sodded or seeded with an appropriate seed mixture. Exposed earth on the pond bottom should also be sodded or seeded. All remaining areas of the tract should be planted with grass or be landscaped and mulched with a 4-inch cover of hog fuel or shredded wood mulch. Shredded wood mulch is made from shredded tree trimmings, usually from trees cleared on site. The mulch must be free of garbage and weeds and shall not contain excessive resin, tannin, or other material detrimental to plant growth.

General Landscaping Guidelines

The following guidelines shall be followed if landscaping is proposed for facilities.

Setbacks from Structures and Pipes

No trees or shrubs may be planted within 25 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, shall be avoided within 50 feet of pipes or manmade structures.

Berms

Planting shall be restricted on berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.

- Trees or shrubs may not be planted on portions of water-impounding berms taller than 4 feet high. Only grasses may be planted on berms taller than 4 feet.
- Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.
- Trees planted on portions of water impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and have a fibrous root system. These trees reduce the likelihood of blow-down trees, or the possibility of channeling or piping of water through the root system, which may contribute to dam failure on berms that retain water.

  Note: *The internal berm in a wet pond is not subject to this planting restriction since the failure of an internal berm would be unlikely to create a safety problem.*
- All landscape material, including grass, shall be planted in good topsoil. Poor underlying soils may be made suitable for planting if amended with 4 inches of well-aged compost tilled into the subgrade. General information and links on soil amendment and can be found at the Soils for Salmon web site: <www.soilsforsalmon.org>.

- Soil in which trees or shrubs are planted may need additional enrichment or additional compost top-dressing. Consult a nursery, landscape professional, or arborist for site-specific recommendations.

Trees and Shrubs

- For a naturalistic effect as well as ease of maintenance, trees or shrubs should be planted in clumps to form *"landscape islands"* rather than evenly spaced.

- The landscaped islands should be a minimum of 6 feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet. Where tree foliage extends low to the ground, the 6-foot setback should be counted from the outer drip line of the trees (estimated at maturity).

- This setback allows a 6-foot wide mower to pass around and between clumps.

- Evergreen trees and trees which produce relatively little leaf-fall (such as Oregon ash, mimosa, or locust) are preferred in areas draining to the pond.

- Deciduous trees must be set back so that branches do not extend over the pond (to prevent leaf-drop into the water).

Naturalistic Planting

Two generic kinds of naturalistic planting are outlined below, but other options are also possible. Native vegetation is preferred in naturalistic plantings.

Open Woodland

In addition to the general landscaping guidelines above, the following are recommended.

- Landscaped islands (when mature) shall cover a minimum of 30 percent or more of the tract, exclusive of the pond area.

- Shade-tolerant shrubs and groundcover plants should be planted under tree clumps. The goal is to provide a dense understory that need not be weeded or mowed.

- Landscaped islands should be placed at several elevations rather than "ring" the pond, and the size of clumps should vary from small to large to create variety.

- Not all islands need to have trees. Shrub or groundcover clumps are acceptable, but lack of shade should be considered in selecting vegetation.

  Note: *Landscaped islands are best combined with the use of wood-based mulch (hog fuel) or chipped onsite vegetation for erosion control (only for slopes above the flow control water surface). It is often difficult to sustain a low-maintenance understory if the site was previously hydroseeded. Compost or composted mulch (typically used for constructed wetland soil) can be used below the flow control water surface (materials that are resistant to and preclude flotation). The method of construction of soil landscape systems can also cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations.*

Northwest Savannah or Meadow

In addition to the general landscape guidelines above, the following are recommended.

- Landscape islands (when mature) shall cover 10 percent or more of the site, exclusive of the pond area.
- Planting groundcovers and understory shrubs is encouraged to eliminate the need for mowing under the trees when they are young.
- Landscape islands should be placed at several elevations rather than “ring” the pond.

The remaining site area shall be planted with an appropriate grass seed mix, which may include meadow or wildflower species. Native or dwarf grass mixes are preferred. Table E-2 below gives an example of dwarf grass mix developed for central Puget Sound. Grass seed should be applied at 2.5 to 3 pounds per 1,000 square feet.

Note: *Amended soil or good topsoil is required for all plantings.*

Creation of areas of emergent vegetation in shallow areas of the pond is recommended. Native wetland plants, such as sedges (*Carex* sp.), bulrush (*Scirpus* sp.), water plantain (*Alisma* sp.), and burreed (*Sparganium* sp.) are recommended. If the pond does not hold standing water, a clump of wet-tolerant, non-invasive shrubs, such as salmonberry or snowberry, is recommended below the detention design water surface.

Note: *This landscape style is best combined with the use of grass or sod for site stabilization and erosion control.*

Seed Mixes. The seed mixes listed in Tables E-2 through E-4were developed for central Puget Sound.

Seed Mixes for Specific Bioinfiltration Swales

The seed mixes listed below were developed for central Puget Sound.

Plant Recommendations for Bioretention Facilities

Bioretention facilities generally feature three planting zones, reflecting the different soil moisture and frequency of inundation. Tables E-5 through E-7 provide planting recommendations for the different planting zones. Tables E-5 through E-7 include both native and non-native plant species commonly available in the Puget Sound region and suitable for bioretention facilities. Refer to the bioretention facility design guidelines (BMP LID.08 in Chapter 2) for additional planting requirements. Consultation with a landscape architect is recommended for site-specific planting recommendations.

Table E-2. Stormwater Tract "Low Grow" Seed Mix

Seed Name	Percentage of Mix
Dwarf tall fescue	40%
Dwarf perennial rye "Barclay"*	30%
Red fescue	25%
Colonial bentgrass	5%

* If wildflowers are used and sowing is done before Labor Day, the amount of dwarf perennial rye can be reduced proportionately to the amount of wildflower seed used.

Table E-3. Grass Seed Mixes Suitable for Biofiltration Swale Treatment Areas

Mix 1		Mix 2	
75-80 percent	tall or meadow fescue	60-70 percent	tall fescue
10-15 percent	seaside/colonial bentgrass	10-15 percent	seaside/colonial bentgrass
5-10 percent	Redtop	10-15 percent	meadow foxtail
		6-10 percent	alsike clover
		1-5 percent	marshfield big trefoil
		1-6 percent	Redtop

Note: all percentages are by weight.
* based on Briargreen, Inc.

Table E-4. Groundcovers and Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington

Groundcovers	
kinnikinnick*	*Arctostaphylos uva-ursi*
Epimedium	*Epimedium grandiflorum*
creeping forget-me-not	*Omphalodes verna*
--	*Euonymus lanceolata*
yellow-root	*Xanthorhiza simplissima*
--	*Genista*
white lawn clover	*Trifolium repens*
white sweet clover*	*Melilotus alba*
--	*Rubus calycinoides*
strawberry*	*Fragaria chiloensis*
broadleaf lupine*	*Lupinus latifolius*
Grasses (drought-tolerant, minimum mowing)	
dwarf tall fescues	*Festuca* spp. (e.g., Many Mustang, Silverado)
hard fescue	*Festuca ovina duriuscula* (e.g., Reliant, Aurora)
tufted fescue	*Festuca amethystine*
buffalo grass	*Buchloe dactyloides*
red fescue*	*Festuca rubra*
tall fescue grass*	*Festuca arundinacea*
blue oatgrass	*Helictotrichon sempervirens*

Table E-5. Plant Species Appropriate for Area of Periodic or Frequent Standing or Flowing Water (Zone 1)

Species	Common Name	Exposure	Mature Size/Spread	Comments
Trees				
*Alnus rubra**	Red alder	Sun/partial shade	30-120 feet/ 25 ft. spread	Prefers moist, rich soils, highly adaptable, drought tolerant; nitrogen fixer; rapid growing, relatively short-lived (60-90 years)
*Fraxinus latifolia**	Oregon ash	Sun/partial shade	30 ft. spread	Moist, saturated or ponded soils; flood tolerant; small green-white flowers
*Malus fusca**	Pacific crabapple	Sun/partial shade	To 40 feet/35 ft. spread	Tolerant of prolonged soil saturation; produces fruit (do not plant near public walkways)
*Salix lucida**	Pacific willow	Sun	40-60 feet/ 30 ft. spread	Wet soils; tolerates seasonal flooding should not be planted in areas near pavement or underground structures
Shrubs				
*Cornus sericea**	Red-osier dogwood, Red-twig dogwood	Sun/partial shade	To 15 feet	Prefers wet to moist organically rich soils, but is adaptable; tolerates seasonal flooding; small white flowers; berrylike fruits
Cornus sericea ‘Kelseyi’	Dwarf dogwood	Sun	To 1.5 feet	Prefers wet to moist organically rich soils, but is adaptable; small white flowers; berrylike fruit; low growing, compact form; good ground cover.
Cornus sericea	‘Flaviramea’ Yellow dogwood	Sun/partial shade	6-8 feet	Prefers wet to moist organically rich soils, but is adaptable; easily transplanted and grown; small, white flowers; yellow stems and reddish, purple fall color
Cornus sericea ‘Isanti’	Isanti dogwood	Sun/partial shade	4-5 feet	Prefers wet to moist organically rich soils, but is adaptable; deciduous shrub; tiny white flowers; red stems; purple fall color
*Lonicera involucrata**	Black twinberry	Partial shade/ Shade	2-8 feet	Moist soils; prefers loamy soils; tolerant of shallow flooding; yellow, tubular flowers attract hummingbirds
*Myrica californica**	Pacific wax myrtle	Sun/partial shade	To 30 feet	Evergreen shrub preferring moist soils; inconspicuous spring flowers; drought tolerant; if drought tolerance is not an issue try the smaller Washington native, *Myrica gale**
*Physocarpus capitatus**	Pacific ninebark	Sun/partial shade	6-13 feet	Moist or dry soils; drought tolerant; snowball shaped; white flowers; seeds persist into winter

Species	Common Name	Exposure	Mature Size/Spread	Comments
Shrubs (continued)				
*Rosa pisocarpa**	Clustered wild rose	Sun/partial shade	6-8 feet	Moist soils, tolerates seasonal flooding but also tolerant of dry conditions; pink clustered flowers; fruits persist
Salix purpunea 'Nana'	Dwarf Arctic willow	Sun/partial shade	3-5 feet	Grows well in poor soils; moderately drought tolerant; small yellow flowers in the fall
*Spiraea douglasii**	Douglas spirea, Steeplebush	Sun/partial shade	4-7 feet	Moist or dry, to seasonally inundated soils; spikes of small, pink flower clusters
Emergents				
*Carex obnupta**	Slough sedge	Sun/partial shade	1-5 feet	Moist to seasonally saturated soils; shiny foliage; excellent soil binder; drought tolerant
*Carex stipata**	Sawbeak sedge	Partial shade	10 inches-3 feet	Wet soils; excellent soil binder
*Juncus effusus**	Common rush	Sun/partial shade	1-2 feet	Wet soils; evergreen perennial; hardy and adaptable; drought tolerant; small, non-showy flowers
*Juncus ensifolius**	Daggerleaf rush	Sun	12-18 inches	Wet soils; shallow water; excellent soil binder
*Juncus tenuis**	Slender rush	Sun	.5–2.5 feet	Moist soils; tufted perennial
*Scirpus acutus**	Hardstem bulrush	Sun	4-8 feet	Wet soils; favors prolonged inundation; excellent soil binder
*Scirpus microcarpus**	Small-fruited bulrush	Sun/shade	2-4 feet	Wet soils; tolerates prolonged inundation; good soil binder; drought tolerant

Source: Adapted from PSAT 2005.
* Denotes native plant species.

Table E-6. Plant Species Appropriate for Bioretention Facility Areas Subject to Periodic Saturation During Large Storms (Zone 2)

Species	Common Name	Exposure	Mature Size	Comments
Trees				
Acer truncatum	Pacific sunset maple	Sun	To 25 feet/ 20 ft. spread	Prefers moist, well-drained soils, but drought tolerant; very cold hardy; deciduous tree with moderate growth rate
*Amelanchier alnifolia**	Western serviceberry	Sun/partial shade	10-20 feet/ 25 ft. spread	Moist to dry, well-drained soils; drought tolerant; large white flowers; purple to black berries; deciduous
*Corylus cornuta**	Beaked hazelnut	Sun/partial shade	20–30 feet/ 15 ft. spread	Moist, well-drained soils; edible nuts; intolerant of saturated soils; catkins throughout winter add interest; deciduous
*Crataegus douglasii**	Black hawthorn	Sun/partial shade	3-30 feet/ 25 ft. spread	Moist to dry, well drained, gravelly soils; small white flowers, black berries; 1 inch spines; forms thickets; deciduous
Fraxinus oxycarpa	Raywood ash	Sun	25-50 feet/ 25 ft. spread	Drought tolerant; grows in varying soil types; deciduous; can take extreme temperatures; does not tolerate constant wind or fog; resists pests and disease better than other non-native ashes; inconspicuous flowers
*Rhamnus purshiana**	Cascara sagrada	Sun/shade	20-40 feet/ 25 ft. spread	Moist to fairly dry soils; small greenish-yellow flowers; deciduous; sensitive to air pollution; yellow fall color
*Salix scouleriana**	Scouler willow	Sun/partial shade	6-40 feet/ 15 ft. spread	Moist to dry soils; drought tolerant; deciduous tree; do not plant near paved surfaces or underground structures
*Salix sitchensis**	Sitka willow	Sun/partial shade	3-26 feet/ 25 ft. spread	Moist soils; tolerates seasonal flooding; deciduous tree; do not plant near paved surfaces or underground structures
*Thuja plicata**	Western red cedar	Partial shade/shade	200 feet+/ 60 ft. spread	Moist to swampy soils; tolerates seasonal flooding and saturated soils; long-lived; prefers shade while young
Shrubs – Deciduous				
*Acer circinatum**	Vine maple	Filtered sun/shade	To 25 feet	Dry to moist soils; tolerant of shade and clay soils; excellent soil binder; beautiful fall color
Hamamelis intermedia	Diane witchhazel	Sun/partial shade	10-20 feet/ 10 ft. spread	Moist, fertile, acidic soil; showy fall color – yellow to yellow-orange; long-lasting, slightly fragrant, coppery-red flowers; not drought tolerant; may require watering in dry season

Species	Common Name	Exposure	Mature Size	Comments
Shrubs – Deciduous (continued)				
*Oemleria cerasiformis**	Indian plum/Osoberry	Sun/partial shade	5-16 feet	Moist to dry soils; prefers shade; tolerates fluctuating water table
Philadelphus x lemoinei	'Belle Etoile' Mock-orange	Sun/partial shade	5-6 feet	Prefers moist, well-drained soils, high in organic matter, but soil and pH adaptable; easily transplanted and established; fragrant, large white flowers, tinged red at the base; other cultivars available
*Ribes lacustre**	Black swamp gooseberry	Partial shade	1.5–3 feet	Moist soils; deciduous shrub; reddish flowers in drooping clusters; dark purple berries; *R. divaricatum** (Wild gooseberry) grows to 5 feet and is also an option; attracts butterflies, but is very thorny
*Rosa nutkana**	Nootka rose	Sun/partial shade	6-10 feet	Moist to fairly dry soils; tolerates inundation and saturated soils; aggressive spreader; fruits persist; less thorny that *R. rugosa*
Rosa rugosa	Rugosa rose	Sun	To 8 feet	Drought resistant; hardy, vigorous and aggressive; highly prickly; fragrant white to purple flowers; fruits persist
*Rubus parviflorus**	Thimbleberry	Sun/partial shade	4-10 feet	Moist to dry soils; white flowers; red berries; makes thickets and spreads easily
*Rubus spectabilis**	Salmonberry	Partial sun/shade	5-10 feet	Prefers moist, wet soils; good soil binder; magenta flowers; yellow/ orange fruit; early nectar source for hummingbirds; makes thickets
*Sambucus racemosa**	Red elderberry	Partial sun/partial shade	To 20 feet	Moist to dry soils; small white flowers; bright red berries; vase shaped; pithy stems lead to "messy" form – prune for tidiness
*Symphoricarpos albus**	Snowberry	Sun/shade	2-6 feet	Wet to dry soils, clay to sand; excellent soil binder; drought and urban air tolerant; provides good erosion control; spreads well in sun; white berries; flowers attract hummingbirds
*Vaccinium parvifolium**	Red huckleberry	Partial shade/shade	4-10 feet	Slightly moist to dry soils; prefers loamy, acid soils or rotting wood; tolerant of dry, shaded conditions; red fruit; tricky to transplant

Herbaceous				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
*Aquilegia formosa** / Western columbine	Sun/partial shade	1-3 feet	Spring	Moist soils of varying quality; tolerant of seasonal flooding; red and yellow flowers attract hummingbirds and butterflies
*Asarum caudatum** / Wild ginger	Partial shade/shade	To 10 inches	Mid spring	Moist organic soils; heart-shaped leaves; reddish-brown flowers
*Aster chilensis** / Common California aster	Sun	1.5 – 3 feet	June - September	Moist soils; white to purple flowers
*Aster subspicatus** / Douglas aster	Sun	.5 – 2.5 feet	June - September	Moist soils; blue to purple flowers
*Camassia quamash** / Common camas	Sun/partial shade	To 2.5 feet	May - June	Moist to dry soils; lots of watering needed to establish; loose clusters of deep blue flowers
Camassia leichtlinii / Giant camas		2–4 feet	May - June	Moist to dry soils; lots of watering to establish; large clusters of white, blue or greenish-yellow flowers
*Iris douglasiana** / Pacific coast iris	Sun/partial shade	1-2 feet	Spring	Tolerates many soils; withstands summer drought and seasonal flooding; white, yellow, blue, reddish purple flowers; fast growing; velvety purple flowers; vigorous
Iris foetidissima / Gladwin iris	Sun/partial shade	1-2 feet	May	Moist to dry, well-drained soils; pale lilac flower; also called Stinking Iris
*Juncus tenuis** / Slender rush	Sun	6 inches – 2.5 feet		Moist soils; yellow flowers
Iris sibirca / Siberian Iris	Sun	1-2.5 feet	Late spring – early summer	Moist soils; deep blue, purple to white flowers
*Tellima grandiflora** / Fringecup	Partial sun/shade	1-3 feet	March - June	Perennial preferring moist soils; yellowish-green to pink flowers
*Tiarella trifoliata** / Foamflower	Partial sun/shade	To 1 foot	Early - mid summer	Moist soils; perennial with some drought tolerance after established; can form dense colonies; white flowers
*Tolmiea menziesii** / Youth-on-age/Piggy-back plant	Partial shade/shade	1-2 feet	April - August	Moist soils; brownish-purple flowers; also makes and effective groundcover
Viola species* / Violets	Partial shade/shade	6-12 inches	Late spring – early summer	Moist soils; yellow to blue flowers

Table E-7. Plant Species Appropriate for Rarely Inundated Areas of Bioretention Facility (Zone 3)

Trees				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
Arbutus unedo / Strawberry tree	Sun/partial shade	8-35 feet/ 8-20 ft. spread	November - December	Tolerant of extremes; tolerant of urban/ industrial pollution; white or greenish white flowers
*Calocedrus decurrens** / Incense cedar	Sun	75-90 feet/ 12 ft. spread		Tolerant of poor soils; drought tolerant after established; fragrant evergreen with a narrow growth habit; slow growing
Chamaecyparis obtusa / Hinoki false cypress	Sun/partial shade	40-50 feet/ 15-30 ft. spread		Moist, loamy, well-drained soils; very slow growing; prefers sun, but tolerates shade; does not transplant well or do well in alkaline soils. Note there are
				many alternative varieties of false cypress of varying sizes and forms from which to choose
Cornus spp. / Dogwood	Sun/partial shade	20-30 feet/ 30 ft. spread	May	Reliable flowering trees with attractive foliage and flowers; may need watering in dry season; try *C. florida* (Eastern dogwood), or *C. nuttallii** (Pacific dogwood) or hybrid 'Eddie's White Wonder'. Also, *C. kousa* for small tree/ shrub which is resistant to anthracnose
Pinus mugo / Swiss mountain pine	Sun/partial shade	15-20 feet/ 25-30 ft. spread		Prefers well-drained soil; slow growing, broadly spreading, bushy tree; hardy evergreen
Pinus thunbergiana / Japanese black pine	Sun	To 100 feet/ 40 ft. spread		Dry to moist soils; hardy; fast growing
*Prunus emarginata** / Bitter cherry	Sun/partial shade	20-50 feet/ 20 ft. spread	May - June	Dry or moist soils; intolerant of full shade; bright red cherries are attractive to birds; roots spread extensively
Prunus virginiana / Choke cherry		15-25 feet/ 15-20 ft. spread	Late spring – Early summer	Dry or moist soils; deep rooting; attractive white fragrant flowers; good fall color
*Pseudotsuga menziesii** / Douglas-fir	Sun	100-250 feet/ 50-60 ft. spread		Does best in deep, moist soils; evergreen conifer with medium to fast rate of growth; provides a nice canopy, but potential height will restrict placement
*Quercus garryana** / Oregon white oak	Sun	To 75 feet		Dry to moist, well-drained soils; slow growing; acorns

Shrubs				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
*Holodiscus discolor** / Oceanspray	Sun/partial shade	To 15 feet	June - July	Dry to moist soils; drought tolerant; white to cream flowers; good soil binder
*Mahonia aquifolium** / Tall Oregon grape	Sun/partial shade	6-10 feet	March - April	Dry to moist soils; drought resistant; evergreen; blue-black fruit; bright yellow flowers; 'Compacta' form averages 2 feet tall; great low screening barrier
*Philadelphus lewisii** / Mock-orange	Sun/partial shade	5-10 feet	June - July	Adapts to rich moist soils or dry rocky soils; drought tolerant; fragrant flowers

▶ ZONE 3

Shrubs				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
Pinus mugo pumilio / Mugho pine	Sun	3-5 feet/ 4-6 ft. spread		Adapts to most soils; slow growing and very hardy; newer additions with trademark names such as 'Slo-Grow' or 'Lo-Mound' are also available
Potentilla fruticosa / Shrubby cinquefoil	Sun	To 4 feet	May - September	Moist to dry soils; several cultivars available with varying foliage and flower hues; try 'Tangerine' or 'Moonlight'
*Ribes sanguineum** / Red-flowering currant	Sun/partial shade	8-12 feet	March - April	Prefers dry soils; drought tolerant; white to deep-red flowers attract hummingbirds; dark-blue to black berries; thornless
*Rosa gymnocarpa** / Baldhip rose	Partial shade	To 6 feet	May - July	Dry or moist soils; drought tolerant; small pink to rose flowers

Shrubs-Evergreen				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
Abelia x grandiflora / Glossy abelia	Partial Sun/Partial shade	To 8 feet/ 5 foot spread	Summer	Prefers moist, well-drained soils, but drought tolerant; white or faintly pink flowers
Arbutus unedo 'Compacta' / Compact strawberry tree	Sun/partial shade	To 10 feet	Fall	Prefers well drained soils; tolerant of poor soils; good in climate extremes; white to greenish-white flowers; striking red-orange fruit

Cistus purpureus / Orchid rockrose	Sun	To 4 feet	June - July	Moist to dry well-drained soils; drought resistant; fast growing; reddish purple flowers
Cistus salvifolius / White rockrose	Sun	2-3 feet/ 6 ft spread	Late spring	Moist to dry well-drained soils preferred, but can tolerate poor soils; tolerant of windy conditions and drought; white flowers
Escallonia x exoniensis ‘fradesii’ / Pink Princess	Sun/partial sun	5-6 feet	Spring - Fall	Tolerant of varying soils; drought tolerant when established; pink to rose colored flowers; good hedge or border plant; attracts butterflies
Osmanthus delavayi / Delavay Osmanthus	Sun/partial shade	4-6 feet	March - May	Tolerant of a broad range of soils; attractive foliage and clusters of white fragrant flowers; slow growing
Osmanthus x burkwoodii / Devil wood	Sun/partial shade	4-6 feet	March - April	Drought tolerant once established; masses of small, white fragrant flowers
Rhododendron / ‘PJM’ hybrids	Sun/partial shade	To 4 feet	Mid – late April	Moist to fairly dry soils; well drained organic soil; lavender to pink flowers
Stranvaesia davidiana	Sun	6-20 feet	June	Moist soils; white flowers in clusters; showy red berries
Stranvaesia davidiana / undulata	Sun	To 5 feet	June	Moist soils; lower growing irregularly shaped shrub; great screening plant
Vaccinium ovatum* / Evergreen huckleberry	Partial shade/ shade	3-15 feet	March	Moist to slightly dry soils; small pinkish-white flowers; berries in August

▶ ZONE 3

Groundcover – Evergreen				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
*Arctostaphylos uva-ursi** / Kinnikinnik	Sun/partial shade		April - June	Prefers sandy/rocky, well-drained soils; flowers pinkish-white; bright red berries; slow to establish; plant closely for good results
*Gaultheria shallon** / Salal	Partial shade/ shade	3-7 feet	March - June	Dry and moist soils; white or pinkish flowers; reddish-blue to dark-purple fruit
*Fragaria chiloensis** / Wild/Coastal strawberry	Sun/partial shade	10 inches	Spring	Sandy well drained soils; flowers white; small hairy strawberries; evergreen; aggressive spreader

Helianthemum nummularium / Sunrose	Sun	To 2 feet/ 2 ft. spread	May - July	Prefers well-drained soils, but will tolerate various soils; low-growing, woody sub shrub; many varieties are available with flowers in salmon, pink, red, yellow and golden colors
Lavandula angustifolia / Lavender	Sun/partial shade	To 1.5 feet	June - August	Adaptable to various soils; blue, lavender, pink to white flowers, semi-evergreen aromatic perennial
*Mahonia nervosa** / Cascade Oregon grape/Dull Oregon grape	Partial shade/ shade	To 2 feet	April – June	Dry to moist soils; drought resistant; evergreen; yellow flowers; blue berries
Mahonia repens / Creeping mahonia	Sun/partial shade	3 feet	April - June	Dry to moist soils; drought resistant; yellow flowers; blue berries; native of Eastern Washington
*Penstemon davidsonii** / Davidson's penstemon	Sun	To 3 inches	June - August	Low growing evergreen perennial; prefers well-drained soils; drought tolerant; blue to purple flowers

Perennials & Ornamental Grasses				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
*Achillea millefolium** / Western yarrow	Sun	4 inches – 2.5 feet	June - September	Dry to moist, well-drained soils; white to pink/reddish flowers; many other yarrows are also available
Anaphalis margaritaceae / Pearly everlasting	Sun/partial shade	To 18 inches		Drought tolerant perennial; spreads quickly; attracts butterflies
*Bromus carinatus** / Native California brome	Sun/partial shade	3-5 feet		Dry to moist soils; tolerates seasonal saturation
Carex buchannii / Leather leaf sedge	Sun/partial shade	1-3 feet		Prefers well-drained soils; copper-colored foliage; perennial clumping grass; tolerant of a wide range of soils; inconspicuous flowers
Carex comans / 'Frosty curls' New Zealand hair sedge	Sun/partial shade	1-2 feet	June -August	Prefers moist soils; finely textured and light green; compact, clumping perennial grass; drought tolerant when established; inconspicuous flowers

Perennials & Ornamental Grasses				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
Coreopsis spp. / Tick-Seed	Sun	1-3 feet		Dry to moist soils; drought tolerant; seeds attract birds; annual and perennial varieties; excellent cut flowers
Echinacea purpurea / Purple coneflower	Sun	4-5 feet		Prefers well drained soils; hardy perennial; may need occasional watering in dry months
*Elymus glaucus** / Blue wildrye	Sun/partial shade	1.5-5 feet		Dry to moist soils; shade tolerant; rapid developing, but short lived (1-3 years); not good lawn grass
*Dicentra formosa** / Pacific bleeding-heart	Sun/shade	6-20 inches	Early spring - early summer	Moist, rich soils; heart-shaped flowers
*Erigeron speciosus** / Showy fleabane	Sun/partial shade	To 2 feet	Summer	Moist to dry soils; dark violet or lavender blooms; fibrous roots
Festuca ovina 'Glauca' / Blue fescue	Sun/partial shade	To 10 inches	May - June	Prefers moist, well-drained soils; blue-green evergreen grass; drought tolerant; shearing will stimulate new growth
*Festuca idahoensis** / Idaho fescue	Sun/partial shade	To 1 foot		Bluish-green bunching perennial grass; drought tolerant
*Fragaria vesca** / Wood strawberry	Partial shade	To 10 inches	Late spring - early summer	Dry to moist soils; white flowers
Gaura lindheimeri / Gaura	Sun	2.5-4 feet		Perennial; fairly drought tolerant and adaptable to varying soil types; long blooming period
*Geum macrophyllum** / Large-leaved avens	Sun/partial shade	To 3 feet	Spring	Moist, well-drained soil; bright yellow flowers; other Geum cultivars available, some which may require supplemental watering
Geranium maculatum / Spotted geranium	Sun/shade	To 1.5 feet	July	Moist, well-drained soils; low perennial; pale pink, blue to purple flowers
Geranium sanguineum / Cranesbill	Sun/partial shade	To 1.5 feet	May - August	Moist soils; deep purple almost crimson flowers
Helichrysum italicum / Curry Plant	Sun	To 2 feet	Summer	Moist or dry soils; hardy evergreen perennial; a good companion to lavender; bright yellow flowers; fragrant

Perennials & Ornamental Grasses				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
Helictotrichon sempervirens / Blue oat grass	Sun/partial shade	1-1.5 feet	June - August	Tolerant of a variety of soil types but prefers well-drained soil; clumping bright blue evergreen grass; bluish white flowers
Hemerocallis fulva / Day lilies	Sun/partial shade	1-4 feet	Summer	Tolerant of a variety of soil types; easy to grow and tolerant of neglect; hardy perennial; entire plant is edible
Heuchera americana / Coral bells (alumroot)	Sun/partial shade	1-2 feet	June - August	Moist to dry, well-drained soils; never wet; easily transplantable perennial; red, greenish-white flowers; may need supplemental watering in dry season
Heuchera micrantha / 'Palace purple' (alumroot)	Sun/partial shade	1-2 feet	June - August	Moist, well-drained soils; bronze to purple foliage in shade; small, yellowish-white flowers; perennial, evergreen; a number of other species and varieties are available. Try *H. sanguinea* for bright red flowers
*Lupinus** spp. / Lupines	Sun	3-5 feet	March - September	Moist to dry soils; various native varieties; blue to purple, violet to white flowers; both native and non-native varieties
*Lupinus bicolor** / Two-color lupine	Sun	4 inches - 1.5 feet	Spring	Dry gravelly soils; small-flowered; annual
*Lupinus latifolius** / Broadleaf lupine	Sun	To 1 foot	June - August	Dry to moist soils; perennial; bushy herb; bluish flowers
*Lupinus polyphyllus** / Large-leafed lupine	Sun	To 3 feet	Spring - summer	Dry to moist, sandy to gravelly soils; perennial
*Maianthemum dilatatum** / False lily-of-the-valley	Partial shade/ shade	3-12 inches	Spring	Prefers moist soils; small, white flowers; light-green to red berries
Pennisetum alopecuroides / Fountain grass	Sun/partial shade	1-2 feet	August - September	Moist, well-drained soils; tolerant of many soil types; clump-forming grasses. A number of varieties are available in different heights and bloom times. Try *P. caudatum* (White-flowering fountain grass) and *P. alopecuroides* cultivars 'Hameln' and 'Little Bunny' (Dwarf fountain grass)

Perennials & Ornamental Grasses				
Species / Common Name	**Exposure**	**Mature Size**	**Time of Bloom**	**Comments**
Pennisetum orientale / Oriental fountain grass	Sun/partial shade	1-3 feet	June - October	Prefers moist, well-drained soils; somewhat drought tolerant; small clumping, blooming grass, showy pink flowers; fountain grasses will benefit from annual shearing in late winter/early spring, but not required
Penstemon fruticosus / Shrubby penstemon	Sun	8–10 inches	May	Prefers well-drained soils; evergreen perennial; drought tolerant; violet-blue flowers 1 inch long attract hummingbirds
*Polystichum munitum** / Swordfern	Partial shade/ Deep shade	2-4 feet		Prefers moist, rich soil conditions, but drought tolerant; large evergreen fern
*Potentilla gracilis** / Graceful cinquefoil	Sun	1-2 feet	July	Moist to dry soils; yellow flowers
Rudbeckia hirta / Black-eyed susan	Sun/partial shade	3-4 feet	Summer	Moist to dry soils; showy flowers, hardy and easy to grow; several other varieties are available
*Smilacina racemosa** / False Solomon's seal	Partial sun/shade	1-3 feet	April - May	Moist soils; creamy white flowers; red berries