

Thurston County Drainage Design and Erosion Control Manual

Volume V Stormwater BMPs

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Table of Contents

Chapter 1 - Introduction to Volume V	1-1
1.1 What is the Purpose of this Volume?	1-1
1.2 How This Volume is Organized.....	1-4
1.3 How Do I Get Started?	1-4
Chapter 2 - Low Impact Development (LID)	2-5
2.1 LID Site Design BMPs	2-5
2.1.1 LID.01 Native Vegetation Protection, Reforestation, and Maintenance	2-6
2.1.2 LID.02 Post-Construction Soil Quality and Depth	2-14
2.1.3 LID.03 Minimize Impervious Areas	2-24
2.2 LID Stormwater Management BMPs.....	2-28
2.2.1 LID.04 Downspout Infiltration Systems	2-29
2.2.2 LID.04A Perforated Stub-out Connections.....	2-39
2.2.3 LID.05 Downspout Dispersion Systems.....	2-42
2.2.4 LID.06 Sheet Flow Dispersion	2-49
2.2.5 LID.07 Concentrated Flow Dispersion	2-53
2.2.6 LID.08 Bioretention	2-56
2.2.7 LID.08A Rain Gardens.....	2-87
2.2.8 LID.09 Permeable Pavements	2-91
2.2.9 LID.10 Vegetated Roofs.....	2-112
2.2.10 LID.11 Full Dispersion.....	2-121
2.2.11 LID.12 Rural Road Natural Dispersion.....	2-133
2.2.12 LID.13 Rural Road Engineered Dispersion	2-143
2.2.13 LID.14 Tree Planting and Tree Retention (for Flow Control Credit).....	2-152
2.2.14 LID.15 Minimal Excavation Foundation Systems.....	2-159
2.2.15 LID.16 Rainwater Harvesting.....	2-158
Chapter 3 - Infiltration BMPs	3-1
3.1 General Considerations	3-1
3.1.1 Runoff Treatment and Flow Control	3-1
3.1.2 Site Suitability	3-1
3.1.3 Underground Injection Control	3-2
3.1.4 Groundwater Protection Areas.....	3-4
3.1.5 Verification of Performance.....	3-4
3.1.6 Contingency Planning	3-5
3.2 Infiltration BMPs.....	3-5
3.2.1 IN.01 Infiltration Basins	3-6
3.2.2 IN.02 Infiltration Trenches.....	3-12
3.2.3 IN.03 Infiltration Vaults and Drywells	3-21

Chapter 4 - Detention BMPs	4-1
4.1 Detention Facility BMPs	4-1
4.1.1 D.01 Detention Ponds	4-2
4.1.2 D.02 Detention Tanks	4-11
4.1.3 D.03 Detention Vaults	4-17
4.1.4 D.04 Use of Parking Lots for Additional Detention	4-22
Chapter 5 - Biofiltration BMPs	5-1
5.1 Biofiltration BMPs	5-1
5.1.1 BF.01 Basic Biofiltration Swale	5-2
5.1.2 BF.02 Wet Biofiltration Swale	5-24
5.1.3 BF.03 Continuous Inflow Biofiltration Swale	5-28
5.1.4 BF.04 Basic Filter Strip	5-30
5.1.5 BF.05 Compost-Amended Vegetated Filter	5-35
Chapter 6 - Wet Pool BMPs	6-1
6.1 Wet Pool BMPs	6-1
6.1.1 WP.01 Stormwater Treatment Wetlands	6-2
6.1.2 WP.02 Wet Ponds	6-12
6.1.3 WP.03 Wet Vaults	6-26
6.1.4 WP.04 Combined Detention and Wet Pool Facilities	6-34
6.1.5 WP.05 Presettling Basins and Pretreatment	6-43
Chapter 7 - Media Filtration BMPs	7-1
7.1 Media Filtration Design BMPs	7-1
7.1.1 MF.01 Sand Filter Basin	7-2
7.1.2 MF.02 Sand Filter Vault	7-16
7.1.3 MF.03 Linear Sand Filter	7-21
7.1.4.11 MF.04 Media Filter Drain	7-24
Chapter 8 - Oil and Water Separation BMPs	8-1
8.1 Oil and Water Separation BMPs	8-1
8.1.1 OW.01 API (Baffle Type) Separator	8-2
8.1.2 OW.02 Coalescing Plate (CP) Separator	8-8

Chapter 9 - Chapter 9 - Emerging Technologies	9-1
9.1 Background.....	9-1
9.2 Ecology Role in Evaluating Emerging Technologies.....	9-1
9.3 Emerging Technology Use in Retrofit Situations.....	9-2
9.4 Acceptable Evaluation Protocols (TAPE and C-TAPE).....	9-2
9.5 Acceptance and Use of Emerging Technologies for New Developments and Redevelopments	9-2
Volume V References.....	Ref-1
Appendix V-A – Structures	A-1
Control Structures.....	A-1
Applicability.....	A-1
Hydrologic and Hydraulic Design Considerations.....	A-1
Bypass and Diversion Structures.....	A-12
Applicability.....	A-12
Hydrologic and Hydraulic Design Considerations.....	A-13
Design Criteria.....	A-13
Flow Spreading Options	A-17
General Design Criteria	A-17
Appendix V-B – Facility Liners and Geotextiles.....	B-1
Applicability.....	B-1
Liners Design Criteria	B-1
Appendix V-C – Maintenance Guidelines.....	C-1
Appendix V-D – Access Roads and Ramps	D-1
Access Roads.....	D-1
Applicability.....	D-1
Design Criteria.....	D-1
Site Design Elements	D-2
Access Ramps.....	D-2
Applicability.....	D-3
Design Criteria.....	D-3
Structural Design Considerations	D-3
Appendix V-E – Site Design Elements	E-1
Fencing.....	E-1
Applicability.....	E-1
Design Criteria.....	E-1
Signage	E-2
Applicability.....	E-2

Design Criteria.....	E-3
Setbacks and Easements	E-4
Applicability.....	E-4
Design Criteria.....	E-4
Planting and Landscaping Requirements	E-8
Applicability.....	E-8
Design Criteria.....	E-8
General Landscaping Guidelines.....	E-8
Naturalistic Planting.....	E-10
Northwest Savannah or Meadow.....	E-10
Seed Mixes for Specific Bioinfiltration Swales	E-11
Plant Recommendations for Bioretention Facilities	E-11

Tables

Table V - 1.1 Thurston County Stormwater BMPs	1-2
Table V - 2.1 Selected Native Vegetation, Size, and Spacing Requirements.....	2-10
Table V - 2.2 Soil Management Plan for BMP LID.02.....	2-22
Table V - 2.3 Roof Drywell Sizes by Soil Hydrologic Group.....	2-36
Table V - 2.4 Aggregate for Bioretention Soil Mix.....	2-76
Table V - 5.1 Sizing Criteria Biofiltration Swale	5-3
Table V - 5.2 Guide for Selecting Degree of Retardance	5-12
Table V - 5.4 Soil Recommendations for Swales	5-18
Table V - 5.5 Grass Seed Mixes Suitable for Biofiltration Swale Treatment Areas ...	5-19
Table V - 5.6 Groundcovers and Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington.....	5-19
Table V - 5.7 Recommended Plants for Wet Biofiltration Swale	5-23
Table V - 6.2 Emergent Wetland Plant Species Recommended for Wet Ponds	6-9
Table V - 7.1 Sand Filter Design Parameters	7-6
Table V - 7.2 Sand Filter Design and Sizing Criteria.....	7-6
Table V - 7.3 Sand Medium Specification.....	7-8
Table V - 7.4 Clay Liner Specifications.....	7-9
Table V - 7.5 Design Widths for Media Filter Drains	7-29
Table V - 7.6 Media Filter Drain Mix.....	7-33
Table V - A.1 Values for Cd for Sutro Weirs	A-5
Table V - B.1 Lining Types Required for Runoff Treatment Facilities	B-2
Table V - B.2 Compacted Till Liners	B-4
Table V - B.3 Geotextile Properties for Underground Drainage	B-6
Table V - B.4 Geotextile for Underground Drainage Filtration Properties.....	B-7
Table V - B.5 Geotextile Strength Properties for Impermeable Liner Protection	B-7
Table V - E.1 Stormwater Tract “Low Grow” Seed Mix	E-12
Table V - E.2 Grass Seed Mixes Suitable for Biofiltration Swale Treatment Areas	E-12
Table V - E.3 Groundcovers and Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington	E-12
Table V - E.4 Plant Species Appropriate for Area of Periodic or Frequent Standing or Flowing Water (Zone 1).....	E-13
Table V - E.5 Plant Species Appropriate for Bioretention Facility Areas Subject to Periodic Saturation During Large Storms (Zone 2).....	E-15
Table V - E.6 Plant Species Appropriate for Rarely Inundated Areas of Bioretention Facility (Zone 3)	E-18

Figures

Figure V - 2.1. Typical soil amendment sections Source: City of Seattle (reproduced with permission)	2-21
Figure V - 2.2 Typical Downspout Infiltration Trench.....	2-34

Figure V - 2.3 Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel.....	2-35
Figure V - 2.4 Typical Downspout Infiltration Drywell	2-37
Figure V - 2.5 Perforated Stub-Out Connection, Source: Department of Ecology	2-40
Figure V - 2.6 Typical Downspout Dispersion Trench Note: Catch Basin or yard drain sump for downspout dispersion trench shall be consistent with CB Sump detail of Figure 2.1	2-44
Figure V - 2.7 Standard dispersion trench with Notched Grade Board. Source: Department of Ecology	2-45
Figure V - 2.8 Typical Downspout Splashblock Dispersion	2-47
Figure V - 2.9 Sheet Flow Dispersion for Driveways	2-51
Figure V - 2.10 Typical Concentrated Flow Dispersion for Steep Driveways	2-54
Figure V - 2.11 Bioretention Area (shown with optional underdrain) - Source Pierce County	2-60
Figure V - 2.12 Bioretention Area (typical)	2-86
Figure V - 2.13 Curb Cut Inlet.....	2-73
Figure V - 2.13 Alternative Paving Surfaces.....	2-102
Figure V - 2.14 Porous Paving Surfacing Details	2-103
Figure V - 2.15 Permeable Paver Section	2-104
Figure V - 2.16 Porous Asphalt or Pervious Concrete Section.....	2-105
Figure V - 2.17 Typical Vegetated Roof Section	2-112
Figure V - 2.18 Vegetated Roof.....	2-115
Figure V - 2.19 Natural Dispersion	2-138
Figure V - 2.20 Engineered Dispersion	2-146
Figure V - 2.21 Critical Root Zone (courtesy of Pierce County Stormwater Management Manual)	2-155
Figure V - 2.22 Root Bridge, Source: Pierce County Stormwater Management Manual.....	2-156
Figure V - 2.23 Pin Foundations.....	2-160
Figure V - 3.1 Typical Infiltration Pond/Basin	3-7
Figure V - 3.2 Schematic of an Infiltration Trench	3-13
Figure V - 3.3 Parking Lot Perimeter Trench Design.....	3-14
Figure V - 3.4 Median Strip Trench Design	3-14
Figure V - 3.5 Oversized Pipe Trench Design	3-15
Figure V - 3.6 Swale/Trench Design.....	3-16
Figure V - 3.7 Underground Trench with Oil/Grit Chamber	3-17
Figure V - 3.8 Infiltration Vault.....	3-24
Figure V - 4.1 Typical Detention Pond.....	4-5
Figure V - 4.2 Typical Detention Pond Sections	4-6
Figure V - 4.3 Typical Detention Tank	4-12
Figure V - 4.4 Detention Tank Access Detail.....	4-13
Figure V - 4.5 Typical Detention Vault.....	4-18
Figure V - 5.1 Ratio of SBUH Peak/Water Quality Flow Online.....	5-5
Figure V - 5.2 Ratio of SBUH Peak/Water Quality Flow Offline.....	5-16
Figure V - 5.3 Geometric Formulas on Common Swale Slopes	5-11

Figure V - 5.4 The Relationship of Manning's n with VR for Various Degrees of Flow Retardance (A-E).....	5-14
Figure V - 5.5 Biofiltration Swale Underdrain detail.....	5-16
Figure V - 5.6 Biofiltration Swale Low Flow Drain Detail	5-17
Figure V - 5.7 Swale Dividing Berm.....	5-18
Figure V - 5.8 Swale Access Feature	5-19
Figure V - 5.9 Typical Filter Strip.....	5-31
Figure V - 6.1 Stormwater Wetland – Option One.....	6-3
Figure V - 6.2 Stormwater Wetland — Option Two	6-4
Figure V - 6.3 Wet Pond.....	6-13
Figure V - 6.4 Wet Pond.....	6-14
Figure V - 6.5 Wet Vault.....	6-27
Figure V - 6.6 Combined Detention and Wetpond.....	6-36
Figure V - 6.7 Combined Detention and Wetpond (continued).....	6-37
Figure V - 6.8 Alternative Configurations of Detention and Wetpool Areas	6-38
Figure V - 7.1 Sand Filtration Basin Preceded by Presettling Basin (Variation of a Basic Sand Filter).....	7-10
Figure V - 7.2 Sand Filter with Pretreatment Cell	7-11
Figure V - 7.3 Sand Filter with Pretreatment Cell – Section	7-12
Figure V - 7.4 Sand Filter with Level Spreader.....	7-13
Figure V - 7.5 Sand Filter with Level Spreader – Sections and Details	7-14
Figure V - 7.6 Sand Filter Vault	7-17
Figure V - 7.7 Sand Filter Vault: Sections	7-18
Figure V - 7.8 Linear Sand Filter	7-22
Figure V - 7.9 Media Filter Drain: Side Slope Application with Underdrain.....	7-25
Figure V - 7.10 Dual Media Filter Drain: Median Application with Underdrain.....	7-25
Figure V - 7.11 Media Filter Drain: Side Slope Application without Underdrain.....	7-26
Figure V - 8.1 API (Baffle Type) Separator.....	8-5
Figure V - 8.2 Coalescing Plate Separator	8-9
Figure V - A.1 Simple Orifice.....	A-2
Figure V - A.2 Rectangular, Sharp-Crested Weir	A-3
Figure V - A.3 V-Notch, Sharp-Crested Weir.....	A-4
Figure V - A.4 Sutro Weir	A-5
Figure V - A.5 Riser Inflow Curves	A-8
Figure V - A.6 Flow Restrictor (TEE).....	A-9
Figure V - A.7 Flow Restrictor (Baffle).....	A-10
Figure V - A.8 Flow Restrictor (Weir).....	A-11
Figure V - A.9 Flow Splitter Option A.....	A-14
Figure V - A.10 Flow Splitter Option B.....	A-15
Figure V - A.11 Example Isolation/Diversion Structure.....	A-16
Figure V - A.12 Flow Spreader Option A: Anchored Plate.....	A-18
Figure V - A.13 Flow Spreader Option B: Concrete Sump Box.....	A-20
Figure V - A.14 Flow Spreader Option C: Notched Curb Spreader	A-21
Figure V - A.15 Flow Spreader Option D: Through-Curb Port.....	A-22
Figure V - E.1 Informational Sign for Wet Pond in Olympia, Washington.....	E-2

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 including BMPs best suited for meeting the Low Impact Development core requirement (CR #5).
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 to meet the low impact development (LID) requirements of CR#5. 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 V - 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 V - 1.1 Thurston County Stormwater BMPs

BMP No.	Title	Type of BMP					
		LID	Flow Control	Runoff Treatment			
				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.04A	Perforated Stub-out Connections	√					
LID.05	Downspout Dispersion Systems	√					
LID.06	Sheet Flow Dispersion	√					
LID.07	Concentrated Flow Dispersion	√					
LID.08	Bioretention	√	√	√	√		
LID.08A	Rain Gardens	√					
LID.09	Permeable Pavements	√					
LID.10	Vegetated Roofs	√					
LID.11	Full Dispersion	√					
LID.12	Rural Roads Natural Dispersion	√					
LID.13	Rural Roads Engineered Dispersion	√					
LID.14	Tree Planting and Tree Retention	√	√				
LID.15	Minimal Excavation Foundation Systems	√					
Infiltration BMPs							
IN.01	Infiltration Basins		√	*	*	*	
IN.02	Infiltration Trenches		√	*	*	*	
IN.03	Infiltration Vault and Drywells		√	*	*	*	
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			√			

BMP No.	Title	Type of BMP					
		LID	Flow Control	Runoff Treatment			
				Basic	Enhanced	Phosphorus	Oil Control
BF.03	Continuous Inflow Biofiltration Swale			√			
BF.04	Basic Filter Strip			√	*		*
BF.05	Compost-Amended Vegetated Filter Strip (CAVFS)			√	*		*
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						√
OW.02	Coalescing Plate (CP) Separator						√

√ 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 core requirements for stormwater treatment and flow management (Core Requirements #4 through #8) and selection of stormwater BMPs. After determining core 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 Core Requirement #5 (Onsite Stormwater Management), #6 (Runoff Treatment), and #7 (Flow Control). Core 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 Core 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 2012).

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: Minimize Impervious Areas

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

Preserving native vegetation onsite to the maximum extent practicable will minimize the impacts of development on stormwater runoff. Per the Applicability section below, it is preferable that 65 percent or more of the project site be protected for the purposes of retaining or enhancing existing forest cover and preserving wetlands and stream corridors. The following sections present the strategies and practices for meeting the native vegetation preservation requirements. Additional details on flow dispersion to native vegetation areas are presented under Section 2.3, Full Dispersion.

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.

2.1.1.1 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.

On lots that are one acre or greater, preservation of 65 percent or more of the site in native vegetation will allow the use of full dispersion techniques presented in BMP LID.11. Sites that can fully disperse are not required to provide runoff treatment or flow control facilities.

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, buffers, and habitat areas.
- Minimum native vegetation areas required by zoning codes (for example in the Green Cove Basin).

2.1.1.2 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.

2.1.1.3 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.

2.1.1.4 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:

2.1.1.4.1 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.

2.1.1.4.2 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.

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

Table V - 2.1 Selected Native Vegetation, Size, and Spacing Requirements

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

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

Species	Type	Sun and Moisture Preferences	Planted Size	Spacing
Shrubs (continued)				
Hollyleaved barberry (<i>Mahonia aquifolium</i>)	Shrub	Sun to shade, dry to moist soil	1 gallon	4' o.c.
Snowberry (<i>Symphoricarpos albus</i>)	Shrub	Sun to shade, dry to wet soil	1 gallon, 30-36"	4' o.c.
Service berry (<i>Amelanchier alnifolia</i>)	Shrub	Sun to shade, dry to wet soil	1 gallon	6' o.c.
Indian plum (<i>Oemleria cerasiformis</i>)	Shrub	Sun to shade, moist soil	1 gallon	4' o.c.
Twinberry (<i>Lonicera involucrate</i>)	Shrub	Sun to partial shade, moist soil	1 gallon	4' o.c.
Ground Cover (Plant 2 species minimum).				
Evergreen huckleberry (<i>Vaccinium ovatum</i>)	Groundcover	Sun to partial shade, moist soil	1 gallon	2' o.c.
Kinnikinick (<i>Arctostaphylos uva-ursa</i>)	Groundcover	Sun to partial shade, dry soil	1 gallon	2' o.c.
Salal (<i>Gaultheria shallon</i>)	Groundcover	Sun to shade, dry to moist soil	1 gallon	18" o.c.
Low Oregon grapes (<i>Mahonia repens</i>)	Groundcover	Sun to partial shade, dry to moist soil	9-12"	18" o.c.
Sword fern (<i>Polystichum munitum</i>)	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 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 V – 2.1.*

- a. 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.
- b. 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.

2.1.1.4.4 Materials

Developments shall use native trees for replacement in areas separate from residential lots, or storm drainage areas adjacent to roadways 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.

2.1.1.5 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.

Permanent signs shall be installed indicating that removal of trees or vegetation is prohibited within the native vegetation retention areas. If a ISA certified arborist determines that dangerous and diseased trees are present, then removal of those trees are allowed. If trees are removed, each tree shall be replaced with a minimum of 6 trees, or the area covered by the drip line(s) of the tree(s) shall be revegetated, whichever is greater, in accordance with Conversion of Previously Developed Surfaces to Native Vegetation above.

Permanent fencing is required around the limits of the vegetation retention areas. The type, size, and location of the fencing shall be approved by county review staff and should be made of materials that blend in with the natural surroundings (e.g., wood split-rail, pinned if necessary) and located in such a manner as to not impede the movement of wildlife within the vegetation retention areas.

2.1.2 LID.02 Post-Construction Soil Quality and Depth

Most projects require that site soils meet minimum quality and depth requirements at project completion. Requirements may be achieved by either retaining and protecting undisturbed soil or restoring the soil (e.g., amending with compost) in disturbed areas.

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.

2.1.2.1 Applicability

This BMP is required in projects subject to Core Requirement #5, Onsite Stormwater Management. When used in combination with other onsite stormwater management BMPs, soil preservation and amendment can help achieve compliance with the Performance Standard option of Core Requirement #5. 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).

On sites that are underlain by cemented till layers, which are nearly impermeable, the upper soil horizon (native topsoil) processes the majority of stormwater on the site. Ensure that the existing depth of the upper soil horizon is either left in place or removed and replaced (according to the requirements herein) during the grading process. On sites which are underlain by outwash soils, the existing topsoil is not usually as deep (as with till soils), but must still be preserved or replaced.

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.

2.1.2.2 Limitations

Native soils with robust native landscapes must be protected from disturbance whenever possible. See the Thurston County Code for more information.

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.

Portions of a site comprised of till soils with slopes greater than 33 percent or other areas a geotechnical engineer indicates are unsuitable for post-construction soils restoration need not implement this BMP.

2.1.2.2.1 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.

2.1.2.2.2 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 or TCC Title 24, 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. Plant vegetation in native soil and mulch with 2 inches of compost with 2-3 inches of bark mulch over the top of the compost..

2.1.2.3 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 (for Abbreviated and Engineered Abbreviated Drainage Plans the soils restoration information can be shown on the Plot Plan). 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- 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).

2.1.2.4 Hydrologic and Hydraulic Design Considerations

2.1.2.4.1 Flow Credit for Dispersion

Lawn and landscaped areas that meet the requirements of this section may be modeled, using approved runoff models, as “Pasture” rather than “Lawn/Landscaping” surface over the underlying soil (till or outwash).

In addition, flow control credit is given in runoff modeling when soil preservation and amendment BMP requirements are met and used 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.

2.1.2.5 Design Guidelines

This section describes the implementation options and design requirements for soil preservation and amendment. Typical cross-sections of compost-amended soil in planting bed and turf applications are shown in Figure V - 2.1. Design criteria are provided in this section for the following elements: 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 site: www.SoilsforSalmon.org.

2.1.2.5.1 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.

2.1.2.5.2 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 meeting these requirements:

- Turf areas: Place 1.75 inches of compost and till in to an 8 inch depth. Achieve an organic matter content, as measured by the loss-on-ignition test, of a minimum 4 percent (target 5 percent) organic matter content.¹
- Planting beds: Place 3 inches of compost and till in to an 8 inch depth. Achieve an organic matter content, as measured by the loss-on-ignition test, of a minimum 8 percent (target 10 percent) dry weight.¹
- A pH from 6.0 to 8.0 or matching the pH of the original undisturbed soil.
- A minimum depth of 8 inches.

Root zones where tree roots limit the depth of incorporation of amendments are exempted from this requirement. Fence and protect these root zones from stripping of soil, grading, or compaction to the maximum extent practical.

Scarify (loosen) subsoils below the topsoil layer at least 4 inches for a finished minimum depth of 12 inches of uncompacted soil. Incorporate some of the upper material to avoid stratified layers, where feasible. Planting beds must be mulched with 2 to 4 inches of organic material such as arborist wood chips, bark, shredded leaves, compost, etc. Do not use fine bark because it can seal the soil surface.

For turf installations: water or roll to compact to 85 percent of maximum. dry density, rake to level, and remove surface woody debris and rocks larger than 1 inch in diameter. (Building Soil manual [Stenn et al. 2012] or web site <www.buildingsoil.org>).

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

2.1.2.5.3 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://app.leg.wa.gov/WAC/default.aspx?cite=173-350-220>.
- The compost must also have an organic matter content of 35 percent to 65 percent, and a carbon to nitrogen ratio below 25:1.

¹ Acceptable test methods for determining loss-on-ignition soil organic matter include the most current version of ASTM D2974 “Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils” and TMECC 05.07A “Loss-On-Ignition Organic Matter Method”

- 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; “pre-approved” amendment rates can only be met using compost meeting the compost specification for bioretention (see Section 2.2.5), with the exception that the compost may have up to 35 percent biosolids or manure.

2.1.2.5.4 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, C100, 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 see Figure V - 2.1) 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. Imported soils should not contain excessive clay or silt fines (more than 5 percent passing the US #200 sieve) because that could

restrict stormwater infiltration. 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.

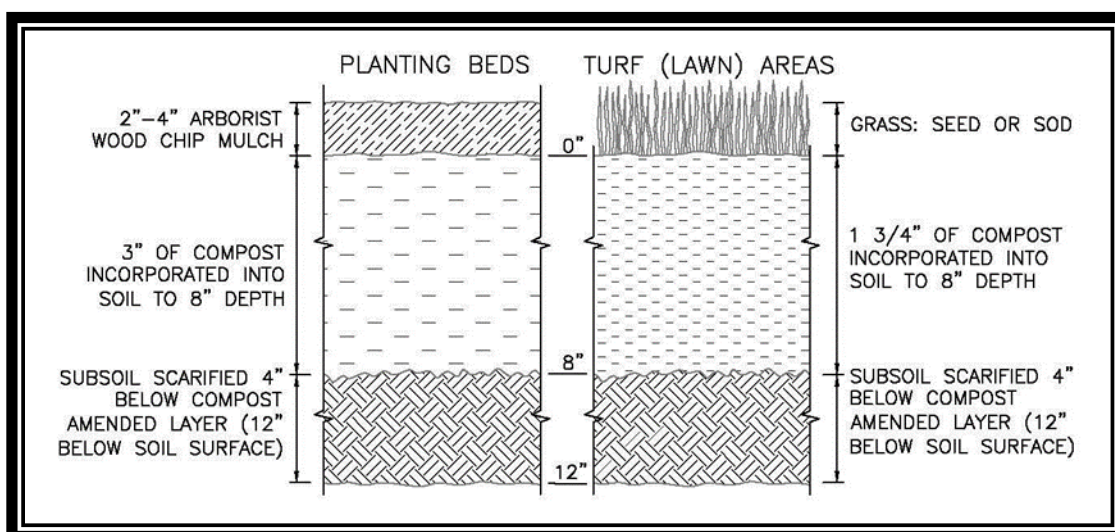


Figure V - 2.1 Typical soil amendment sections Source: City of Seattle (reproduced with permission)

2.1.2.6 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"* (available at www.buildingsoil.org) for details on implementing the Post-Construction Soil Quality and Depth BMP.

2.1.2.6.1 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 V - 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)

<input type="checkbox"/> Site Plan showing, to scale:	<input type="checkbox"/> Areas of undisturbed native vegetation (no amendment required) <input type="checkbox"/> New planting beds and turf areas (amendment required) <input type="checkbox"/> Type of soil improvement proposed for each area
<input type="checkbox"/> Soil test results (required if proposing custom amendment rates)	
<input type="checkbox"/> Product test results for proposed amendments	

AREA # _____ (should match Area # on Site Plan)

PLANTING TYPE <input type="checkbox"/> Turf <input type="checkbox"/> Undisturbed native vegetation <input type="checkbox"/> Planting Beds <input type="checkbox"/> 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: <input type="checkbox"/> Topsoil import <input type="checkbox"/> Amend with compost <input type="checkbox"/> Stockpile and amend (_____ cu. yds. stockpiled)	_____ inches of compost or imported topsoil applied X <u>3.1</u> (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 <input type="checkbox"/> Topsoil import <input type="checkbox"/> Topsoil & compost lift <input type="checkbox"/> Amend <input type="checkbox"/> Stockpile and amend (_____ cu. yds. stockpiled)	Attach test results and calculations. _____ inches organic matter or topsoil import X <u>3.1</u> _____ = 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 <u>6.2</u> (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)

<input type="checkbox"/> Product #1: _____ _____ cu. yds.	<input type="checkbox"/> Quantity: _____
<input type="checkbox"/> Test Results: _____ % organic matter _____ C:N ratio <25:1 (except mulch, or <35:1 for native plants) _____ "stable" (yes/no)	
<input type="checkbox"/> Product #2: _____ _____ cu. yds.	<input type="checkbox"/> Quantity: _____
<input type="checkbox"/> Test Results: _____ % organic matter _____ C:N ratio <25:1 (except mulch, or <35:1 for native plants) _____ "stable" (yes/no)	

2.1.3 LID.03 Minimize Impervious 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.

2.1.3.1 Applicability

The following sections describe strategies for reducing the impacts of impervious surfaces associated with transportation and mobility related networks.

2.1.3.2 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, the associated city may request more stringent standards than the Thurston County Road Standards depending on the project location. Road Standards include maximum grade, minimum roadway width, emergency access, compliance with the Americans with Disabilities Act (ADA), permeable pavement, 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.

2.1.3.3 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.

2.1.3.4 Design Criteria

2.1.3.4.1.a *Urban Strategies*

Urban areas in Thurston County are normally under the jurisdiction of cities (Olympia, Lacey, Tumwater, Yelm) with the exception of Grand Mound and some Urban Growth Areas. 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.

2.1.3.4.1.b Reduce Roadway Widths

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

2.1.3.4.1.c Permeable Pavement

The use of permeable paving surfaces (see BMP LID.09) are an important integrated management practice within the LID approach and can be designed to accommodate pedestrian, bicycle and auto traffic while allowing infiltration, treatment and storage of stormwater. Permeable paving surfaces are a good strategy for reducing impervious areas associated with transportation facilities. For projects that trigger Core Requirements #1 through #5 or #1 through #11 (see Volume I, Chapter 2), permeable pavement is one option that must be evaluated for onsite stormwater management for roads with very low traffic volumes and very low truck traffic (see Volume V, Section 2.2.9 for additional details). If permeable pavement surfaces are used adjacent to conventional impervious road sections for sidewalks or pullout parking, use design techniques described in Volume V, Section 2.2.9.7 to prevent saturation of the impervious road section and migration of aggregate base material from the impervious to the permeable section.

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.

2.1.3.4.1.d 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.

2.1.3.4.1.e Sidewalks**2.1.3.4.1.f 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.

2.1.3.4.1.g 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.

2.1.3.4.1.h 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.

2.1.3.4.2 Parking**2.1.3.4.2.a Parking Lots**

Use the minimum off-street parking requirements outlined in Thurston County Code Titles 20 to 23, as applicable for non-residential uses. Pervious materials should be considered for parking lots where feasible.

2.1.3.4.2.b 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 Thurston County Code Title 20 (Non-North County UGA), Title 21 (Lacey UGA), Title 22 (Tumwater UGA), or Title 23 (Olympia UGA) for restrictions and requirements on shared parking.

2.1.3.4.2.c 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.

2.1.3.4.3 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.04A Perforated Stub-out Connections
- LID.05 Downspout Dispersion Systems
- LID.06 Sheet Flow Dispersion
- LID.07 Concentrated Flow Dispersion
- LID.08 Bioretention
- LID.08A Rain Gardens
- LID.09 Permeable Pavements
- LID.10 Vegetated Roofs
- LID.11 Full Dispersion
- LID.12 Rural Road Natural Dispersion
- LID.13 Rural Road Engineered Dispersion
- LID.14 Tree Planting and Tree Retention (for Flow Control Credit)
- LID.15 Minimal Excavation Foundation Systems
- LID.16 Rainwater Harvesting

2.2.1 LID.04 Downspout Infiltration Systems

Downspout infiltration systems are used for infiltrating runoff from roof downspout drains and include infiltration trenches and drywells. They are not designed to directly infiltrate runoff from pollutant generating impervious surfaces.

Runoff surfaces that comply with this BMP are considered to be “fully infiltrated” (i.e., zero percent effective imperviousness).

2.2.1.1 Applicability

- Downspout infiltration can be used to help meet the flow control standards of Core Requirement #7.
- When used in combination with other onsite stormwater management BMPs, downspout infiltration can also help achieve compliance with Core Requirement #5.

2.2.1.2 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. All infiltration facilities must be at least 50 feet from the top of any slope over 40 percent. This setback may be reduced to 15 feet based on a geotechnical evaluation, but in no instances may it be less than the buffer width.

All infiltration system should be at least 10 feet from any structure, property line, or sensitive area (except slopes over 40%).

For sites with septic systems, infiltration systems must be downgradient of the drainfield unless the site topography clearly prohibits subsurface flows from intersecting the drainfield.

2.2.1.3 Submittals and Approval

2.2.1.3.1 UIC Registration

Infiltration drywells are considered underground injection chambers (UIC) and are therefore subject to Ecology UIC registration requirements, as noted in Chapter 3, with the following exceptions:

- 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 or are used to control basement flooding are not currently required to register as a UIC.

2.2.1.3.2 Soil Testing and Report

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

2.2.1.3.3 Pretreatment

No pretreatment is required.

2.2.1.4 Hydraulic, Hydrologic and Soil Design Considerations

2.2.1.4.1 Runoff Model Representation

Roof areas served by downspouts that drain to infiltration dry wells or infiltration trenches that are sized in accordance with this BMP do not have to be entered into the runoff model. They are presumed to fully infiltrate the roof runoff.

2.2.1.4.2 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 Core Requirements #7 (Flow Control).

2.2.1.4.3 Hydraulic Design Elements

A structure with a sump (see Figure 2.1) shall be located upstream of the infiltration trench or drywell, 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.

2.2.1.4.4 Procedure for Evaluating Feasibility

1. A soils report must be prepared by one of the following professionals to determine if soils suitable for infiltration are present on the site:
 - A professional soil scientist certified by the Soil Science Society of America (or an equivalent national program)
 - A locally licensed on-site sewage designer
 - A suitably trained person working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington.

The report shall reference a sufficient number of soils logs to establish the type and limits of soils on the project site. The report should at a minimum identify the limits of any outwash type soils (i.e., those meeting USDA soil

texture classes ranging from coarse sand and cobbles to medium sand) versus other soil types and include an inventory of topsoil depth.

2. Complete additional site-specific testing on lots or sites containing outwash (coarse sand and cobbles to medium sand) and loam type soils.

Individual lot or site tests must consist of at least one soils log at the location of the infiltration system, a minimum of 4 feet in depth from the proposed grade and at least 1 foot below the expected bottom elevation of the infiltration trench or drywell.

Identify the NRCS series of the soils and the USDA textural class of the soil horizon through the depth of the log, and note any evidence of high groundwater level, such as mottling.

3. Downspout full infiltration is considered feasible on lots or sites that meet all of the following:
 - 3 feet or more of permeable soil from the proposed final grade to the seasonal high groundwater table.
 - At least 1-foot clearance from the expected bottom elevation of the infiltration trench or dry well to the seasonal high groundwater table.
 - The downspout full infiltration system can be designed to meet the minimum design criteria specified below.

2.2.1.5 Design Criteria for Downspout Infiltration Systems

2.2.1.5.1 Downspout Infiltration Trench

Figure V - 2.2 shows a typical downspout infiltration trench system, and Figure V - 2.3 presents an alternative infiltration trench system for sites with coarse sand and cobble soils. These systems are designed as specified below.

2.2.1.5.2 Geometry

- Length of trench must not exceed 100 feet from the inlet sump
- Minimum spacing between distribution pipe centerlines must be 6 feet.
- The following minimum lengths (linear feet) per 1,000 square feet of roof area based on soil type may be used for sizing downspout infiltration trenches.
 - Course sands and cobbles: 20 LF
 - Medium sand: 30 LF

- Fine sand, loamy sand: 75 LF
 - Sandy loam: 125 LF
 - Loam: 190 LF
- Silt and clay type soils have a saturated hydraulic conductivity that is too small for adequate infiltration and are infeasible for downspout infiltration trenches.

2.2.1.5.3 Materials

- The aggregate material for the infiltration trench shall consist of $\frac{3}{4}$ " to 1- $\frac{1}{2}$ " diameter washed round rock that meets WSDOT Specification 9-03.12(5).
- 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. Trench length in fill shall be 60 linear feet per 1,000 square feet of roof area. Infiltration rates can be tested using the methods described in Volume III.

2.2.1.5.4 Other Design Criteria

- Infiltration trenches shall not be built on slopes steeper than 25 percent (4:1). A geotechnical analysis and report may be required on slopes over 15 percent or if the proposed trench is located within 200 feet of the top of a slope steeper than 40 percent, or in a geologic hazard area.
- Infiltration trenches may be located under pavement if a catch basin with grate cover is placed at the end of the trench pipe such that overflow would occur out of the catch basin at an elevation at least one foot below that of the pavement, and in a location which can accommodate the 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 a system failure.
- 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 6 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:
 - Trenches must, as nearly as practical, follow a contour line.
 - Parallel trenches shall be spaced no closer than 25 feet apart.



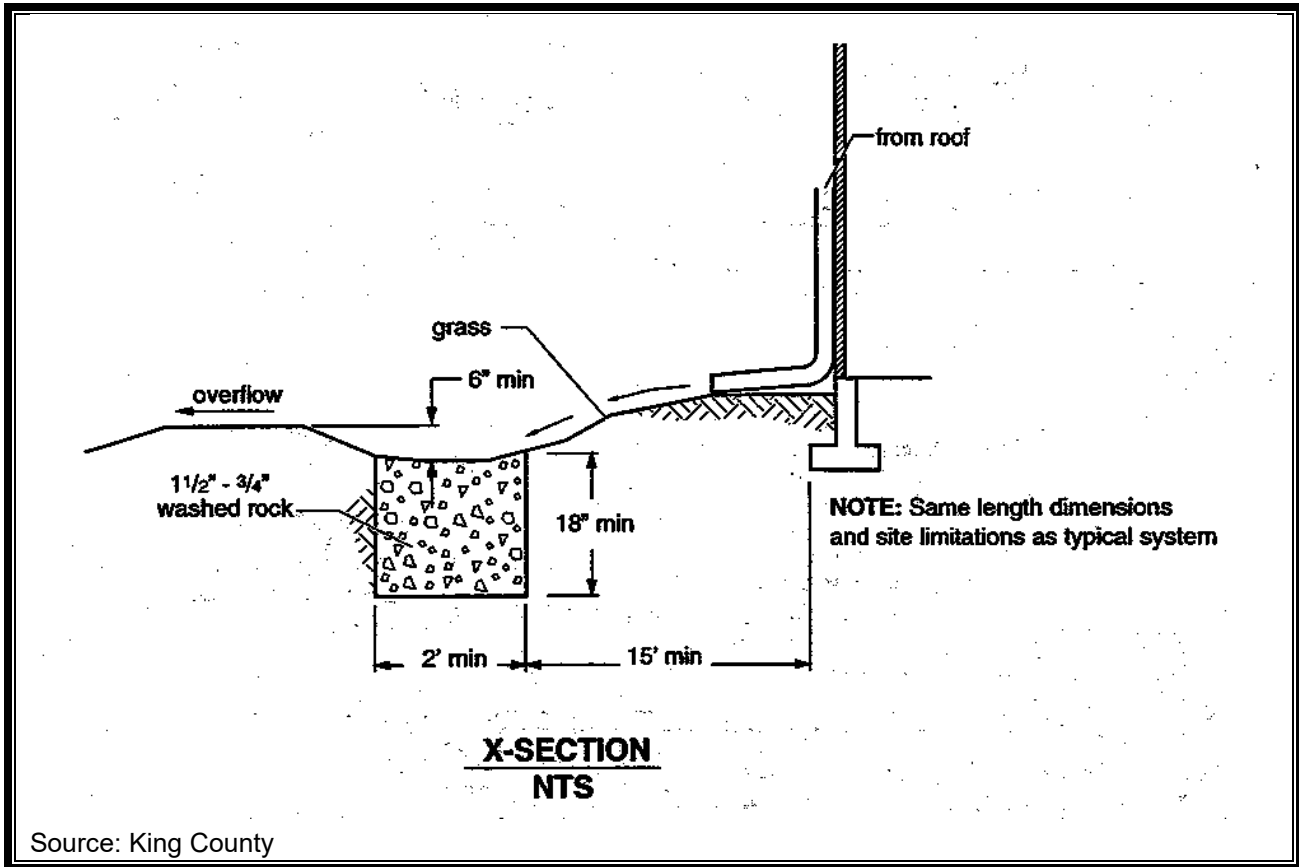


Figure V - 2.3 Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel

2.2.1.6 Design Criteria for Infiltration Drywell Systems

Two alternatives are available for infiltration drywells, Figure V - 2.4 presents the design of a typical downspout infiltration drywell system. When located in coarse sands and cobbles, drywells must contain a volume of gravel equal to or greater than 60 cubic feet per 1,000 square feet of impervious surface served. When located in medium sands, drywells must contain at least 90 cubic feet of gravel per 1,000 square feet of impervious surface served.

The simplified sizing for drywells as shown in Figure V - 2.3 may use alternative configurations such as shown in Figure V - 2.2 and be used for other soil types, but is limited to those projects located in rural areas (i.e. outside of the NPDES Phase II permit boundary and UGA's) or projects in urban areas that are not subject to Core Requirement #7. The drywells shall include a catch basin (as shown in Figure V - 2.4), or its equivalent upstream of the drywell for particulate removal. These systems are designed as specified below:

2.2.1.6.1 Simplified Sizing for Drywells

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

Table V - 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 (Silt, 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.

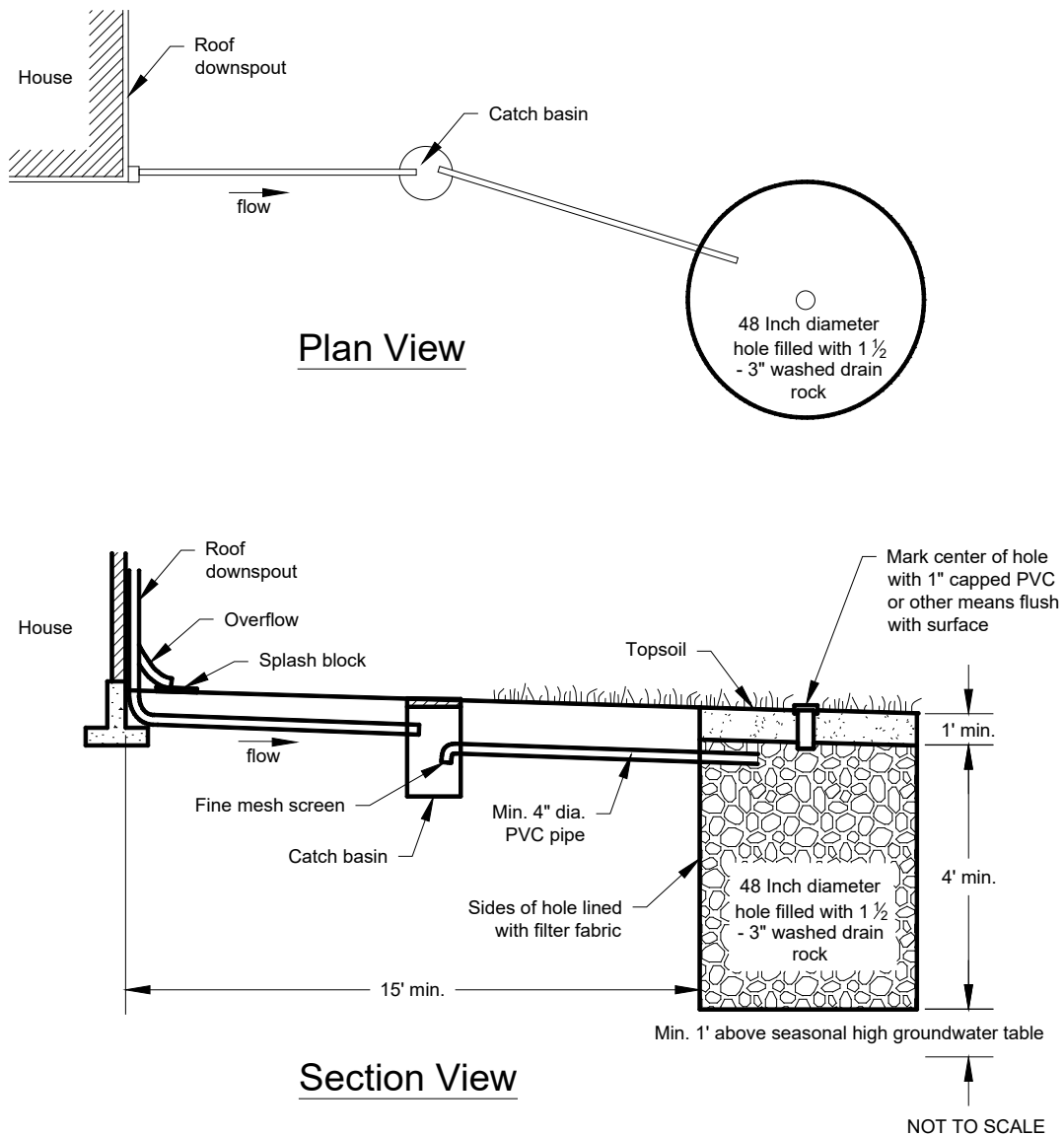
² Drywells are not recommended for Hydrologic Group D soils due to extremely slow percolation rates. Drywells should be used only if other reasonable alternatives are infeasible.

2.2.1.6.2 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 10 feet.

2.2.1.6.3 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: Department of Ecology

Figure V - 2.4 Typical Downspout Infiltration Drywell

Note: Catch Basin sump for infiltration drywells shall be consistent with CB Sump detail of Figure V - 2.1

2.2.1.6.4 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 a landslide hazard area or on slopes greater than 15 percent without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and with Thurston County acceptance from the DDECM Administrator (or designee).

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.).

2.2.1.6.5 Verification of Performance

The project engineer or designee shall inspect infiltration systems before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place. See Sections 3.1.5 and 3.1.6 below for all applicable requirements.

2.2.2 LID.04A Perforated Stub-out Connection

A perforated stub-out connection is a length of perforated pipe within a gravel-filled trench that is placed between roof downspouts and a stub-out to the local drainage system. Figure V - 2.5 illustrates a perforated stub-out connection. These systems are intended to provide some infiltration during drier months. During the wet winter months, they may provide little or no flow control.

2.2.2.1 Applications & Limitations

Perforated stub-outs are not appropriate when seasonal water table is less than one foot below trench bottom. In projects subject to Minimum Requirement #5 (see Volume I), perforated stub-out connections may be used only when all other higher priority on-site stormwater management BMPs are not feasible, per the criteria for each of those BMPs.

Select the location of the connection to allow a maximum amount of runoff to infiltrate into the ground (ideally a dry, relatively well drained, location). To facilitate maintenance, do not locate the perforated pipe portion of the system under impervious or heavily compacted (e.g., driveways and parking areas) surfaces. Use the same setbacks as for infiltration trenches in Appendix V-E – Site Design Elements.

Have a licensed geologist, hydrogeologist, or engineering geologist evaluate potential runoff discharges towards landslide hazard areas. Do not place the perforated portion of the pipe on or above slopes greater than 20% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or qualified geologist and jurisdiction approval.

For sites with septic systems, the perforated portion of the pipe must be downgradient of the drainfield primary and reserve areas. This requirement can be waived if site topography will clearly prohibit flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

2.2.2.2 Design Criteria

Perforated stub-out connections consist of at least 10 feet of perforated pipe per 5,000 square feet of roof area laid in a level, 2-foot wide trench backfilled with washed drain rock. Extend the drain rock to a depth of at least 8 inches below the bottom of the pipe and cover the pipe. Lay the pipe level and cover the rock trench with filter fabric and 6 inches of fill.

2.2.2.3 Runoff Model Representation

Any flow reduction is variable and unpredictable. No computer modeling techniques are allowed that would predict any reduction in flow rates and volumes from the connected area.

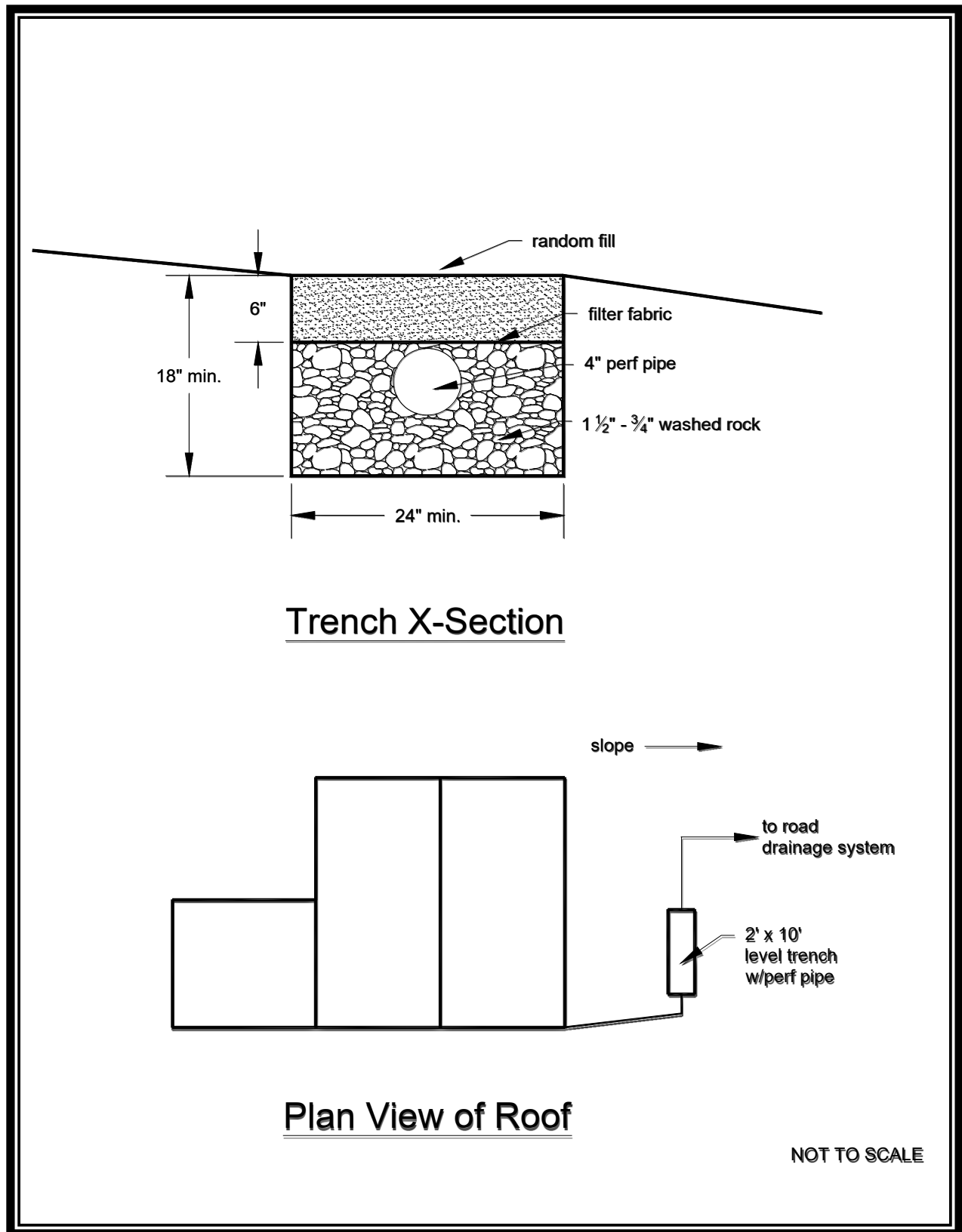


Figure V - 2.5 Perforated Stub-Out Connection, Source: Department of Ecology

2.2.3 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.

2.2.3.1 Applicability

- Downspout dispersion can be used to help meet the flow control standards of Core Requirement #7.
- When used in combination with other onsite stormwater management BMPs, downspout dispersion can also help achieve compliance with Core Requirement #5

2.2.3.2 Limitations

No erosion or flooding of downstream properties may result.

Have a geotechnical engineer or a licensed geologist, hydrogeologist, or engineering geologist evaluate runoff discharged towards landslide hazard areas. Do not place the discharge point from splash blocks or dispersion trenches on or above slopes greater than 15% or above erosion hazard areas without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and with Thurston County acceptance from the DDECM Administrator..

2.2.3.3 Hydrologic and Hydraulic Design Considerations

2.2.3.3.1 Runoff Model Representation

The designer has the following options to model the amount of Flow Control presumed to be provided by this BMP:

- When splashblocks or dispersion trenches are used per the guidance above, and the length of the vegetated flow path is at least 50 feet:
 - When modeling in an approved continuous runoff model, the connected roof area should be modeled as a lateral flow impervious area. Do this in WWHM or the Mitigated Scenario screen by connecting the dispersed impervious area (the roof area) to the lawn/landscaped lateral flow soil basin element representing the area that will be used for dispersion (the vegetated flow path).

In situations where multiple downspout dispersions will occur, Ecology allows the area to be modeled as a landscaped area

(grass) so that the project schematic in the approved continuous runoff model becomes manageable.

- When calculating the runoff curve number to include in calculations described in Volume III, Chapter 2, Single Event Hydrograph Method, the curve number may be determined by considering the roof areas as landscaped area (grass).
- When dispersion trenches are used per the guidance above, and the length of the vegetated flow path is 25 – 50 feet:
 - When modeling in an approved continuous runoff model, the connected roof area should be modeled as a lateral flow impervious area. Do this in WWHM on the Mitigated Scenario screen by connecting the dispersed impervious area (the roof area) to the lawn/landscape lateral flow soil basin element representing the area that will be used for dispersion (the vegetated flow path).

In situations where multiple downspout dispersions will occur, Ecology allows the roof area to be modeled as 50% landscaped/50% impervious so that the project schematic in the approved continuous runoff model becomes manageable.

- When calculating the runoff curve number to include in calculations described in Volume III, Chapter 2, Single Event Hydrograph Method, the curve number may be determined by considering the runoff areas as 50% landscaped/50% impervious.

2.2.3.4 Design Criteria

2.2.3.4.1 Dispersion Trenches

Dispersion trenches shall be designed as shown in Figure V - 2.6.

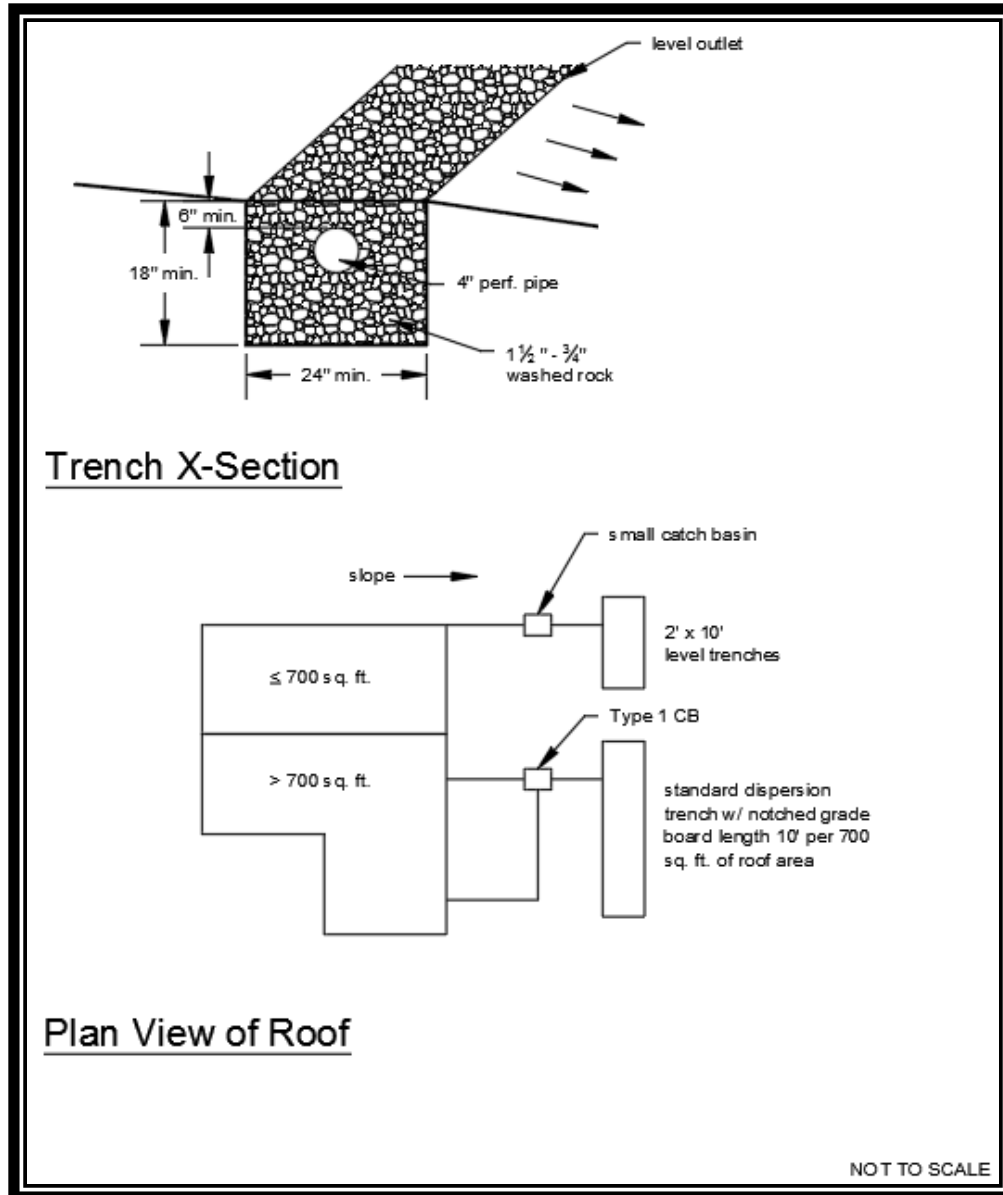


Figure V - 2.6 Typical Downspout Dispersion Trench

Note: Catch Basin or yard drain sump for downspout dispersion trench shall be consistent with CB Sump detail of Figure V - 2.1

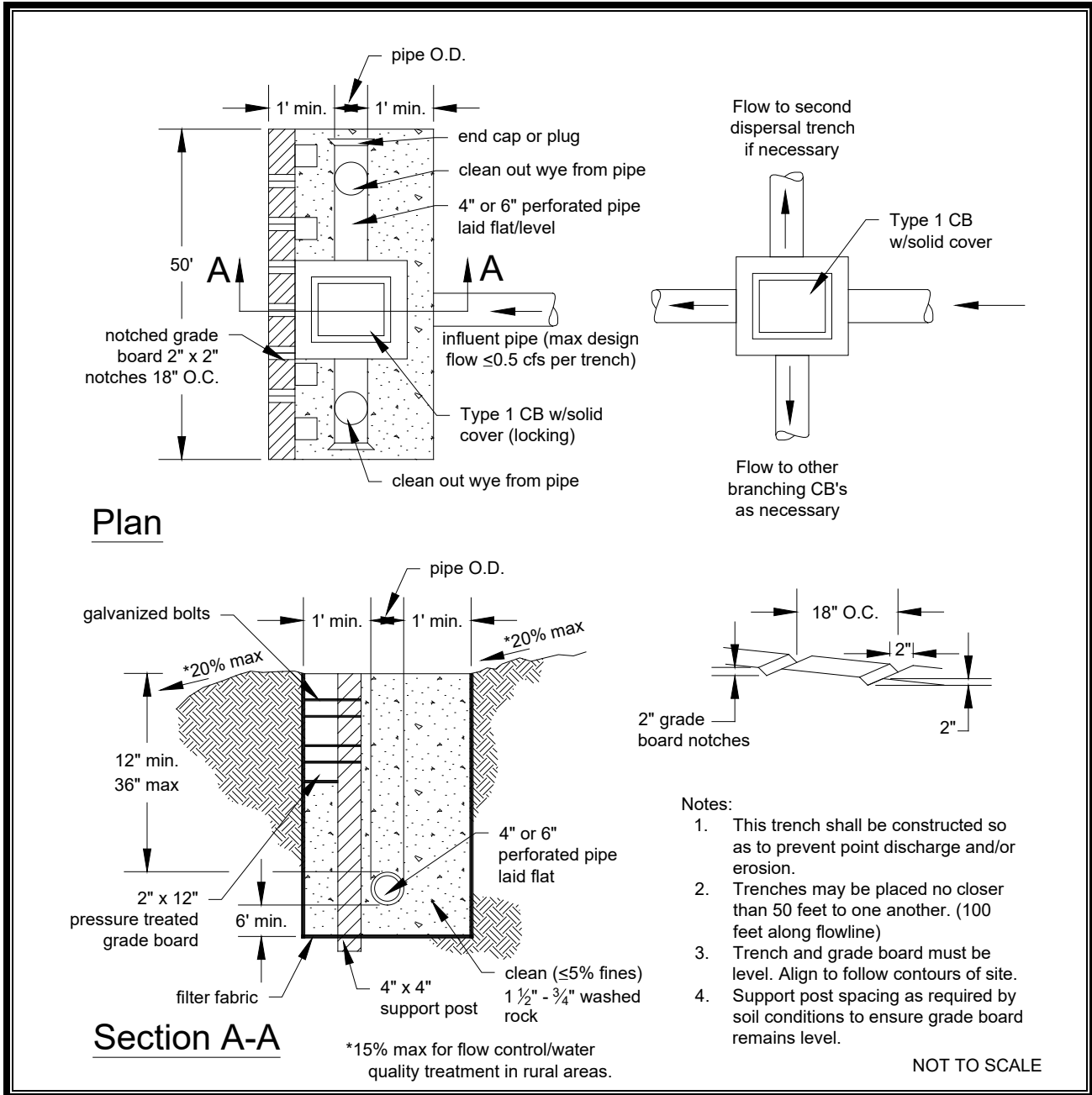


Figure V - 2.7 Standard dispersion trench with Notched Grade Board.

Source: Department of Ecology

- A vegetated flow path at least 25 feet in length must be maintained between the outlet of the dispersion trench and any property line, structure, critical area (i.e., stream, wetland), or impervious surface. A vegetated flow path of at least 50 feet in length must be maintained between the outlet of the trench and any slope steeper than 15%. Critical area buffers may count towards flow path lengths. However, the critical area buffer 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 V - 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.

2.2.3.4.2 Splash Blocks

Splash blocks shall be designed as shown in Figure V - 2.8

In general, if the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion, splash blocks will adequately disperse storm runoff. If the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions may be a better choice because the discharge point is moved away from the foundation. Downspout extensions can include piping to a splashblock/discharge point a considerable distance from the downspout, as long as the runoff can travel through a well-vegetated area as described below:

- Maintain a vegetated flow path of at least 50 feet between the discharge point and any property line, structure, slope steeper than 15%, stream, wetland, lake, or other impervious surface. Sensitive area buffers may count toward flow path lengths.
- A maximum of 700 square feet of roof area may drain to each splash block.
- Place a splash block or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) at each downspout discharge point.

2.2.3.5 Site Design Elements

2.2.3.5.1 Vegetated Flow path

For both dispersion trenches and splash blocks, the vegetated flow path must consist of well-established lawn or pasture, landscaping with well-established groundcover, native vegetation with natural groundcover, or an area that meets the requirements of BMP

LID.02, Soil Amendments, Quality and Depth. The groundcover shall be dense enough to help disperse and infiltrate flows and to prevent erosion.

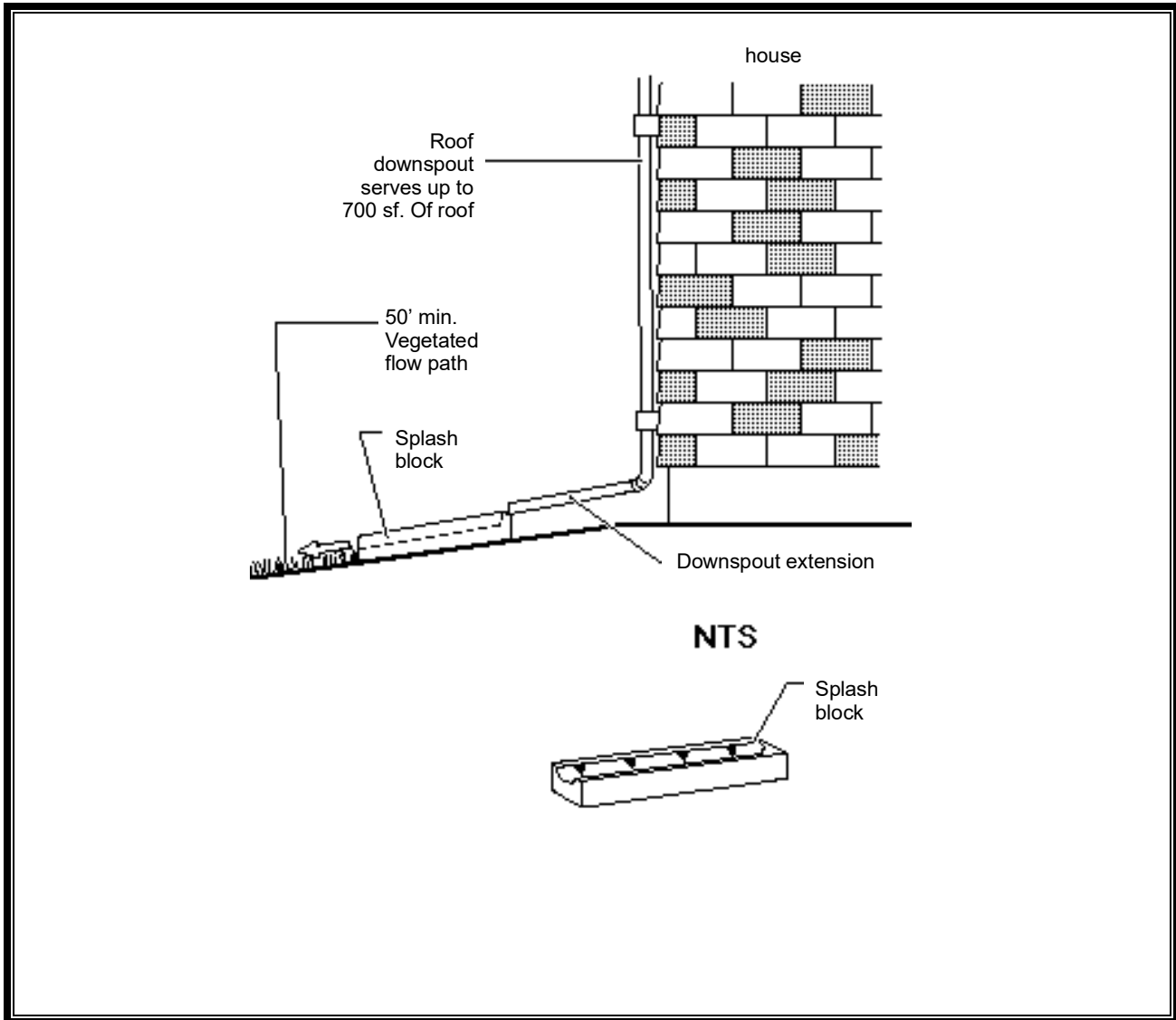


Figure V - 2.8 Typical Downspout Splash block Dispersion

2.2.3.5.2 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 may be required to address the potential impact of the facility on the slope. Increased setbacks or prohibition of infiltration facilities may result from this report. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

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 or where site conditions (soil permeability, distance between systems, etc.) indicate that this unnecessary.

A setback of at least 5 feet shall be maintained between any edge of a dispersion trench and any structure or property line.

2.2.4 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 on-site stormwater management.

2.2.4.1 Applicability

Use this BMP for flat or moderately sloping (less than 15 percent) surfaces such as driveways, private roadways, sport courts, patios, roofs without gutters, lawns, or pastures, or any situation where concentration of flows can be avoided.

When used in combination with other onsite stormwater management BMPs, sheet flow dispersion can also help achieve compliance with the Performance Standard option of Core Requirement #5.

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: Full Dispersion) 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 Municipal 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.

2.2.4.2 Limitations

No erosion or flooding of downstream properties may result.

2.2.4.3 Hydrologic and Hydraulic Design Considerations

Runoff Model Representation

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: Post-Construction Soil Quality and Depth, the impervious area should be modeled as a lateral flow impervious area. Do this in the WWHM on the Mitigated Scenario screen by connecting the lateral flow impervious area element (representing the area that is dispersed) to the lawn/landscape lateral flow soil basin element (representing the area that will be used for dispersion).

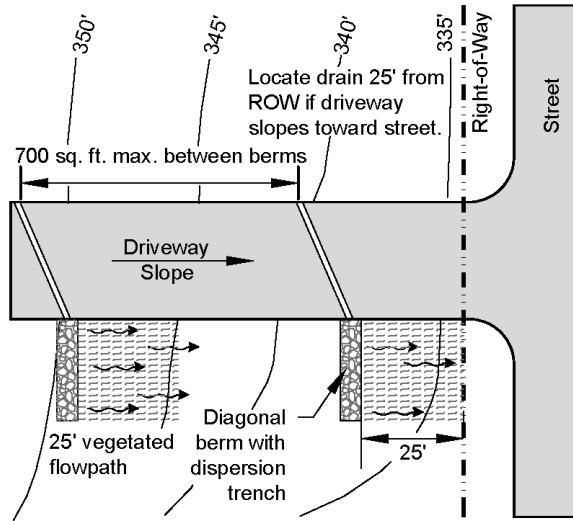
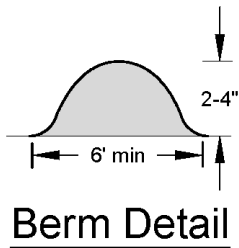
2.2.4.4 Design Criteria

See Figure V - 2.9 for details for driveways.

See BMP LID.05: Downspout Dispersion System for dispersion trench design criteria.

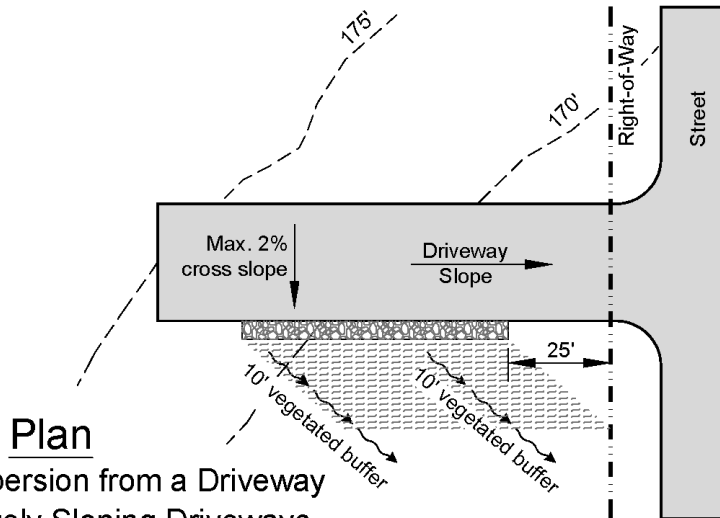
A transition zone (2-foot minimum) to discourage channeling shall be provided between the edge of the impervious surface and the downslope vegetation, or under building eaves. This may be an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material approved by Thurston County and shall be lower than the adjacent impervious surface by approximately 1-inch.

Source: King County Department of Natural Resources, 1998



Plan

Driveway Dispersion Trench
Driveway Slope Varies and Slopes Toward Street



Plan

Sheet Flow Dispersion from a Driveway
Flat to Moderately Sloping Driveways

NOT TO SCALE



Sheet Flow Dispersion for Driveways

Revised December 2016

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Figure V - 2.9 Sheet Flow Dispersion for Driveways

A vegetated buffer width of 10 feet must be provided for up to 20 feet of width of paved or impervious surface. An additional 10 feet of width must be added for each additional 20 feet of width (or fraction thereof). For example, if a driveway is 30 feet wide and 60 feet long provide a 20-foot wide by 60-foot long vegetated buffer, with a 2-foot by 60-foot transition zone.

2.2.4.5 Site Design Elements

Sheet flow dispersion may not be appropriate where the drainage discharges toward slopes steeper than 20 percent or geologic hazard areas as defined by TCC 17.15 or TCC Title 24. The Administrator or designee may require a geotechnical report to evaluate whether a slope exceeding 20 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.

For sites with septic systems, the discharge area must be 10 feet downgradient of the drainfield primary and reserve areas (WAC 246-272A-0210). Thurston County may waive this requirement if site topography clearly prohibits flow from intersecting the drainfield.

2.2.5 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 V - 2.10.

2.2.5.1 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: Full Dispersion) in terms of maximum impervious surface and native vegetation retention. If the minimum requirements of BMP LID.11: Full Dispersion 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.

When used in combination with other onsite stormwater management BMPs, concentrated flow dispersion can also help achieve compliance with the Performance Standard option of Core Requirement #5.

Figure V - 2.10 shows two possible ways of spreading flows from steep driveways.

2.2.5.2 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.

Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. Do not place the discharge point on or above slopes greater than 20%, or above erosion hazard areas, without assessment by a geotechnical engineer or qualified geologist and with Thurston County acceptance from the DDECM Administrator.

2.2.5.3 Submittals and Approval

Runoff discharged towards geologic or landslide hazard areas as defined by TCC 17 and 24 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.

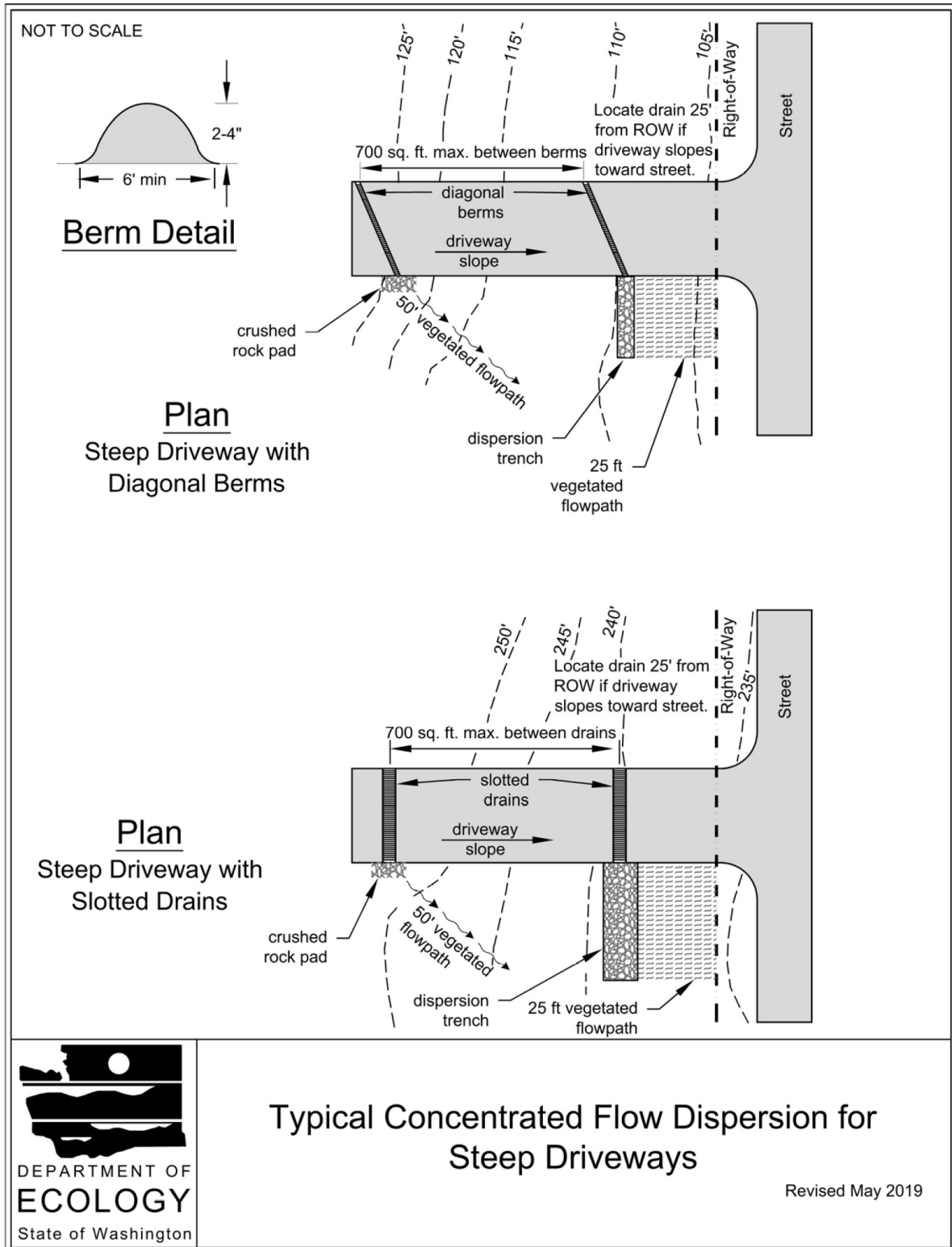


Figure V - 2.10 Typical Concentrated Flow Dispersion for Steep Driveways

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.

2.2.5.4 Hydrologic and Hydraulic Design Considerations

2.2.5.4.1 Runoff Model Representation

Where concentrated flow dispersion is used to disperse impervious area runoff into an undisturbed native landscape area or an area that meets BMP LID.02:Post-Construction Soil Quality and Depth, the impervious area should be modeled as a lateral flow impervious area. Do this in WWHM on the Mitigated Scenario screen by connecting the lateral flow impervious area element (representing the area that is dispersed) to the lawn/landscape lateral flow soil basin element (representing the area that will be used for dispersion). The design must adhere to the flow path lengths and dispersion trench/rock pad options described in 2.2.5.5 below as a prerequisite to using the lateral flow elements.

In situations where multiple instances of concentrated flow dispersion will occur, the following options are allowed:

- When a pad of crushed rock or dispersion trenches are used per the guidance above, and the length of the vegetated flow path is at least 50 feet, the impervious area may be modeled as a landscaped area (grass) so that the project schematic in the approved continuous runoff model becomes manageable.
- When dispersion trenches are used per the guidance above, and the length of the vegetated flow path is 25 - 50 feet, the impervious area may be modeled as 50%landscaped / 50%impervious so that the project schematic in the approved continuous runoff model becomes manageable.

2.2.5.5 Design Criteria

Maintain a vegetated flow path of at least 25 feet between the discharge point and any property line, structure, steep slope, stream, wetland, lake, or other impervious surface..

- If the vegetated flow path is 25 – 50 ft, the design must include a dispersion trench prior to discharge over the vegetated flow path.
- If the vegetated flow path is 50 ft or more, the design may use either a dispersion trench or pad of crushed rock (as described below) prior to discharge over the vegetated flow path.

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.

See BMP LID.05: Downspout Dispersion Systems for dispersion trench design criteria.

2.2.5.6 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.

2.2.6 LID.08 Bioretention

2.2.6.1 Description

Bioretention has the potential to meet Core Requirement #5: Onsite Stormwater Management, Core Requirement #6: Runoff Treatment, and Core Requirement #7: Flow Control for the tributary drainage areas depending upon site conditions and sizing.

The purpose of bioretention is to provide effective removal of many stormwater pollutants, and provide reductions in stormwater runoff quantity and surface runoff flow rates. Where the surrounding native soils have adequate infiltration rates, bioretention can provide both Runoff Treatment and Flow Control. Where the native soils have low infiltration rates, underdrain systems can be installed and the bioretention BMP can still be used as a Runoff Treatment BMP. However, designs utilizing underdrains provide less Flow Control benefits.

Bioretention areas are shallow landscaped depressions, with a designed soil mix (the bioretention soil mix) and plants adapted to the local climate and soil moisture conditions, that receive stormwater from a contributing area.

Bioretention uses the imported bioretention soil mix as a treatment medium. As in infiltration, the pollutant removal mechanisms include filtration, adsorption, and biological action. Bioretention BMPs can be built within earthen swales or placed within vaults. Water that has passed through the bioretention soil mix (or approved equivalent) may be discharged to the ground or collected and discharged to surface water.

The terms bioretention and rain garden are sometimes used interchangeably. Bioretention areas and rain gardens are applications of the same LID concept and can be highly effective for reducing surface runoff and removing pollutants. Although rain gardens provide pollutant removal benefits, the amount of benefit is unquantifiable. Therefore, rain gardens cannot be used to meet:

- The LID Performance Standard or List #2 within Core Requirement #5: Onsite Stormwater Management,

- Core Requirement #6: Runoff Treatment,
- Core Requirement #7: Flow Control, or
- Core Requirement #8: Wetlands Protection

In Thurston County (in accordance with the Department of Ecology's distinction), the term bioretention is used to describe an engineered facility that includes designed soil mixes and perhaps underdrains and control structures. The term, rain garden, is used to describe a non-engineered, shallow landscaped depression with compost-amended soils and adapted plants. Rain gardens function by storing stormwater as surface ponding before it filters through the underlying amended soil. Stormwater that exceeds the surface storage capacity overflows to an adjacent drainage system. A portion of the treated water is infiltrated into the underlying soil.

Rain gardens have less restrictive design criteria for the soil mix and do not include underdrains or other control structures. See *Rain Garden Handbook for Western Washington: A Guide for Design, Installation, and Maintenance* (WSU, 2013 or as revised) for more information on rain garden design.

The term, bioretention, is used to describe various designs using soil and plant complexes to manage stormwater. The following terminology is used in this manual:

- **Bioretention cells:** Shallow depressions with a designed planting soil mix and a variety of plant material, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells may or may not have an underdrain and are not designed as a conveyance system.
- **Bioretention swales:** Incorporate the same design features as bioretention cells; however, bioretention swales are designed as part of a system that can convey stormwater when maximum ponding depth is exceeded. Bioretention swales have relatively gentle side slopes and ponding depths that are typically 6 to 12 inches.
- **Bioretention planters and planter boxes:** Designed soil mix and a variety of plant material including trees, shrubs, grasses, and/or other herbaceous plants within a vertical walled container usually constructed from formed concrete, but could include other materials. Planter boxes are completely impervious and include a bottom (must include an underdrain). Planters have an open bottom and allow infiltration to the subgrade. These designs are often used in ultra-urban settings.

Note: Ecology has approved use of certain manufactured treatment that use specific, high rate media for treatment. Such systems do not use bioretention soil mix, are not considered a bioretention BMP (even though marketing materials for these

manufactured treatment devices may compare them to bioretention). See Chapter 9 – Emerging Technologies for more information on manufactured treatment devices.

Figure V - 2.11 Bioretention Area (shown with optional underdrain) - Source Pierce County provides an example illustration of a bioretention area. See Attachments Section A, Details 26.0, 26.1, and 26.2 for examples of bioretention areas in various configurations and site settings.

2.2.6.2 Applications and Limitations

Because bioretention BMPs use an imported soil mix that has a moderate design infiltration rate, they are best applied for small drainages, and near the source of the stormwater runoff. Bioretention cells may be scattered throughout a subdivision; a bioretention swale may run alongside the access road; or a series of bioretention planter boxes may serve the road. In these situations, they can but are not required to fully meet the requirement to treat 91% of the stormwater runoff file (the Water Quality Design Volume, as described in Volume III, 2.3 Sizing Runoff Treatment BMPs) from pollution-generating surfaces. The amount of stormwater that is predicted to pass through the bioretention soil mix is treated, and may be subtracted from the 91% volume that must be treated to meet Core Requirement #6: Runoff Treatment. Downstream Runoff Treatment BMPs may be significantly smaller as a result.

Bioretention BMPs that infiltrate into the ground can also provide significant Flow Control. They can, but are not required to fully meet the Flow Control Performance Standard of Core Requirement #7: Flow Control. Because they typically do not have an orifice restricting overflow or underflow discharge rates, they typically don't fully meet Core Requirement #7: Flow Control. However, their performance contributes to meeting the standard, and that can result in much smaller additional Flow Control BMPs at the bottom of the project site. Bioretention can also help achieve compliance with the LID Performance Standard of Core Requirement #5: Onsite Stormwater Management.

Bioretention constructed with imported composted material should not be used within one-quarter mile of phosphorus-sensitive waterbodies if the underlying native soil does not meet the criteria for Runoff Treatment per Volume V, Chapter 2.3 Site Suitability and Hydrologic Analysis of Infiltration Facilities. Preliminary monitoring indicates that new bioretention BMPs can add phosphorus to stormwater. Therefore, they should also not be used with an underdrain when the underdrain water would be routed to a phosphorus-sensitive receiving water.

In May of 2021, Ecology released *publication 21-10-023: Guidance on using new high performance bioretention soil mixes*. This report provides information on a new alternative bioretention soil mix (BSM) that can be used in locations near phosphorus-sensitive waterbodies. The report provides the specifications for the new BSM, the treatment performance of the new BSM, and the regulatory status of the new BSM in the municipal stormwater NPDES permit program. Refer to the report for projects which plan to include bioretention BMPs in locations near phosphorus-sensitive waterbodies.

Bioretention areas are applicable to new development, redevelopment and retrofit projects. Typical applications with or without underdrains include:

- Individual lots for rooftop, driveway, and other on-lot impervious surface.
- Shared facilities located in common areas for individual lots.
- Areas within loop roads or cul-de-sacs.
- Landscaped parking lot islands (i.e., situated lower than the height of the parking lot surface so that stormwater runoff is directed as sheet flow into the bioretention area.). This application, in concert with permeable surfaces in the parking lot, can greatly attenuate stormwater runoff.
- Within rights-of-ways along roads (often linear bioretention swales and cells).
- Common landscaped areas in apartment complexes or other multifamily housing designs.
- Planters on building roofs, patios, and as part of streetscapes.

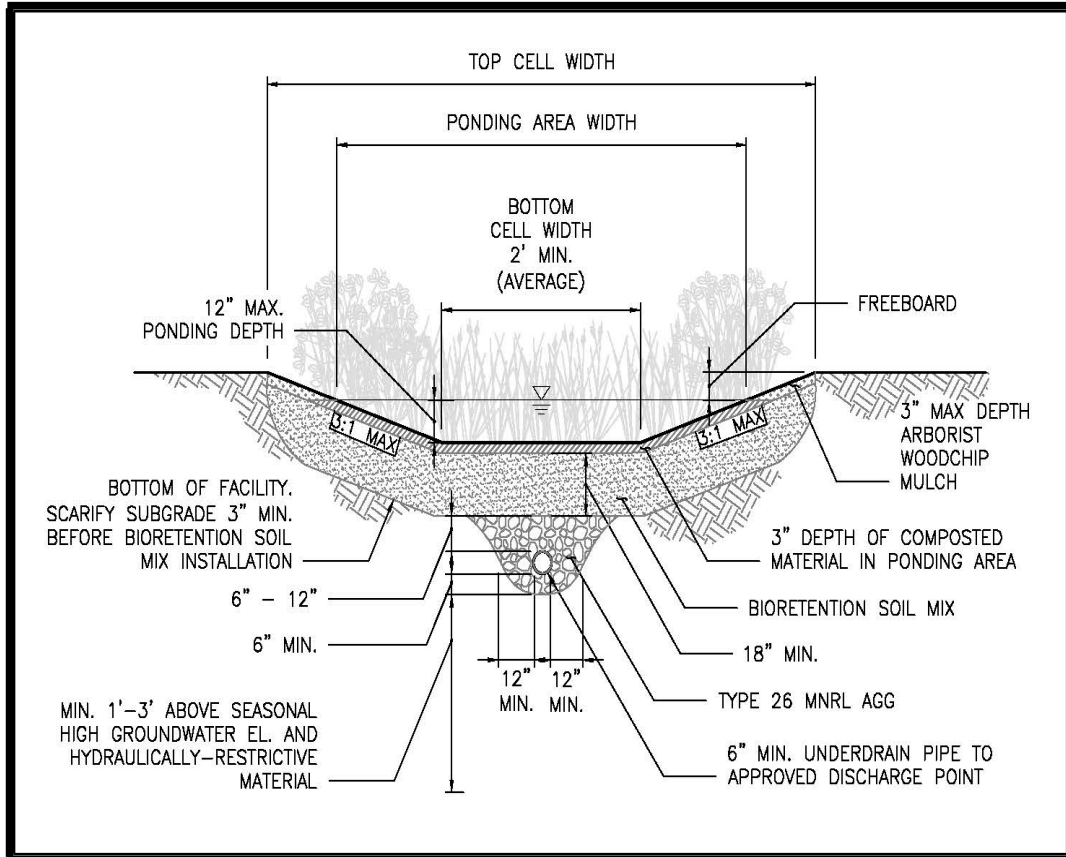


Figure V - 2.11 Bioretention Area (shown with optional underdrain) - Source Pierce County

2.2.6.3 Infeasibility Criteria

See Appendix III-D in Volume III for infeasibility criteria. The criteria describe conditions that make bioretention infeasible when applying The List Approach within Core Requirement #5: Onsite Stormwater Management. In addition, other bioretention design criteria and site limitations that make bioretention areas infeasible (e.g., setback requirements) may also be used to demonstrate infeasibility, subject to approval by the county. If a project proponent wishes to use a bioretention BMP though not required to because of these feasibility criteria, they may propose a functional design to the county.

2.2.6.3.1 Other Site Suitability Factors:

- Utility conflicts:** Consult Thurston County requirements for horizontal and vertical separation required for publicly-owned utilities, such as sewer. Consult the appropriate franchise utility owners for separation requirements from their utilities, which may include communications, water, power, and gas. When separation requirements cannot be met, designs should include appropriate mitigation measures, such as

impermeable liners over the utility, sleeving utilities, fixing known leaky joints or cracked conduits, and/or adding an underdrain to the bioretention.

- **Transportation safety:** The design configuration and selected plant types should provide adequate sight distances, clear zones, and appropriate setbacks for roadway applications in accordance with the County's requirements.
- **Ponding depth and surface water draw-down:** Flow control needs, as well as location in the development, and mosquito breeding cycles will determine draw-down timing. For example, front yards and entrances to residential or commercial developments may require rapid surface dewatering for aesthetics.
- **Impacts of surrounding activities:** Human activity influences the location of the facility in the development. For example, locate bioretention areas away from traveled areas on individual lots to prevent soil compaction and damage to vegetation or provide elevated or bermed pathways in areas where foot traffic is inevitable and provide barriers, such as wheel stops, to restrict vehicle access in roadside applications.
- **Visual buffering:** Bioretention areas can be used to buffer structures from roads, enhance privacy among residences, and for an aesthetic site feature.
- **Site growing characteristics and plant selection:** Appropriate plants should be selected for sun exposure, soil moisture, and adjacent plant communities. Native species or hardy cultivars are recommended and can flourish in the properly designed and placed bioretention soil mix with no nutrient or pesticide inputs and 2 to 3 years irrigation for establishment. Invasive species control may be necessary.

2.2.6.4 Modeling and Sizing

Note that if the project is using bioretention to only meet The List Approach within Core Requirement #5: Onsite Stormwater Management, there is no need to model the bioretention in a continuous runoff model. Size the bioretention as described above in Ponding Area.

This guidance is to show compliance with the LID Performance Standard in Core Requirement #5: Onsite Stormwater Management, or the standards in Core Requirement #6: Runoff Treatment, Core Requirement #7: Flow Control, and/or Core Requirement #8: Wetlands Protection.

Continuous runoff modeling software include modeling elements for bioretention.

The equations used by the elements are intended to simulate the wetting and drying of soil as well as how the soils function once they are saturated. This group of LID elements uses the modified Green Ampt equation to compute the surface infiltration into the amended soil. The water then moves through the top amended soil layer at the computed rate, determined by Darcy's and Van Genuchten's equations. As the soil approaches field capacity (i.e., gravity head is greater than matric head), the model determines when water will begin to infiltrate into the second soil layer (lower layer). This occurs when the matric head is less than the gravity head in the first layer (top layer). The second layer is intended to prevent loss of the amended soil layer. As the second layer approaches field capacity, the water begins to move into the third layer – the gravel underlayer. For each layer, the user inputs the depth of the layer and the type of soil.

Within the WWHM continuous runoff model, for the Ecology-recommended soil specifications for each layer in the design criteria for bioretention, the model will automatically assign pre-determined appropriate values for parameters that determine water movement through that soil. These include: wilting point, minimum hydraulic conductivity, maximum saturated hydraulic conductivity, and the Van Genuchten number.

For bioretention with underlying perforated drain pipes that discharge to the surface, the only volume available for storage (and modeled as storage as explained herein) is the void space within the aggregate bedding layer below the invert of the drain pipe. Use 40% void space for the Type 26 mineral aggregate specified in Underdrain (optional) (above).

Modeling:

It is preferable to enter each bioretention device and its drainage area into the approved computer models for estimating their performance.

However, where site layouts involve multiple bioretention facilities, the modeling schematic can become extremely complicated or not accommodated by the available schematic grid.

In those multiple bioretention facilities with similar designs (i.e., soil depth, ponding depth, freeboard height, and drainage area to ponding area ratio), and infiltration rates (Ecology suggests within a factor of 2) may have their drainage areas and ponded areas be combined, and represented in the runoff model as one drainage area and one bioretention device. In this case, use a weighted average of the design infiltration rates at each location. The averages are weighted by the size of their drainage areas.

For bioretention with slide slopes of 3H:1V or flatter, infiltration through the side slope areas can be significant. Where side slopes are 3H:1V or flatter, bioretention can be modeled allowing infiltration through the side slope areas to the native soil. In WWHM,

modeling of infiltration through the side slope areas is accomplished by switching the default setting for “Use Wetted Surface Area (sidewalls): from “NO” to “YES.”

2.2.7 Field and Design Procedures

Geotechnical analysis is an important first step to develop an initial assessment of the variability of site soils, infiltration characteristics and the necessary frequency and depth of infiltration tests. This section includes infiltration testing requirements and application of appropriate safety factors specific to bioretention areas.

Refer to Appendix III-A for detailed descriptions of methods for infiltration rate testing procedures; however, note that the subgrade safety factors in Appendix III-A may not apply to bioretention (additional details provided below).

If the bioretention area includes a liner and does not infiltrate into the underlying soils, they are not considered infiltration facilities and are not subject the infiltration procedures or the setbacks provided in this section. Adhere to setbacks and site constraints for detention vaults included in Section 4.1.3.5.1 for these facilities.

2.2.7.1.1 Determining Design Infiltration Rate

2.2.7.1.1.a Determining the Native Soil Infiltration Rates

Determining the infiltration rate of the site soils is necessary to determine feasibility of designs that intend to infiltrate stormwater on site. It is also necessary to estimate flow reduction benefits of such designs when using a continuous runoff model.

The certified soils professional or engineer can exercise discretion concerning the need for and extent of infiltration rate (saturated hydraulic conductivity, K_{sat}) testing. The professional can consider a reduction in the extent of infiltration (K_{sat}) testing if, in their judgment, information exists confirming that the site is unconsolidated outwash material with high infiltration rates, and there is adequate separation from groundwater.

Initial (measured) infiltration rates are determined through soil infiltration tests. Infiltration tests should be run at the anticipated elevation of the top of the native soil beneath the bioretention area. The following provides recommended test procedures for analysis of the soils underlying bioretention BMP.

Refer to Volume III, Determine Design Infiltration Rate in section 2.7 for further guidance on the methods to determine the infiltration rate of the native soils.

- For small bioretention cells (bioretention areas receiving water from 1 or 2 individual lots or < 0.25 acre of pavement or other impervious surface), a small-scale PIT, or other methods outlined in Appendix III-A, should be performed at each potential bioretention site. Tests at more than one site could reveal the advantages of one location over another.

- For large bioretention cells (bioretention areas receiving water from several lots or 0.25 acre or more of pavement or other impervious surface), a small-scale PIT, or other methods outlined in Appendix III-A should be performed every 5,000 square feet. The more test pits/borings used, and the more evidence of consistency in the soils, the less of a safety factor may be used. If soil characteristics across the site are consistent, a geotechnical professional may recommend a reduction in the number of tests.
 - If using the PIT method, multiple small-scale or one large-scale PIT can be used. If using the small-scale test, measurements should be taken at several locations within the area of interest.
- For bioretention swales or long, narrow bioretention areas (i.e., one following the road right-of-way), small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A should be performed every 200 lineal feet and within each length of road with varying subsurface characteristics, i.e., groundwater elevation, soils type, infiltration rates. However, if the site subsurface characterization, including soil borings across the development site, indicate consistent soil characteristics and depths to seasonal high groundwater conditions, the number of test locations may be reduced to a frequency recommended by a geotechnical professional.
- Test hole or test pit explorations shall be conducted during mid to late in the wet season (December 1 through April 30) to provide accurate groundwater saturation and groundwater information.
- The soil log shall extend a minimum of 4 feet below the bottom of the subgrade (which is the lowest point of excavation where soil is to be amended).
- Note that only the small-scale or large-scale PIT methods may be used to demonstrate infeasibility for Minimum Requirement #5 (i.e., measured infiltration rate of less than 0.3 inches per hour).
- If a single bioretention area serves a drainage area exceeding one acre, infiltration receptor analysis and performance testing, as well as a mounding analysis may be necessary. See Volume III Section 2.7 for specific requirements for infiltration receptor characterization and mounding analysis.

Assignment of Appropriate Correction Factor

- If deemed necessary by a qualified professional engineer, a correction factor may be applied to the measured Ksat of the subgrade soils to estimate its design (long-term) infiltration rate. Depending on the size of

the facility, the variability of the underlying soils, and the number of infiltration tests performed, a correction factor may be advisable. (Note: This is a separate design issue from the assignment of a safety factor to the overlying, designed bioretention soil mix. See the “Bioretention Soil Mix” subsection below).

The overlying bioretention soil mix provides excellent protection for the underlying native soil from sedimentation. Accordingly, when using the simplified approach to calculating the design infiltration rate, a correction factor for the sub-grade soil) does not have to take into consideration the extent of influent control and clogging over time. The correction factor to be applied to in-situ, small-scale infiltration test results for bioretention sites is determined by the site variability and number of locations tested as well as the method used to determine initial K_{sat} . Using Volume III, Table III - 4.1: Correction Factors to be Used With In-Situ Saturated Hydraulic Conductivity Measurements to Estimate Design Rates, the correction factor for bioretention design is revised based on this guidance as:

$$\text{Total Correction Factor, } CF_T = CF_V \times CF_t$$

- Tests should be located and be at an adequate frequency capable of producing a soil profile characterization that fully represents the infiltration capability where the bioretention areas are to be located. The partial correction factor CF_V depends on the level of uncertainty that variable subsurface conditions justify. If a pilot infiltration test is conducted for all bioretention areas or the range of uncertainty is low (for example, conditions are known to be uniform through previous exploration and site geological factors) one pilot infiltration test may be adequate to justify a CF_V of one. If the level of uncertainty is high, a CF_V near the low end of the range may be appropriate. Two example scenarios where low CF_V s may be appropriate include:
 - Site conditions are highly variable due to a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high.
 - Conditions are variable, but few explorations and only one pilot infiltration test is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

2.2.7.1.1.b Determining the Bioretention Soil Mix Design Infiltration Rate

- Determine the initial saturated hydraulic conductivity (K_{sat}) based on the type of bioretention soil mix, as follows:

- If using Ecology's default bioretention soil mix (detailed below), the initial K_{sat} is 12 inches per hour (30.48 cm/hr).
- If using a custom bioretention soil mix (per the guidance for custom mixes below), use ASTM D 2434 Standard Test Method for Permeability of Granular Soils (Constant Head) with a compaction rate of 85 percent using ASTM D1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. See the additional guidance below for specific procedures for conducting ASTM D 2434. The designer must enter the derived K_{sat} value into the continuous modeling software.
- After determining the initial K_{sat}, determine the appropriate safety factor:
 - If the contributing area to the bioretention BMP is equal to or exceeds any of the following limitations:
 - 5,000 square feet of pollution-generating impervious surface;
 - 10,000 square feet of impervious surface;
 - $\frac{3}{4}$ acre of lawn and landscape;
 - Use 4 as the K_{sat} safety factor.
 - If the contributing area is less than all of the above areas, or the design includes a pretreatment BMP for solids removal, use 2 as the K_{sat} safety factor.
- The continuous runoff model has a field for entering K_{sat} and the appropriate safety factor.

Recommended Modifications to ASTM D 2434 When Measuring Hydraulic Conductivity for Bioretention Soil Mixes

Proctor method ASTM D1557 Method C (6-inch mold) shall be used to determine maximum dry density values for compaction of the bioretention soil sample. Sample preparation for the Proctor test shall be amended in the following ways:

1. Maximum grain size within the sample shall be no more than $\frac{1}{2}$ inches in size.
2. Snip larger organic particles (if present) into $\frac{1}{2}$ inch long pieces.
3. When adding water to the sample during the Proctor test, allow the sample to pre-soak for at least 48 hours to allow the organics to fully saturate before

compacting the sample. This pre-soak ensures the organics have been fully saturated at the time of the test.

ASTM D2434 shall be used and amended in the following ways:

1. Apparatus:

- a. 6-inch mold size shall be used for the test.
- b. If using porous stone disks for the testing, the permeability of the stone disk shall be measured before and after the soil tests to ensure clogging or decreased permeability has not occurred during testing.
- c. Use the confined testing method, with 5- to 10-pound force spring.
- d. Use de-aired water.

2. Sample:

- a. Maximum grain size within the sample shall not be more than ½ inch in size.
- b. Snip larger organic particles (if present) into ½-inch long pieces.
- c. Pre-soak the sample for at least 48 hours prior to loading it into the mold. During the pre-soak, the moisture content shall be higher than optimum moisture but less than full saturation (i.e., there shall be no free water). This pre-soak ensures the organics have been fully saturated at the time of the test.

3. Preparation of Sample:

- a. Place soil in cylinder via a scoop.
- b. Place soil in 1-inch lifts and compact using a 2-inch-diameter round tamper. Pre-weigh how much soil is necessary to fill 1-inch lift at 85% of maximum dry density, then tamp to 1-inch thickness. Once mold is full, verify that density is at 85% of maximum dry density (+ or – 0.5%). Apply vacuum (20 inches Hg) for 15 minutes before inundation.
- c. Inundate sample slowly under a vacuum of 20 inches Hg over a period of 60 to 75 minutes.
- d. Slowly remove vacuum (> 15 seconds).
- e. Sample shall be soaked in the mold for 24 to 72 hours before starting test.

4. Procedure:

- a. The permeability test shall be conducted over a range of hydraulic gradients between 0.1 and 2.
- b. Steady state flow rates shall be documented for four consecutive measurements before increasing the head.
- c. The permeability test shall be completed within one day (one-day test duration).

2.2.7.1.2 Prepare Soils Report

A soils report must be prepared that is stamped by a professional engineer with geotechnical expertise, a licensed geologist, a hydrogeologist, or an engineering geologist registered in the State of Washington that summarizes site characteristics and demonstrates that sufficient permeable soil for infiltration exists at the proposed facility location. At a minimum, the report must contain the following:

- Figure showing the following:
 - Topography within 500 feet of the proposed facility
 - Locations of any water supply wells within 500 feet of the proposed facility
 - Location of groundwater protection areas, aquifer recharge areas, or 1-, 5-, and 10-year times of travel zones for wellhead protection areas
 - Locations of test pits or test holes. A minimum of one soil log or test pit is required at each bioretention area location.
- Results of soils tests including but not limited to: detailed soil logs, visual grain size analysis, grain-size distribution (required if using the grain size analysis method to estimate infiltration rates), percent clay content (include type of clay, if known), color/ mottling, variations and nature of stratification.
- Description of local site geology, including soil or rock units likely to be encountered at soil sampling depths and the seasonal high groundwater elevation.
- Detailed documentation of the design infiltration rate determination, as specified above.

- State whether location is suitable for infiltration and recommend a design infiltration rate.
- A primary pathway for stormwater discharge from a bioretention area with less permeable (Type C) soils can be through interflow in the upper soil structure. The soil investigation should include a detailed description of the condition of the upper soil structure, including the pathway the discharged stormwater will take.

2.2.7.2 Bioretention Design Criteria

The following provides a description, recommendations, and requirements for the components of bioretention. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Submittal for facility review must include documentation of the following elements, discussed in detail below:

- Setbacks and site constraints
- Flow entrance / presettling
- Ponding area
- Bottom area and side slopes
- Overflow
- Bioretention soil mix
- Underdrain (if included)
- Underdrain aggregate filter and bedding layer
- Orifice and other flow control structures
- Check dams and weirs
- UIC discharge
- Hydraulic restriction layers
- Plant materials

2.2.7.2.1 Setbacks and Site Constraints

For setbacks and site constraints for non-infiltrating bioretention (lined bioretention cells or planter boxes), refer to the setbacks for detention vaults in Section 3.12.3. See

Infeasibility Criteria in Section 3.4.3 for setbacks and site constraints used to evaluate the bioretention option of The List Approach (Minimum Requirement #5). (See also Appendix III-D for a summary of infeasibility criteria for all BMPs.) The following minimum setbacks and site constraints apply to all infiltrating bioretention areas (bioretention without a liner or planter box).

- All bioretention areas shall be a minimum of 1 foot positive vertical clearance from any open water maximum surface elevation to structures within 25 feet.
- All bioretention areas shall be a minimum of 10 feet away from any structure or property line. This setback may be reduced by the County for facilities within or adjacent to the right-of-way.
- All bioretention areas shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on the slope. The soils report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.
- All bioretention areas shall be a minimum of 5 feet from septic tanks and distribution boxes.
- For sites with onsite or adjacent septic systems, the discharge point must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas (per WAC 246-272A-0210). This requirement may be modified by the Thurston County Health Department if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.
- All bioretention areas shall be a minimum of 3 feet from 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
 - 0.75 acres of lawn and landscape.

- For bioretention systems with a contributing area less than the above thresholds, a minimum of 1 foot of clearance from seasonal high groundwater or other impermeable layer is acceptable.
- Bioretention is prohibited within 300 feet of an erosion hazard, or landslide hazard area (as defined by TCC Title 17 or Title 24) unless the slope stability impacts of such systems have been analyzed and mitigation proposed by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.
- In no case should bioretention areas be placed closer than 100 feet from drinking water wells and springs used for drinking water supplies.
 - Where water supply wells exist nearby, it is the responsibility of the applicant's engineer to locate such wells, meet any applicable protection standards, and assess possible impacts of the proposed infiltration facility on groundwater quality. If negative impacts on an individual or community water supply are possible, additional runoff treatment must be included in the facility design, or relocation of the facility should be considered.
 - Bioretention areas upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Washington State Wellhead Protection Program Guidance Document, DOH, 6/2010. Infiltration systems that qualify as Underground Injection Control Wells must comply with Chapter 173-218 WAC and follow the Washington Department of Ecology's UIC Program guidance in the 2019 SWMMWW.
 - The soils report must be updated to demonstrate and document that the above criteria are met and to address potential impacts to water supply wells or springs.
- Bioretention constructed with imported composted materials should not be used within one-quarter mile of phosphorus-sensitive waterbodies if the underlying native soil does not meet the soil suitability criteria for treatment in Volume V, Chapter 6. Preliminary monitoring indicates that new bioretention areas can add phosphorus to stormwater. Therefore, they should also not be used with an underdrain when the underdrain water would be routed to a phosphorus-sensitive receiving water. For bioretention BMPs located near phosphorus-sensitive waterbodies, see Ecology's *Publication 21-10-023: Guidance on using new high performance bioretention soil mixes* for requirements.
- In the event that the downstream pathway of infiltration, interflow, and/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 bioretention area. The underdrain system can then be conveyed to a nearby vegetated channel, another stormwater facility, or dispersed into a natural protection area. See the underdrain section below for additional information.

2.2.7.2.2 Flow Entrance/Presettling

The design of flow entrance to a bioretention area will depend upon topography, flow velocities, flow volume, and site constraints. Flows entering a facility should have a velocity of less than 1 foot per second to minimize erosion potential. Vegetated buffer strips are the preferred entrance type because they slow incoming flows and provide initial settling of particulates.

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 2-inch grade change between the edge of a contributing impervious surface and the vegetated flow entrance, or 5 percent slope from the outer curb face extending to a minimum of 12 inches beyond the back of curb, is required.

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

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. Landscape areas and vegetated buffer strips slow incoming flows and provide an initial settling of particulates and are the preferred method of delivering flows to the bioretention cell. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.
2. Dispersed flow across pavement or gravel and past wheel stops for parking areas.
3. Drainage curb cuts for roadside, driveway, or parking lot areas – curb cuts shall be according to Thurston County Standard Plans (see Figure V - 2.12 - Curb Cut Inlet), or as described below with approval from the County.
 - Parking lots that incorporate bioretention into landscaped areas should use concrete curb blocks as wheel stops to protect the bioretention area from traffic intrusion while also allowing the parking lot runoff to flow somewhat unobstructed to the bioretention area.

- The minimum 12-inch drainage curb cut results in a 12-inch opening measured at the curb flow line and will require a 3-foot cut in an existing curb. An 18 inch curb cut is recommended for most applications. Avoid the use of angular rock or quarry spalls. Removing sediment from angular rock is difficult. Curb cut flow entrances must have either a minimum of 5 percent slope from the outer curb face extending to a minimum of 12 inches beyond the back of curb, or provide a minimum of a 2-inch vertical drop from the back of curb to the vegetated surface of the facility. Provide an area for settling and periodic removal of sediment and coarse material before flow dissipates to the remainder of the cell.
 - Curb cuts used for bioretention areas in high-use parking lots or roadways require increased level of maintenance due to high coarse particulates and trash accumulation in the flow entrance and associated bypass of flows. The following are methods recommended for areas where heavy trash and coarse particulates are anticipated:
 - Curb cut width: 18 inches.
 - At a minimum the flow entrance should drop 2 to 3 inches from gutter line into the bioretention area and provide an area for settling and periodic removal of debris.
 - Anticipate relatively more frequent inspection and maintenance for areas with large impervious areas, high traffic loads and larger debris loads.
 - Catch basins or forebays may be necessary at the flow entrance to adequately capture debris and sediment load from large contributing areas and high-use areas. Piped flow entrance in this setting can easily clog and catch basins with regular maintenance are necessary to capture coarse and fine debris and sediment.
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.
- Catch basin: In some locations where road sanding or higher than usual sediment inputs are anticipated, catch basins can be used to settle sediment and release water to the bioretention area through a grate for filtering coarse material.
 - Trench drains: can be used to cross sidewalks or driveways where a deeper pipe conveyance creates elevation problems. Trench drains tend to clog and may require additional maintenance.

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.

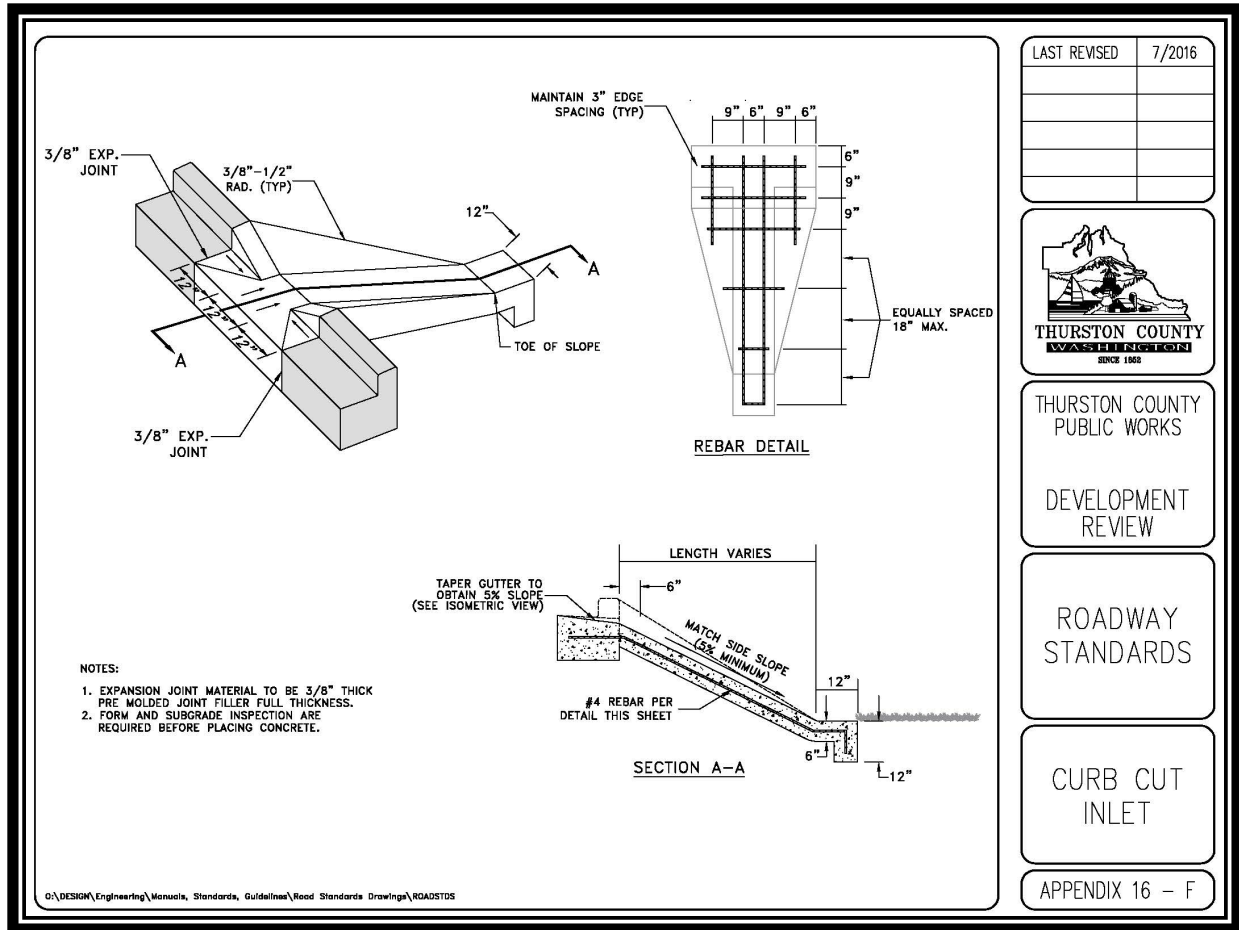


Figure V - 2.12 Curb Cut Inlet

2.2.7.2.3 Ponding Area

Bioretention ponding area may be an earthen depression (for bioretention cells and swales), or a planter box (for bioretention planters or planter boxes). 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.

Minimum requirements associated with the bioretention ponding area design include the following:

- The ponding depth shall be a maximum of 12 inches

- The surface pool drawdown time (surface ponding volume) shall be a maximum of 24 hours (drain time is calculated as a function of ponding depth and native soil design infiltration rate).

For projects subject to Minimum Requirement #5 and choosing to use The List Approach of that requirement, the bioretention area shall have a horizontally projected surface area below the overflow which is at least 5 percent of the area draining to it.

If berming is used to achieve the minimum top elevation needed to meet ponding depth and freeboard needs, maximum slope on berm shall be 3H:1V, and minimum top width of design berm shall be 1 foot. Soil used for berming shall be imported bioretention soil or amended native soil and compacted to a minimum of 90 percent dry density.

For bioretention areas with underdrains, elevating the underdrain to create a temporary saturated zone beneath the drain is advised to promote denitrification (conversion of nitrate to nitrogen gas) and prolong moist soil conditions for plant survival during dry periods (see the Underdrain (Optional) section below for details).

2.2.7.2.4 Bottom Area and Side Slopes

Bioretention areas are highly adaptable and can fit various settings such as rural and urban roadsides, ultra urban streetscapes and parking lots by adjusting bottom area and side slope configuration. Recommended maximum and minimum dimensions include:

- The maximum planted side slope shall be 3H:1V. If steeper side slopes are necessary rockeries, concrete walls, or soil wraps may be effective design options.
- The bottom width for bioretention swales shall be no less than 1 foot, although 2 feet is preferred. Carefully consider flow depths and velocities, flow velocity control (check dams) and appropriate vegetation or rock mulch to prevent erosion and channelization at bottom widths less than 2 feet.

Bioretention areas should have a minimum shoulder of 12 inches between the road edge and beginning of the bioretention side slope where flush curbs are used. Compaction effort for the shoulder should be 90 percent proctor.

2.2.7.2.5 Overflow

Surface overflow can be provided by vertical stand pipes that are connected to underdrain systems, by horizontal drainage pipes or armored overflow channels installed at the designed maximum ponding elevations. Overflow can also be provided by a curb cut at the down-gradient end of the bioretention area to direct overflows back to the street. Overflow conveyance structures are necessary for all bioretention BMPs to safely convey flows that exceed the capacity of the BMP and to protect downstream natural resources and property.

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 6 inches for drainage areas 1,000 square feet or greater.

2.2.7.2.6 Bioretention Soil Mix

Unlike infiltration basins, and trenches, native soil underlying bioretention areas is not subject to the soil infiltration treatment requirements discussed in Volume V (i.e., soil suitability criteria #1 and soil suitability criteria #2). Bioretention areas meet the requirements for basic and enhanced treatment, when the bioretention soil mix meets the requirements of the bioretention soil mix design criteria (see bioretention soil mix criteria below).

Do not use filter fabrics between the subgrade and the bioretention soil mix. The gradation between existing soils and bioretention soil mix is not great enough to allow significant migration of fines into the bioretention soil mix. Additionally, filter fabrics may clog with downward migration of fines from the bioretention soil mix.

The minimum requirements associated with the bioretention soil mix include the following:

- Minimum depth of treatment soil must be 18 inches
- Projects can either use a default bioretention soil mix, high performance bioretention soil mix, or can create a custom bioretention soil mix.
 - Projects which use the default bioretention soil mix do not have to test bioretention soil mix infiltration rate. They may assume the rates specified in the next subsection.
 - See Ecology's *Publication 21-10-023: Guidance on using new high performance bioretention soil mixes* for projects which use the high performance bioretention soil mix.
 - Projects which create a custom bioretention soil mix rather than using the default requirements must demonstrate compliance with the specific design criteria and must test the bioretention soil mix infiltration rate as described in the "Custom Bioretention Soil Mix" section below.

2.2.7.2.6.a Default Bioretention Soil Mix

Bioretention soil shall be a well-blended mixture of mineral aggregate and composted material measured on a volume basis. Bioretention soil shall consist of two parts fine compost (approximately 35 to 40 percent) by volume and three parts mineral aggregate (approximately 60 to 65 percent), by volume. The mixture shall be well blended to produce a homogeneous mix.

- **Mineral Aggregate:**
 - Percent Fines: A range of 2 to 4 percent passing the US #200 sieve is ideal and fines should not be above 5 percent for a proper functioning specification according to ASTM D422.
- **Mineral Aggregate Gradation:**
 - Mineral Aggregate shall be free of wood, waste, coating, or any other deleterious material. The aggregate portion of the Bioretention Soil Mix (BSM) should be well-graded. According to ASTM D 2487-98 (Classification of Soils for Engineering Purposes (Unified Soil Classification System)), well-graded sand should have the following gradation coefficients:
 - Coefficient of Uniformity ($C_u = D_{60}/D_{10}$) equal to or greater than 4, and
 - Coefficient of Curve ($C_c = (D_{30})^2/D_{60} \times D_{10}$) greater than or equal to 1 and less than or equal to 3.

Aggregate shall be analyzed by an accredited lab using the US sieve numbers and gradation noted in Table V - 2.4.

Table V - 2.4 Aggregate for Bioretention Soil Mix

US Sieve Number	Percent Passing
0.375 inch	100
4	95-100
10	75-90
40	24-40
100	4-10
200	2-5

Where existing soils meet the above aggregate gradation, those soils may be amended rather than importing mineral aggregate.

Compost to Aggregate Ratio, Organic Matter Content, Cation Exchange Capacity

- **Compost to aggregate ratio:** 60-65 percent mineral aggregate, 35–40 percent compost.
- **Organic matter content:** 5–8 percent by weight.

- **Cation Exchange Capacity (CEC)** must be > 5 milliequivalents/100 g dry soil. Note: Soil mixes meeting the above specifications do not have to be tested for CEC. They will readily meet the minimum CEC.

Composted Material

To ensure that the BSM will support healthy plant growth and root development, contribute to biofiltration of pollutants, and not restrict infiltration when used in the proportions cited herein, the following compost standards are required.

- Meets the definition of “composted material” in WAC 173-350-100 and complies with testing parameters and other standards in WAC 173-350-220.
- Produced at composting facility that is permitted by the jurisdictional health authority. Permitted compost facilities in Washington are included in a spreadsheet titled Washington composting facilities and material types – 2019 at the following web address:

<https://ecology.wa.gov/Waste-Toxics/Reducing-recycling-waste/Waste-reduction-programs/Organic-materials/Managing-organics-compost>

- The compost product must originate a minimum of 65 percent by volume from recycled plant waste comprised of “yard debris,” “crop residues,” and “bulking agents” as those terms are defined in WAC 173-350-100. A maximum of 35 percent by volume of “post-consumer food waste” as defined in WAC 173-350-100, but not including biosolids or manure, may be substituted for recycled plant waste.
- Stable (low oxygen use and CO₂ generation) and mature (capable of supporting plant growth) by tests show below. This is critical to plant success in bioretention soil mixes.
- Moisture content range: no visible free water or dust produced when handling the material.
- Tested in accordance with the U.S. Composting Council “Test Method for the Examination of Compost and Composting” (TMECC), as established in the Composting Council’s “Seal of Testing Assurance” (STA) program. Most Washington compost facilities now use these tests.
- Screened to the following size gradations for Fine Compost when tested in accordance with TMECC test method 02.02-B, “Sample Sieving for Aggregate Size Classification”.

Fine Compost shall meet the following gradation by dry weight:

Minimum percent passing 2": 100%

Minimum percent passing 1": 99%

Minimum percent passing 5/8": 90%

Minimum percent passing 1/4": 75%

- pH between 6.0 and 8.5 (TMECC 04.11-A). "Physical contaminants" (as defined in WAC 173-350-100) content less than 1% by weight (TMECC 03.08-A) total, not to exceed 0.25 percent film plastic by dry weight.
- Minimum organic matter content of 40% (TMECC 05.07-A "Loss on Ignition").
- Soluble salt content less than 4.0 dS/m (mmhos/cm) (TMECC 04.10-A "Electrical Conductivity, 1:5 Slurry Method, Mass Basis").
- Maturity indicators from a cucumber bioassay (TMECC 05.05-A "Seedling Emergence and Relative Growth") must be greater than 80% for both "emergence and vigor".
- Stability of 7 mg CO₂-C/g OM/day or below (TMECC 05.08-B "Carbon Dioxide Evolution Rate").
- Carbon to nitrogen ratio (TMECC 05.02A "Carbon to Nitrogen Ratio" which uses 04.01 "Organic Carbon" and 04.02D "Total Nitrogen by Oxidation") of less than 25:1. The C:N ratio may be up to 35:1 for plantings composed entirely of Puget Sound Lowland native species and up to 40:1 for coarse compost to be used as a surface mulch (not in a soil mix).

2.2.7.2.6.b Custom Bioretention Soil Mixes

Projects which prefer to create a custom bioretention soil mix rather than using the default requirements above must demonstrate compliance with the following criteria using the specified test method:

- CEC ≥ 5 meq/100 grams of dry soil; USEPA 9081.
- pH between 5.5 and 7.0.
- 5-8 percent organic matter content before and after the saturated hydraulic conductivity test; ASTM D2974 (Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils).
- 2-5 percent fines passing the US #200 sieve; TMECC 04.11-A.

- If compost is used in creating the custom mix, it must meet all of the specifications listed above for compost, except for the gradation specification. An alternative gradation specification must indicate the minimum percent passing for a range of similar particle sizes.
- Measured (Initial) saturated hydraulic conductivity of less than 12 inches per hour; ASTM D 2434 (Standard Test Method for Permeability of Granular Soils (Constant Head)) at 85 percent compaction per ASTM D 1557 (Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort). Also, use Appendix III-A, Recommended Modifications to ASTM D 2434 When Measuring Hydraulic Conductivity for Bioretention Soil Mixes.
- Design (long-term) saturated hydraulic conductivity of more than 1 inch per hour. Design saturated hydraulic conductivity is determined by applying the appropriate infiltration correction factors as explained above under Determining the Bioretention Soil Mix Design Infiltration Rate.

2.2.7.2.7 Underdrain (Optional)

Where the underlying native soils have an estimated initial infiltration rate between 0.3 and 0.6 inches per hour, bioretention BMPs without an underdrain, or with an elevated underdrain directed to a surface outlet, may be used to satisfy The List Approach of Core Requirement #5: On-site Stormwater Management. Under drained bioretention BMPs must meet the following criteria if they are used to satisfy The List Approach of Core Requirement #5.

- The invert of the underdrain must be elevated 6 inches above the bottom of the aggregate bedding layer. A larger distance between the underdrain and bottom of the bedding layer is desirable, but cannot be used to trigger infeasibility due to inadequate vertical separation to the seasonal high water table, bedrock, or other impermeable layer.
- The distance between the bottom of the bioretention soil mix and the crown of the underdrain pipe must be not less than 6 or more than 12 inches.
- The aggregate bedding layer must run the full length and the full width of the bottom of the bioretention BMP.
- The BMP must not be underlain by a low permeability liner that prevents infiltration into the native soil.

Figure V - 2.12: Bioretention BMP (typical) depicts a bioretention BMP with an elevated underdrain. Underdrain systems should be installed only if the bioretention area is located where infiltration is not permitted and a liner is used, or where subgrade soils have infiltration rates that do not meet the maximum pool drawdown time. In these

cases, underdrain systems can be installed and the facility can be used to filter pollutants and detain flows. However, designs utilizing an underdrain and low permeability liner (see Figure 5.14: Typical Bioretention w/Liner (Not LID) in Ecology's 2019 SWMMM) are not considered a low impact development BMP. They cannot be used to implement The List Approach of Core Requirement #5.

The volume above an underdrain pipe in a bioretention area provides pollutant filtering and some flow attenuation; however, only the void volume of the aggregate below the underdrain invert and above the bottom of the bioretention area (subgrade) can be used in the continuous runoff model for dead storage volume that provides flow control benefit.

Assume a 40 percent void volume for the Type 26 mineral aggregate specified below.

Underdrain systems should only be installed when the bioretention BMP is:

- Located near sensitive infrastructure (e.g., unsealed basements) and potential for flooding is likely.
- Used for filtering storm flows from gas stations or other pollutant hotspots (requires impermeable liner).
- Located above native soils with infiltration rates that are not adequate to meet maximum pool and system dewater rates, or are below a minimum rate allowed by the County.

The underdrain can be connected to a downstream bioretention swale, to another bioretention cell as part of a connected treatment system, daylight to a dispersion area using an effective flow dispersion practice, or to a storm drain.

Underdrain Pipe

The minimum requirements associated with the underdrain design include:

- Slotted, thick-walled plastic pipe must be used:
 - The slot opening should be smaller than the smallest aggregate gradation for the gravel filter bed (see Underdrain Aggregate Filter and Bedding Layer below) to prevent migration of the material into the drain. This configuration allows for pressurized water cleaning and root cutting if necessary.
 - Minimum pipe diameter: 4 inches (pipe diameter will depend on hydraulic capacity required, 4 to 8 inches is common).
 - Slotted subsurface drain PVC per ASTM D1785 SCH 40.

- Slots should be cut perpendicular to the long axis of the pipe and be 0.04 to 0.069 inches by 1 inch long and be spaced 0.25 inches apart (spaced longitudinally). Slots should be arranged in four rows spaced on 45-degree centers and cover one-half of the circumference of the pipe. See Filter Materials section for aggregate gradation appropriate for this slot size.
- Underdrain pipe slope must be no less than 0.5 percent
- Pipe must be placed in filter material and have a minimum cover depth of 4 inches
- Filter material shall meet the requirements of WSDOT Standard Specifications 9-03.12(4) (gravel backfill for drains)
- Perforated PVC or flexible slotted HDPE pipe cannot be cleaned with pressurized water or root cutting equipment, are less durable and are not recommended. Wrapping the underdrain pipe in filter fabric increases chances of clogging and is not recommended. A 6-inch rigid non-perforated cleanout must be connected to the underdrain every 250 to 300 feet minimum.

2.2.7.2.8 Underdrain Aggregate Filter and Bedding

Aggregate filter and bedding layers buffer the underdrain system from sediment input and clogging. When properly selected for the soil gradation, geosynthetic filter fabrics can provide adequate protection from the migration of fines. However, aggregate filter and bedding layers, with proper gradations, provide a larger surface area for protecting underdrains and are preferred.

Table V - 2.5 Mineral Aggregate Gradation for Underdrain Filter and Bedding Layer
(Source: Ecology)

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1
Note: The above gradation is a Type 26 mineral aggregate as detailed for gravel backfill for drains in the <i>City of Seattle Standard Specifications for Road, Bridge, and Municipal Construction</i> (Seattle Public Utilities, 2014).	

- Place the underdrain pipe on a bed of the Type 26 aggregate with a minimum thickness of 6 inches and cover with Type 26 aggregate to provide a 1-foot minimum depth around the top and sides of the slotted pipe. See the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012).

2.2.7.2.9 Orifice and Other Flow Control Structures

The minimum orifice diameter should be 0.5 inches to minimize clogging and maintenance requirements.

2.2.7.2.10 Check Dams and Weirs

For sloped bioretention areas, check dams are necessary to provide ponding, reduce flow velocities and reduce the potential for erosion. Typical check dam materials include concrete, wood, rock, compacted dense soil covered with vegetation, and vegetated hedge rows. Design depends on flow control goals, local regulations for structures within road right-of-ways and aesthetics.

Optimum spacing is determined by performance (modeling) and cost considerations. See the *Low Impact Development Technical Guidance Manual for Puget Sound* for typical designs.

2.2.7.2.11 UIC Discharge

Stormwater that has passed through the bioretention soil mix may also discharge to a gravel-filled dug or drilled drain. Underground Injection Control (UIC) regulations are applicable and must be followed (Chapter 173-218 WAC). See I-4 UIC Program in Ecology's 2019 SWMMWW.

2.2.7.2.12 Planting

The design intent for bioretention plantings is to replicate, to the extent possible, the hydrologic function of a mature forest including succession plants and groundcover. 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 minimum requirements associated with the vegetation design include the following:

- The design plans must specify that vegetation coverage of selected plants will achieve 80 percent coverage within 2 years or additional plantings will be provided until this coverage requirement is met
- For facilities receiving runoff from 5,000 square feet or more impervious surface, plant spacing and plant size must be designed to achieve specified coverage by a certified landscape architect

- The plants must be sited according to sun, soil, wind, and moisture requirements
- At a minimum, provisions must be made for supplemental irrigation during the first two growing seasons following installation.

Refer to Appendix V-E, Planting and Landscaping Requirements and the *LID Technical Guidance Manual for Puget Sound* for guidance on plant selection and recommendations for increasing survival rates.

2.2.7.2.13 Mulch Layer

Bioretention areas can be designed with or without a mulch layer. However, properly selected mulch material reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to soil. When used, mulch shall be:

- Medium compost in the bottom of the BMP (compost is less likely to float during cell inundation). Compost shall not include biosolids or manures.
- Wood chip mulch composed of shredded or chipped hardwood or softwood on cell slopes above ponding elevation and rim area. Arborist mulch is mostly woody trimmings from trees and shrubs and is a good source of mulch material. Wood chip operations are a good source for mulch material that has more control of size distribution and consistency. Do not use shredded construction wood debris or any shredded wood to which preservatives have been added.
- Free of weed seeds, soil, roots and other material that is not trunk 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 shall not include weed seeds, soil, roots and other material that are not from the above ground components of a tree, grass clippings (decomposing grass clippings are a source of nitrogen and are not recommended for mulch in bioretention areas), pure bark (bark is essentially sterile and inhibits plant establishment).

In bioretention areas where higher flow velocities are anticipated, an aggregate mulch may be used to dissipate flow energy and protect underlying bioretention soil mix. Aggregate mulch varies in size and type, but 1 to 1.5 inch gravel (rounded) decorative rock is typical. The area covered with aggregate mulch must not exceed one third of the facility bottom area.

As an alternative to mulch, a dense groundcover may be used. Mulch is required in conjunction with the groundcover until groundcover is established.

2.2.7.2.14 Hydraulic Restriction Layer

For infiltrating bioretention areas adjacent to roads, foundations or other sensitive infrastructure, it may be necessary to restrict lateral infiltration pathways to prevent excessive hydrologic loading using a restricting layer (for the sides of the bioretention area only).

Two types of restricting layers can be incorporated into bioretention designs:

- Clay (bentonite) liners are low permeability liners
- Geomembrane liners completely block infiltration. The liner should have a minimum thickness of 30 mils and be ultraviolet (UV) resistant.

Note: only the infiltrating bottom area (i.e., unlined) may be used in sizing calculations or hydrologic modeling.

If it is necessary to prevent infiltration to underlying soils (e.g., contaminated soils or steep slope areas), the facility must include a hydraulic restriction layer across the facility. The facility may be composed of a low permeability (e.g., concrete) container with a closed bottom, or may be lined with a low permeability material (e.g., clay, geomembrane liner) to prevent infiltration. In these cases, underdrains are required.

2.2.7.2.15 Bioretention Construction Criteria

Minimum requirements associated with bioretention area construction include the following:

- Bioretention areas that infiltrate into the underlying soil (i.e., do not include a liner) 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 assure that the pathway is maintained in an unobstructed and uncompacted state. This is true during the construction phase as well as postconstruction.
- During construction, it is critical to prevent clogging and over-compaction of the subgrade and bioretention soils. See Volume II, Section 3.3 for infiltration facility construction requirements. Specific construction criteria for bioretention areas are provided below.
- Place bioretention soil per the requirements of bioretention soil mix requirements specified in this section, and amend the soil per Section 3.1.

Signage

Thurston County that bioretention installations include informational signage upon completion of the installation to help identify the vegetated area as a stormwater BMP

and to inform maintenance crews and the general public about protecting the facility's function

2.2.7.2.15.a Verification of Performance

The project engineer or designee shall inspect bioretention areas before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place. Prior to placement of the Bioretention Soil Mix, the project engineer shall verify that the finished subgrade is scarified and meets the designed infiltration rate. Before release of the financial guarantee, the project engineer shall perform a sufficient number of modified falling-head percolation tests (a minimum of two) after construction to determine that the facility will operate as designed. The county must be notified of the scheduled infiltration testing at least 2 working days in advance of the test. See Appendix III-A for testing requirements. If the tests indicate the facility will not function as designed, this information must be brought to the immediate attention of the county along with any reasons as to why not and how it can be remedied.

2.2.7.2.16 Operations and Maintenance Criteria

See Core Requirement 9 in Volume I, Section 3. 8.4; and Volume I, Appendix I-E for information on maintenance requirements.

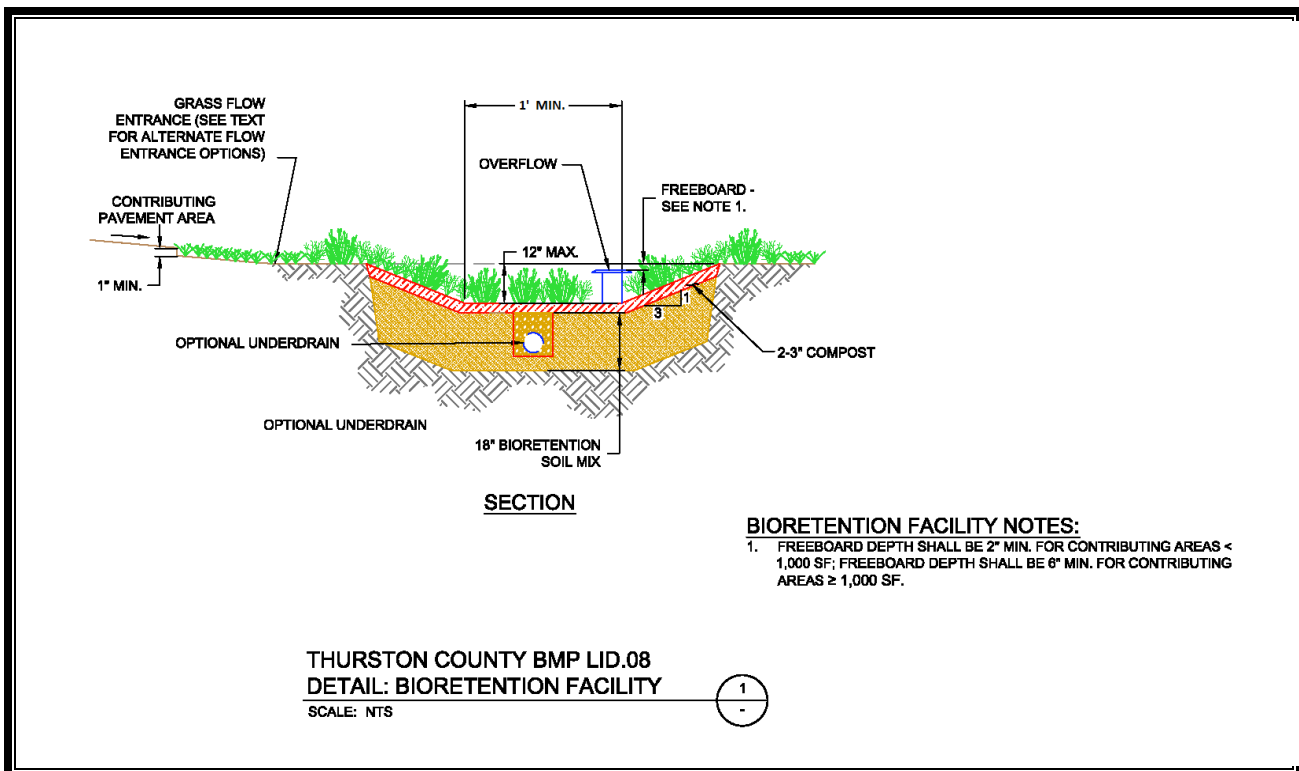


Figure V - 2.3 Bioretention BMP (typical)

2.2.7.2.17 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 submittals shall include the following in addition to the requirements of other sections:

- Source of bioretention soil mix and testing results of treatment soil including test results from the individual components (compost and aggregate components).
- 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.

2.2.8 LID BMP.08A: Rain Gardens

Rain gardens are an LID BMP that can provide effective removal of many stormwater pollutants, and provide reductions in stormwater runoff quantity and surface runoff flow rates. Although rain gardens provide these benefits, the amount of benefit is unquantifiable. Therefore, rain gardens cannot be used to meet any of the following:

- the LID Performance Standard or List #2 within Core Requirement #5: Onsite Stormwater Management
- Core Requirement #6: Runoff Treatment
- Core Requirement #7: Flow Control, or
- Core Requirement #8: Wetlands Protection

Rain gardens are non-engineered, shallow, landscaped depressions with compost-amended soils and adapted plants. The depression ponds and temporarily stores stormwater runoff from adjacent areas. A portion of the influent stormwater passes through the amended soil profile and into the native soil beneath. Stormwater that exceeds the storage capacity is designed to overflow to an adjacent drainage system.

2.2.8.1 Applications and Limitations

Rain gardens are an LID BMP within The List Approach compliance option for Core Requirement #5.

Although not required, the County recommends installation by a landscaping company with experience in rain garden construction.

Rain gardens constructed with imported compost materials should not be used within one-quarter mile of phosphorus-sensitive waterbodies. Preliminary monitoring indicates that new rain gardens can add phosphorus to stormwater. Therefore, they should also not be used with an underdrain when the underdrain water would be routed to a phosphorus-sensitive receiving water.

2.2.8.2 Design Guidelines

Refer to the *Rain Garden Handbook for Western Washington: A Guide for Design, Installation, and Maintenance* (Hinman et al., 2013) for rain garden specifications and construction guidance.

For amending the native soil within the rain garden, Thurston County recommends the use of compost that meets the compost specification for BMP LID.08: Bioretention. Compost that includes biosolids or manures shall not be used.

For design on projects subject to Core Requirement #5, and choosing to use List #1 of that requirement, rain gardens shall have a horizontally projected surface area below the overflow which is at least 5% of the total impervious surface area draining to it. If lawn/landscape area will also be draining to the rain garden, Ecology recommends that the rain garden's horizontally projected surface area below the overflow be increased by 2% of the lawn/landscape area.

Underdrains

Thurston County does not recommend the use of underdrains for rain gardens. Design and construction of an underdrain system likely requires professional expertise and must be approved for use by the County.

Infiltration Testing Guidance Specific to Rain Gardens

The site procedures and design guidelines described here are meant to be implemented after a preliminary project layout has been developed. The designer must perform sufficient infiltration tests to confirm the feasibility of proposed rain garden sites. Testing should occur between December 1 and April 1.

The certified soils professional or engineer can exercise discretion concerning the need for and extent of infiltration rate (saturated hydraulic conductivity, K_{sat}) testing. The professional can consider a reduction in the extent of infiltration (K_{sat}) testing if, in their judgment, information exists confirming that the site is unconsolidated outwash material with high infiltration rates, and there is at least 1 foot separation from the bottom of a rain garden to groundwater.

Perform a Small-Scale Pilot Infiltration Test, or other approved method per Appendix III-A, to determine if the minimum measured infiltration rate of 0.3 in/hr is exceeded at the proposed rain garden location. Also determine whether the site has at least one foot separation from the bottom of the rain garden to the seasonal high groundwater or other hydraulic restriction layer.

Legal Documents to Track Rain Garden Obligations

Where drainage plan submittals include assumptions with regard to size and location of rain gardens, approval of the plat, short-plat, or building permit should identify the rain garden obligation of each lot; and the appropriate lots should have deed requirements for construction and maintenance of the rain gardens.

2.2.8.3 Runoff Model Representation

Due to the variability in rain garden soils, rain gardens do not provide Flow Control or Runoff Treatment that is quantifiable using continuous runoff modeling software. Rain gardens are not represented in Ecology approved continuous runoff models.

2.2.8.4 Maintenance

Refer to *the Rain Garden Handbook for Western Washington: A Guide for Design, Installation, and Maintenance* (Hinman et al., 2013) for tips on mulching, watering, weeding, pruning, and soil management.

Guidance Document: Western Washington Low Impact Development (LID) Operation and Maintenance (O&M) (Herrera and WSC, 2013) may be consulted for more detailed maintenance guidance.

2.2.9 LID.09 Permeable Pavements

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

- **Porous hot or warm-mix asphalt pavement** is a flexible pavement similar to standard asphalt that uses a bituminous binder to adhere aggregate together. However, the fine material (sand and finer) is reduced or eliminated and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate.
- **Pervious Portland cement concrete** is a rigid pavement similar to conventional concrete that uses a cementitious material to bind aggregate together. However, the fine aggregate (sand) component is reduced or eliminated in the gradation and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate.
- **Permeable interlocking concrete pavements (PICP)** are solid, precast, manufactured modular units. The solid pavers are (impervious) high-strength Portland cement concrete manufactured with specialized production equipment. Pavements constructed with these units create joints that are filled with permeable aggregates and installed on an open-graded aggregate bedding course.
- **Aggregate pavers** (sometime called pervious pavers) are a different class of pavers from pervious concrete pavers. These include modular precast paving units made with similar sized aggregates bound together with Portland cement concrete with high-strength epoxy or other adhesives. Like permeable concrete pavers, the joints or openings in the units are filled with open-graded aggregate and placed on an open-graded aggregate bedding course. Aggregate pavers are intended for pedestrian use only.
- **Grid systems** include those made of concrete or plastic. Concrete units are precast in a manufacturing facility, packaged and shipped to the site for installation. Plastic grids typically are delivered to the site in rolls or sections. The openings in both grid types are filled with topsoil and grass or permeable aggregate. Plastic grid sections connect together and are pinned into a dense-graded base, or are eventually held in place by the grass root structure. Both systems can be installed on an open-graded aggregate base as well as a dense-graded aggregate base.

2.2.9.1 Applicability

- Permeable pavement has the potential to meet Core Requirement #5: Onsite Stormwater Management, Core Requirement #6: Runoff

Treatment, and Core Requirement #7: Flow Control for the tributary drainage areas depending upon site conditions, configuration, and sizing.

- Appropriate applications for permeable pavement include parking lots, low volume roads, alleys, access drives, pedestrian and bike trails, and patios. The application of permeable pavement on roads shall be limited to those roadways that receive very low-traffic volumes (i.e., ADT less than or equal to 400).

2.2.9.2 Limitations

Limitations to permeable include:

- No run-on from pervious surfaces is preferred. To reduce the potential of clogging, runoff generated from unstabilized pervious surfaces may not be directed onto a permeable pavement surface. If runoff comes from minor or incidental pervious areas (including lawns), those areas must be fully stabilized.
- Unless the pavement, base course, and subgrade have been designed to accept runoff from adjacent impervious surfaces, slope impervious runoff away from the permeable pavement to the maximum extent practicable. Sheet flow from up-gradient impervious areas is not recommended, but permissible if the permeable pavement area is > the impervious pavement area.
- Soils must not be tracked onto the wear layer or the base course during construction.
- ADA compliance is required if the pavement is part of an accessible route, and should be a consideration in all other cases, in determining where to use alternative paving surfaces. Sidewalk designs incorporate 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 use standard concrete with truncated domes 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.

Permeable pavement surfaces are suitable for use in Type A through C soils and are not recommended for Type D soils. However, with an adequate storage course, the application can be beneficial for encouraging infiltration.

2.2.9.3 Infeasibility Criteria

See Appendix III-D for the conditions that make permeable pavement infeasible when applying the List Approach within Core Requirement #5: Onsite Stormwater Management. These criteria also apply to impervious pavements that would employ stormwater collection from the surface of impervious pavement with redistribution below the pavement. In addition, other permeable pavement design criteria and site limitations that make permeable pavement infeasible (e.g., setback requirements) may also be used to demonstrate infeasibility, subject to approval by the county.

Citation of any of the infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g., engineer, geologist, hydrogeologist).

2.2.9.4 Hydrologic and Hydraulic Design Considerations

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

Where cemented till layers of soil exist under a parking lot, a permeable 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.

2.2.9.4.1 Modeling of Alternative Paving Surfaces

Note that if the project is using permeable pavement to only meet The List Approach within Core Requirement #5: Onsite Stormwater Management, there is no need to model the permeable pavement in a continuous runoff model.

The guidance below is to show compliance with the LID Performance Standard in Core Requirement #5: On-site Stormwater Management, or the standards in Core Requirement #6: Runoff Treatment, Core Requirement #7: Flow Control, and/or Core Requirement #8: Wetlands Protection.

Continuous runoff modeling software include specific modeling elements to use to model the stormwater for permeable pavement.

Within these elements, the model user specifies pavement thickness and porosity, aggregate base material thickness and porosity, maximum allowed ponding depth, and the infiltration rate into the native soil.

- For grades less than 2%, no adjustment to the below ground volumes are necessary.
- For grades greater than 2% without internal dams within the base materials, the below ground storage volume must be adjusted as follows:

- Permeable pavement surfaces that are below the surrounding grade and that are on a slope can be modeled as permeable pavement with an infiltration rate and a nominal depth.
- The dimensions of the permeable pavement are: the length (parallel to and beneath the road) of the base materials that are below grade; the width of the below grade base materials; and an Effective Total Depth of 1 inch. If the continuous runoff model requires the permeable pavement to have an overflow riser to model overflows that occur should the available storage get exceeded, enter 0.04 ft (1/2 inch) for the “Riser Height” and a large Riser Diameter (say 1000 inches) to ensure that there is no head build up.
- If a drainage pipe is embedded and elevated in the below grade base materials, the pipe should only have perforations on the lower half (below the spring line) or near the invert. Pipe volume and trench volume above the pipe invert cannot be assumed as available storage space. If a drainage pipe is placed at the bottom of the base material, the pavement is modeled as an impervious surface without any gravel trench.
- For roads on a slope with internal dams within the base materials that are below grade, the below ground storage volume must be adjusted as follows:
 - Each stretch of permeable pavement (cell) that is separated by barriers can be modeled separately. For each cell, determine the average depth of water within the cell at which the barrier at the lower end will be overtopped.
 - Specify the dimensions of each cell of the below-grade base materials using the permeable pavement dimension fields for: the “Pavement Length” (length of the cell parallel to the road); the “Pavement Bottom Width”(width of the bottom of the base material); and the Effective Total Depth. In WWHM2012, the field entitled “Effective Volume Factor” is used by the program to calculate the effective storage volume within the below-grade base materials for roads on a slope. The Effective Volume Factor is the ratio of the average maximum water depth behind a check dam (typically at the middle of the pavement length) to the below-grade base materials depth.
 - Each cell should have its own tributary drainage area within the permeable pavement element that includes the road above it, any project site areas whose runoff drains onto and through the road (lateral flow soil or impervious basin), and any off-site areas.

Represent each drainage area with a permeable pavement icon and a lateral flow basin icon (if run-on occurs).

In the runoff modeling, similar designs throughout a development can be summed and represented as one large facility. For instance, walkways can be summed into one facility. Driveways with similar designs (and enforced through deed restrictions) can be summed into one facility. In these instances, a weighted average of the design infiltration rates (where within a factor of two) for each location may be used. The averages are weighted by the size of their drainage area. The design infiltration rate for each site is the measured K_{sat} multiplied by the appropriate correction factors.

On the Permeable Pavement screen under “Infiltration”, there is a field that asks the following “Use Wetted Surface Area?” By default, it is set to “NO”. It should stay “NO” if the below-grade base material trench has sidewalls steeper than 2 horizontal to 1 vertical.

2.2.9.4.2 Determining the Native Soil Infiltration Rates

Determining infiltration rates of the site soils is necessary to determine feasibility of designs that intend to infiltrate stormwater on-site. It is also necessary to estimate flow reduction benefits of such designs when using a continuous runoff model.

The certified soils professional or engineer can exercise discretion concerning the need for and extent of infiltration rate (saturated hydraulic conductivity, K_{sat}) testing. The professional can consider a reduction in the extent of infiltration (K_{sat}) testing if, in their judgment, information exists confirming that the site is unconsolidated outwash material with high infiltration rates, and there is adequate separation from groundwater.

Refer to Appendix III-A for further guidance on the methods to determine the infiltration rate of native soils.

Field Testing Requirements Based Upon Project Size

- Projects subject to Core Requirements #1 - #5:
 - A small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A, should be performed for every 5,000 square feet of permeable pavement, but not less than 1 test per site.
 - Note that only the small-scale or large-scale PIT methods may be used to demonstrate infeasibility for Core Requirement #5 (i.e., measured infiltration rate of less than 0.3 inches per hour).
- Projects subject to Core Requirements #1 - #10:
 - On commercial property: a small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A, should be performed

for every 5,000 square feet of permeable pavement, but not less than 1 test per site.

- On residential developments: a small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A, should be performed at every proposed lot, at least every 200 feet of roadway and within each length of road with significant differences in subsurface characteristics. However, if the site subsurface characterization - including soil borings across the development site - indicate consistent soil characteristics and depths to seasonal high groundwater conditions, the number of test locations may be reduced to a frequency recommended by a geotechnical professional.
- Unless seasonal high groundwater elevations across the site have already been determined, upon conclusion of the infiltration testing, infiltration sites should be over-excavated 1 foot to see any restrictive layers or groundwater. Observations through a wet season can identify a seasonal groundwater restriction.
- Perform infiltration testing in the soil profile at the estimated bottom elevation of base materials for the permeable pavement. If no base materials (e.g., a pervious concrete sidewalk), perform the testing at the estimated bottom elevation of the pavement.

2.2.9.4.3 Assignment of Appropriate Safety/Correction Factors

If deemed necessary by a qualified professional engineer, a correction factor may be applied to the measured Ksat of the subgrade soils to estimate its design (long term) infiltration rate. Depending on the size of the facility, the variability of the underlying soils, and the number of infiltration tests performed, a safety factor may be advisable. If the design requires determination of a long-term (design) infiltration rate of the native soils (for example, to demonstrate compliance with the LID Performance Standard and/or the Flow Control Performance Standard), refer to Appendix III-A for determining the design infiltration rate of the native soils and the following additional guidance specific to permeable pavement BMPs:

- The overlying permeable pavement provides excellent protection for the underlying native soil from sedimentation. Accordingly, when using the simplified approach to calculating the design infiltration rate, a correction factor for the sub-grade soil does not have to take into consideration the extent of influent control and clogging over time. The correction factor to be applied to in-situ, small-scale infiltration test results for permeable pavement sites is determined by the site variability and number of locations tested, the quality of the aggregate base material, and the method used to determine initial Ksat. Using Volume III, Table III – 4.1: Correction Factors to be Used With In-Situ Saturated Hydraulic

Conductivity Measurements to Estimate Design Rates, the correction factor for permeable pavement design is revised based on this guidance as:

$$\text{Total Correction Factor, } CF_T = CF_V \times CF_t \times CF_a$$

Where CF_a is the partial correction factor determined by the quality of the pavement aggregate base material. CF_a ranges from 0.9 to 1.0.

- Tests should be located and be at an adequate frequency capable of producing a soil profile characterization that fully represents the infiltration capability where the permeable pavement is located. The partial correction factor CF_V depends on the level of uncertainty that variable subsurface conditions justify. If enough pilot infiltration test is conducted across the permeable pavement subgrade to provide an accurate characterization, or the range of uncertainty is low (for example, conditions are known to be uniform through previous exploration and site geological factors) then a partial correction factor CF_V of one site variability may be justified. Additionally, a partial correction factor CF_a of 1 for the quality of pavement aggregate base material may be necessary if the aggregate base is clean washed material with 1% or less fines passing the 200 sieve.
- If the level of uncertainty is high, a partial correction factor CF_V near the low end of the range may be appropriate. Two example scenarios where a low CF_V may be appropriate include:
 - Site conditions are highly variable due to a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high.
 - Conditions are variable, but few explorations and only one pilot infiltration test is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

2.2.9.5 Prepare Soils Report

A soils report must be prepared that is stamped by a professional engineer with geotechnical expertise, a licensed geologist, a hydrogeologist, or an engineering geologist registered in the State of Washington that summarizes site characteristics and demonstrates that sufficient permeable soil for infiltration exists at the proposed facility location. See Volume I, Section 3.8 and Appendix I-F for submittal requirements.

2.2.9.6 Design Criteria

The following provides a description, recommendations, and requirements for the components of permeable pavement. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Submittal for facility review must include documentation of the following elements, discussed in detail below:

- Setbacks and Site Constraints
- Subgrade
- Permeable wearing course
- Drainage Conveyance Flow entrance/presettling requirements
- Leveling course
- Aggregate storage reservoir
- Lateral subsurface impermeable barriers
- Nonwoven geotextile (optional)
- Water quality treatment layer
- Signage
- Structural design considerations

Typical cross-sections of permeable pavement consist of a top layer (permeable wearing course) underlain by a leveling course (if required), aggregate storage reservoir, geotextile fabric (optional), treatment layer (if required) and subgrade. See Figure V - 3.7 and Figure V - 3.8 for example permeable surface cross-sections.

2.2.9.6.1 Setbacks and Site Constraints

See Infeasibility Criteria in Appendix III - D for setbacks and site constraints used to evaluate the permeable pavement option of List #1 and List #2 (Core Requirement #5). The following minimum setbacks and site constraints apply to all permeable pavement areas.

- All permeable pavement surfaces shall be set back at least 50 feet from top of slopes steeper than 15 percent and greater than 10 feet high. A geotechnical assessment may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope. If the permeable pavement is within 200 feet of a slope exceeding 15 percent or within 300 feet of a Geologic Hazard Area, the Administrator or designee

may require a geotechnical report to evaluate if a slope exceeding 20% is a landslide hazard area.

- For sites with onsite or adjacent septic systems, the discharge point must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas (per WAC 246-272A-0210. This requirement may be modified by the Thurston County if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.
- Permeable pavement should not be located where seasonal high groundwater or an underlying impermeable/low permeable layer would create saturated conditions within 1 foot of the bottom of the lowest gravel base course.
- In no case should permeable pavement surfaces be placed closer than 100 feet from drinking water wells and springs used for drinking water supplies.
 - Where water supply wells exist nearby, it is the responsibility of the applicant's engineer to locate such wells, meet any applicable protection standards, and assess possible impacts of the proposed infiltration facility on groundwater quality. If negative impacts on an individual or community water supply are possible, additional runoff treatment must be included in the facility design, or relocation of the facility should be considered.
 - Pollution generating permeable pavement surfaces located within the 1-year capture zone of any well must meet the soil suitability criteria for providing treatment or provide a six-inch layer of media meeting the soil suitability criteria or sand filter specification. Permeable pavement surfaces upgradient of drinking water supplies and within 1-, 5-, and 10-year time of travel zones must comply with Washington State Wellhead Protection Program Guidance Document, DOH, 6/2010.
 - The soils report must be updated to demonstrate and document that the above criteria are met and to address potential impacts to water supply wells or springs.
- Permeable pavement surfaces are prohibited within 300 feet of a marine bluff hazard, or landslide hazard area (as defined by Thurston County Code Title 17.15 or Title 24) unless the slope stability impacts of such systems have been analyzed and mitigation proposed by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.

2.2.9.6.2 Permeable Wearing Course

The wearing course or surface layer of the permeable pavement surface may consist of porous asphalt, pervious concrete, interlocking concrete pavers, or open-celled paving grid with vegetation or gravel.

- Maximum wearing course slopes for permeable paving surfaces are 5 percent (porous asphalt), 10 percent (pervious concrete), 12 percent (interlocking pavers), and up to 12 percent (grid and lattice systems) (check with manufacturer or local supplier).
- Manufacturer's recommendations on design, installation, and maintenance shall be followed for each application.
- For all surface types, a minimum initial infiltration rate of 20 inches per hour is required. To improve the probability of long-term performance, significantly higher initial infiltration rates are desirable. Use ASTM C1701 to measure initial surface infiltration rates for porous asphalt, pervious concrete, or permeable interlocking concrete pavers. For grid systems, refer to manufacturers testing recommendations.
- **Porous Asphalt:** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 16 – 25% is typical.
- **Pervious Concrete:** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 15 – 35% is typical.
- **Grid/lattice systems filled with gravel, sand, or a soil of finer particles with or without grass:** The fill material must be at least a minimum of 2 inches of sand, gravel, or soil.
- **Permeable Interlocking Concrete Pavement and Aggregate Pavers:** Pavement joints should be filled with No. 8, 89 or 9 stone. Consult with paver manufacturer specifications to determine the appropriate material type and size.

2.2.9.6.3 Drainage Conveyance

Roads should still be designed with adequate drainage conveyance facilities as if the road surface was impermeable. Roads with base courses that extend below the surrounding grade should have a designed drainage flow path to safely move water away from the road prism and into the roadside drainage facilities. Use of perforated storm drains to collect and transport infiltrated water from under the road surface will result in less effective designs and less Flow Control benefit.

Underdrains

2.2.9.6.4 Note that if an underdrain is placed at or near the bottom of the aggregate base in a permeable pavement BMP, the permeable pavement is no longer considered an LID BMP and cannot be used to satisfy The List Approach within Core Requirement #5: Onsite Stormwater Management. However, designs utilizing an underdrain that is elevated within the aggregate base course to protect the pavement wearing course from saturation is considered an LID BMP and can be used to satisfy The List Approach within Core Requirement #5. Flow Entrance/Presettling Requirements

Run-on to permeable pavement system can be effective to attenuate peak flows, preferably dispersed as sheet flow or delivered subsurface to the storage reservoir. If subsurface delivery is used, primary settling is required (e.g., via catch basin, hooded outlet, sump) followed by distribution to storage reservoir (e.g., via perforated drain pipe).

Run-on from up-gradient adjacent impervious paved surfaces is not recommended, but permissible if:

- The permeable pavement area is at least twice the area of the impervious area,
- The length of sheet flow from the impervious paved surface is no greater than half the length across the permeable pavement section, and
- The permeable pavement area section is designed to accommodate and infiltrate the additional water.

2.2.9.6.5 Geometry

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

2.2.9.6.6 Materials

Figure V - 2.4, Figure V - 2.5, Figure V - 2.6, and Figure V - 2.7 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 geotextile fabric.

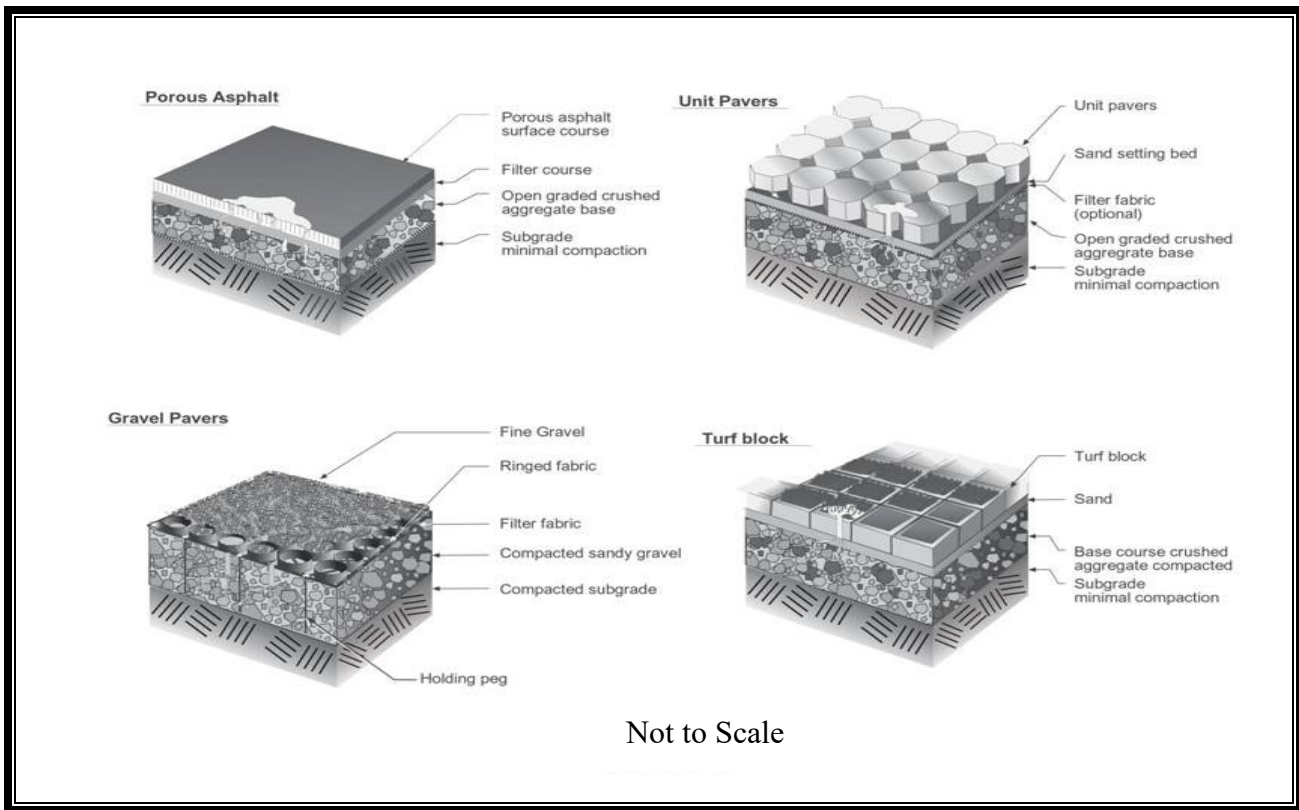


Figure V - 2.4 Alternative Paving Surfaces

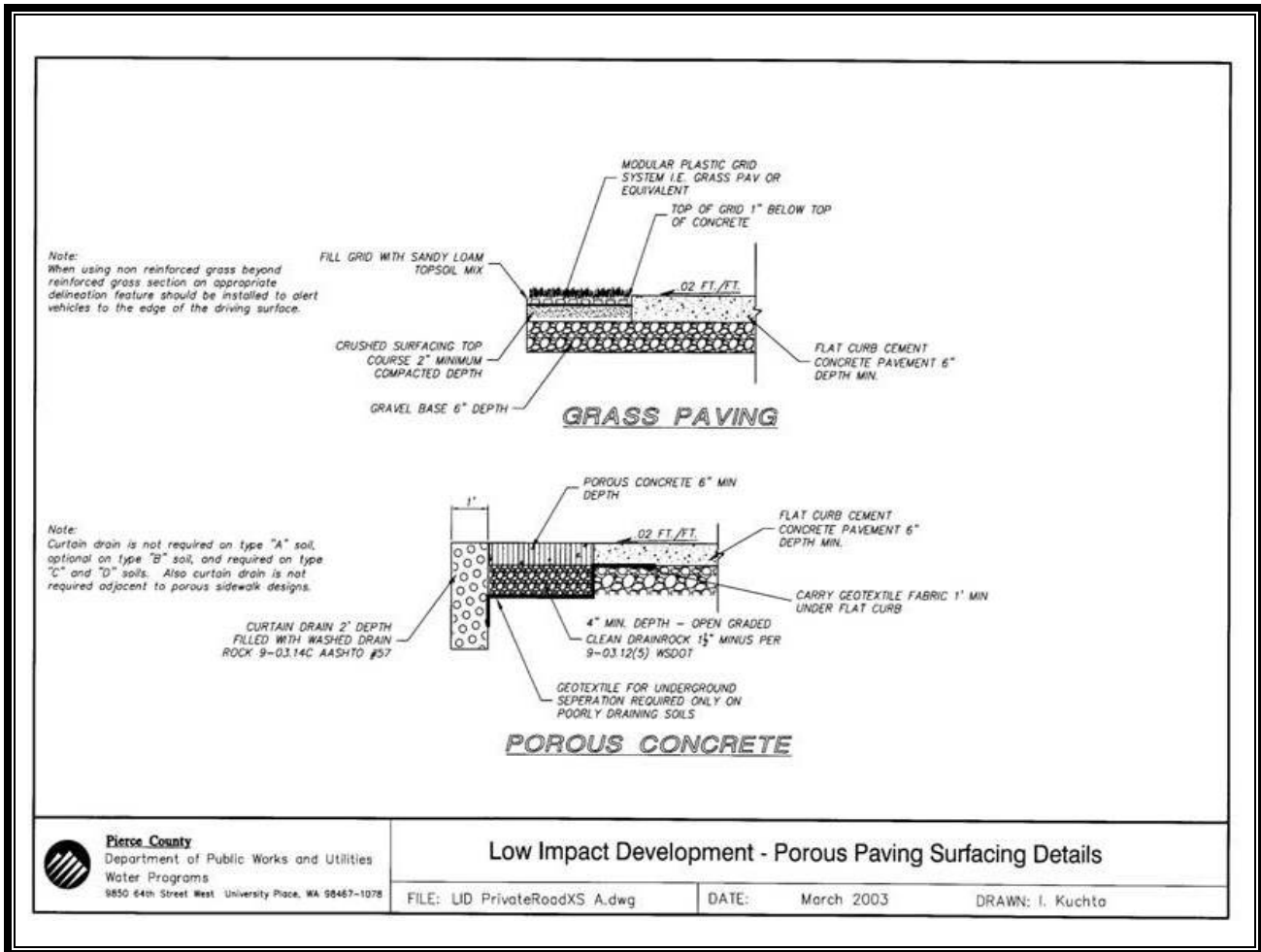


Figure V - 2.5 Porous Paving Surfacing Details

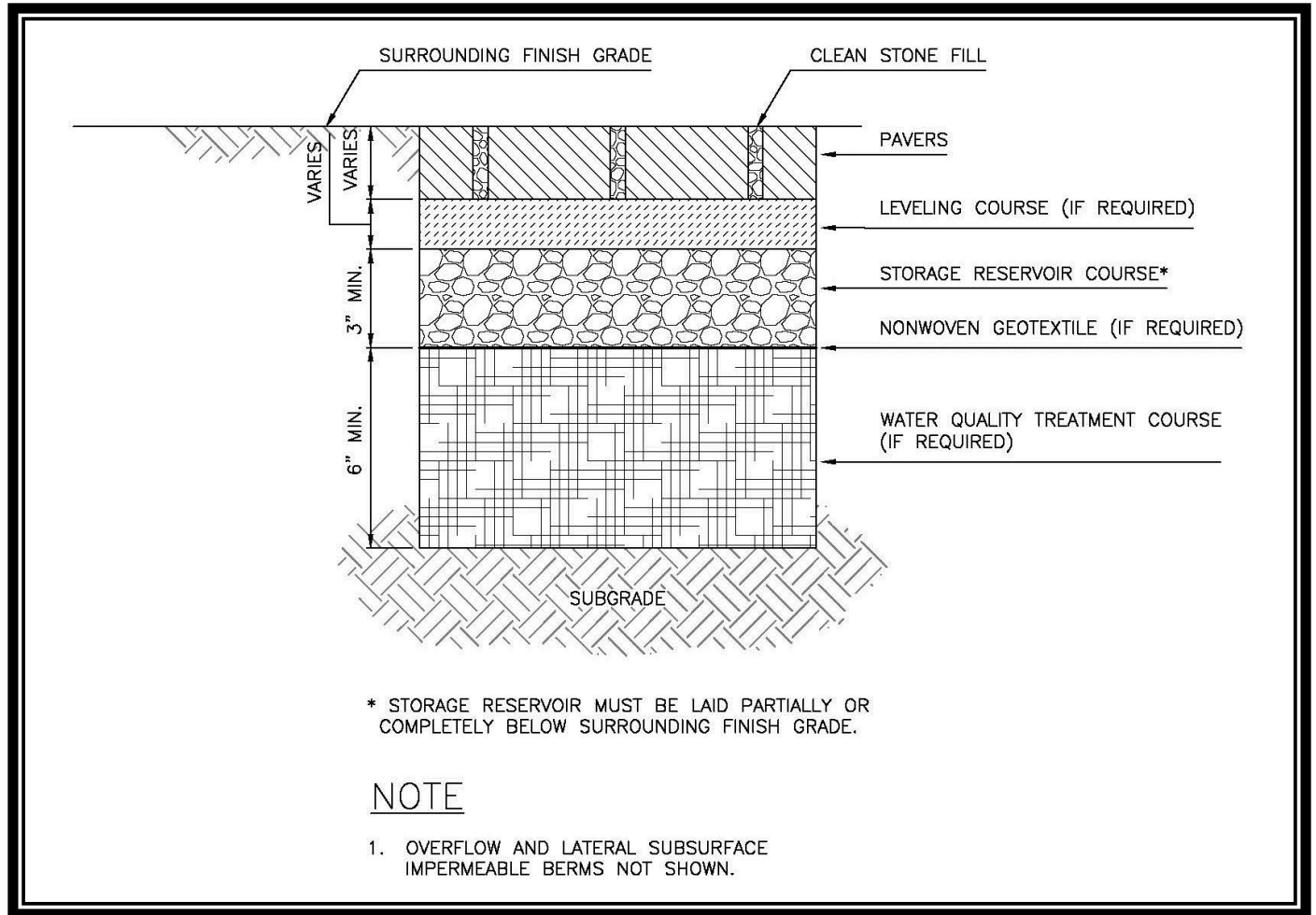


Figure V - 2.6 Permeable Paver Section

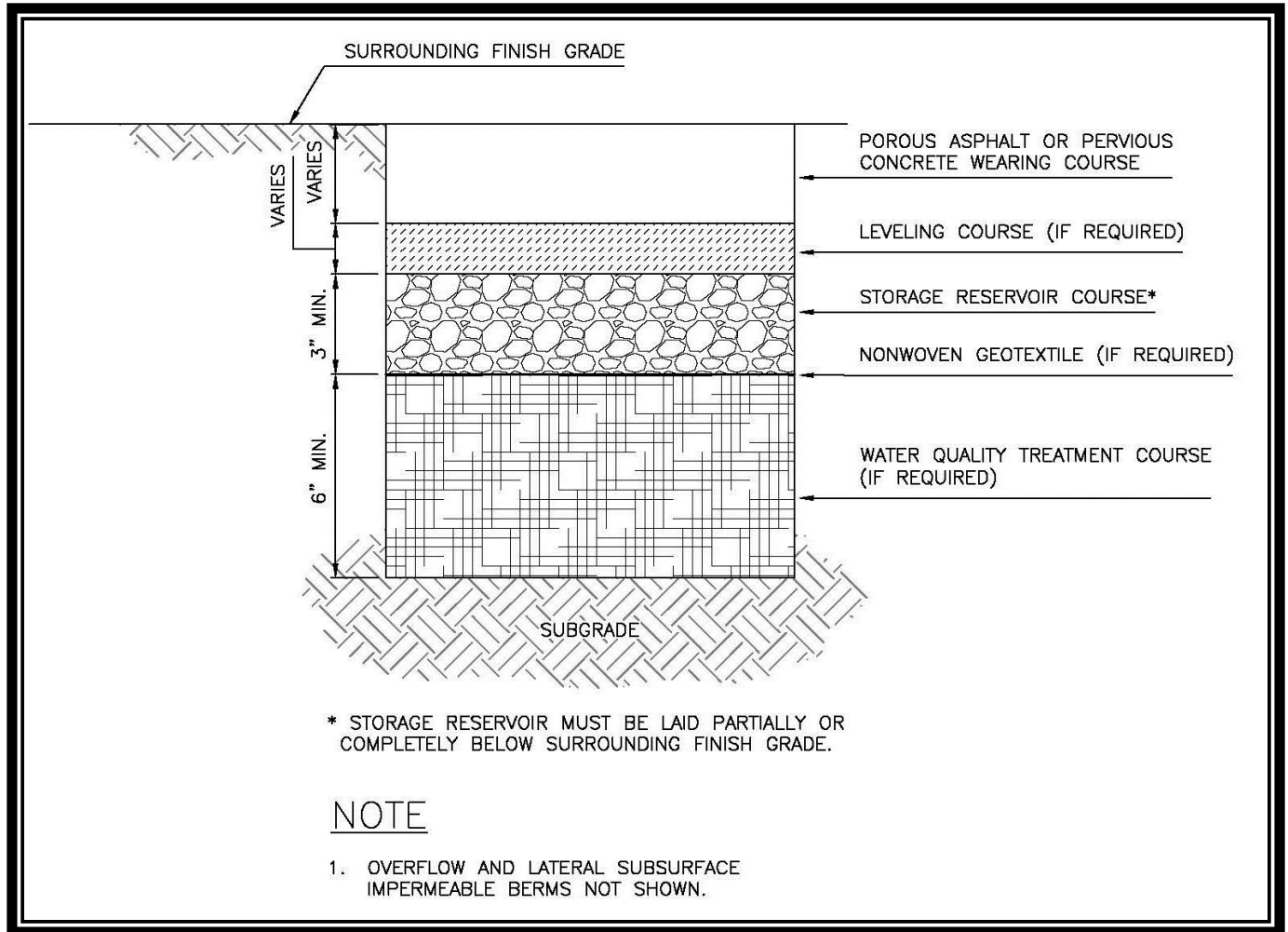


Figure V - 2.7 Porous Asphalt or Pervious Concrete Section

2.2.9.6.7 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 porous asphalt, 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 storage reservoir. Course thickness will vary with permeable pavement type.

Leveling course material and thickness shall be included as required per manufacturer recommendations. Leveling course material must be compatible with underlying aggregate storage reservoir material and shall also have at least a 20 in/hour design infiltration rate. .

2.2.9.6.8 Aggregate Storage Reservoir

Stormwater passes through the wearing and leveling courses to an underlying aggregate storage reservoir, also referred to as “base material,” where it is filtered and stored prior to infiltration into the underlying soil. The aggregate storage reservoir also serves as the support base and must be designed to support the expected loads and be free draining. The aggregate shall meet the following criteria:

- Material must be free draining.
- A 6-inch minimum depth of aggregate storage reservoir is recommended under the permeable wearing course and leveling course (if any) for water storage
- Aggregate storage reservoir shall consist of the leveling course and the storage course. WSDOT Standard Specification 9-03.12(5) is recommended for the storage course. If other gradations are used, the fines (<#200 sieve) shall be less than 2% passing.

Designs utilizing an underdrain that is elevated within the aggregate base course to protect the pavement wearing course from saturation are still considered an LID BMP and can be used to satisfy Core Requirement #5, so long as the underdrain invert is set at or above the maximum design ponding depth.

See Chapter 6 of the “Low Impact Development: Technical Guidance Manual for Puget Sound” for more detailed information for storage courses.

2.2.9.7 Lateral Subsurface Impermeable Barriers

Sloped permeable pavement surfaces have an increased potential for lateral flows through the aggregate storage reservoir along the top of relatively impermeable subgrade soil. This poses a risk of subsurface erosion and reduces the storage and infiltration capacity of the pavement facility. To address this, the subgrade must be designed to create subsurface ponding to detain subsurface flow, increase infiltration, and reduce structural problems associated with subgrade erosion on slopes.

Ponding must be provided using periodic lateral impermeable barriers (e.g. check dams, impermeable liners, or low conductivity geotextiles) oriented perpendicular to the subgrade slope when the slope of the permeable pavement is 3 percent or greater. While the frequency of the barriers is calculated based on the required subsurface ponding depth and the subgrade slope, typical designs include barriers every 6 to 12 inches of grade loss. See Attachments Section A, Details 27.1 for an example of subsurface permeable pavement check dams.

Minimum requirements associated with lateral impermeable barriers include the following:

- Lateral impermeable barriers must be installed at regular intervals perpendicular to the subgrade slope to provide the average subsurface ponding depth in the aggregate storage reservoir required to meet the desired performance standard
- The barriers must not extend to the elevation of the surrounding ground
- Each barrier must have an overflow, as described below, or allow overtopping to the next downslope aggregate storage reservoir section without causing flows to express from the pavement surface or out the sides of the base materials that are above grade.

2.2.9.8 Non-woven Geotextile Fabric

Generally, geotextiles and geogrids are applied:

- To prevent fines from migrating to more open-graded material and the associated structural instability
- For soil types with poor structural stability to prevent downward movement of the aggregate base into the subgrade.

Geotextiles between the permeable pavement subgrade and aggregate base are not required or necessary for many soil types and, if incorrectly applied, can clog and reduce infiltration capability at the subgrade or other material interface. Therefore, the use of geotextiles is discouraged unless it is deemed necessary.

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

2.2.9.8.1 Subgrade

Compact the subgrade to the minimum necessary for structural stability. Two guidelines currently used to specify subgrade compaction are “firm and unyielding” (qualitative), and 90 to 92 percent Standard Proctor (quantitative). Subgrade should not be subject to compaction beyond the qualitative and quantitative levels identified herein. Do not allow construction traffic and equipment onto the subgrade except when construction access on sub-grade is required for the pavement section installation. Follow back dumping approach as noted below.

To prevent compaction when installing the aggregate storage reservoir, the following steps (back-dumping) should be followed:

- The aggregate storage reservoir is dumped onto the subgrade from the edge of the installation and the aggregate is then pushed out onto the subgrade

- Trucks then dump subsequent loads from on top of the aggregate storage reservoir as the installation progresses.

Use on soil types A through C.

The various aggregate storage reservoir materials shall be prevented from intermixing with fines and sediment. All contaminated material must be removed and replaced.

2.2.9.8.2 Water Quality Treatment Layer

Permeable Pavement as Runoff Treatment

Ecology recognizes the permeable pavement BMP as a basic treatment BMP (as described in Volume I, Chapter 4 Stormwater BMP Selection Process) if it meets either of the following criteria:

- The native soils below the permeable pavement meet the criteria for Runoff Treatment per Volume III, 2.7 Site Suitability and Hydrologic Analysis of Infiltration Facilities.

OR

- The permeable pavement design includes a 6" layer of sand that meets the size gradation (by weight) given in Table V – 7.3: Sand Medium Specification.

2.2.9.8.3 Signage

Informational signage is required for permeable pavement installations upon completion of the installation to help identify the area as a stormwater BMP and to inform maintenance crews and the general public about protecting the facility's function.

2.2.9.8.4 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 civil engineer.

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

For more information on structural design considerations see the American Concrete Institute, National Asphalt Pavement Association, or the *Low Impact Development Technical Guidance Manual for Puget Sound*.

2.2.9.9 Construction and Maintenance

2.2.9.9.1 Installation Criteria

Permeable pavement system requires careful preparation of the subgrade and aggregate storage reservoir 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. Permeable pavement systems, such as pavers and grids, 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. See Volume II, Section 3.3 for more information on BMPs to protect LID structures during construction.

If possible, temporary roads should be used during construction and final construction of the aggregate storage reservoir material, and permeable surfacing completed after building construction is complete. This construction method is similar to the installation of leveling courses of asphalt in a subdivision prior to building individual lots and installation of the final wearing course upon completion of building construction.

2.2.9.9.2 Sub-base Infiltration Tests

Field infiltration testing of the subgrade or optional water quality treatment course, as applicable, shall be conducted after any compaction has taken place and prior to placement of overlying courses. See Appendix III-A for testing procedures. It is recommended that the same type of tests used to determine the initial infiltration rate be repeated at this time.

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

2.2.9.9.3 Permeable Pavement Surface Infiltration Test

Permeable pavement driveways can be tested by simply throwing a bucket of water on the surface. If anything other than a scant amount puddles or runs off the surface, additional testing is necessary prior to accepting the construction.

Permeable pavement roads may be initially tested with the bucket test described above. In addition, test the initial infiltration with a 6-inch ring, sealed at the base to the road surface, or with a sprinkler infiltrometer. Wet the road surface continuously for 10 minutes. Begin test to determine compliance with 20 inches per hour minimum rate. Use of ASTM C1701 or ASTM C1781, as appropriate, is also recommended.

2.2.9.9.4 Verification of Performance

For parking lots, roads, or other permeable pavement areas larger than 5000 square feet, the project engineer or designee shall inspect permeable pavement areas before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place. Prior to placing the aggregate storage reservoir, the project engineer shall verify that the finished subgrade is scarified and meets the designed infiltration rate. The project engineer shall verify that the aggregate storage reservoir has been adequately installed and protected (e.g., from compaction and sedimentation) per the design specifications, prior to paving.

Prior to the installation of the storage course, the project engineer shall perform tests as outlined in Section 2.2.9.9.2 to determine that the facility will operate as designed. The county must be notified of the scheduled infiltration testing at least 2 working days in advance of the test. See Appendix III-A for testing requirements. If the tests indicate the facility will not function as designed, this information must be brought to the immediate attention of the county along with any reasons as to why not and how it can be remedied.

Field infiltration test of the permeable surface shall be conducted after complete pavement section is installed to verify that it meets the minimum initial uncorrected infiltration rate of 20 inches per hour (see Wearing Course section).

As directed by the Administrator or designee, test the facility using ASTM C1701. For grid systems, refer to manufacturers testing recommendations. Wet the road surface continuously for 10 minutes. Test to determine compliance with the 10 inches per hour minimum infiltration rate.

Test facilities annually.

2.2.9.9.5 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. The surface design can have a significant influence on clogging of void space. Where run-on flows onto permeable pavement, these areas shall be identified in the Maintenance Plan as requiring more frequent cleaning and inspection.
- 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.

2.2.10 LID.10 Vegetated Roofs

Vegetated roofs are thin layers of engineered soil and vegetation installed on top of conventional flat or sloped roofs. Vegetated roofs are also known as ecoroofs, green roofs, and roof gardens. Vegetated roofs can provide multiple benefits, including stormwater volume reduction and flow attenuation, resulting in some amount of Flow Control. The range of benefits for a green roof depends on a number of design factors such as plant selection, depth and composition of soil mix, location of the roof, orientation and slope, weather patterns, and the maintenance plan.

All vegetated roofs consist of four basic components: a waterproof membrane, a drainage layer, a light-weight growth medium, and vegetation (see Figure V - 2.17: Typical Vegetated Roof Structure). In addition to these basic components, many systems may also incorporate a protection layer and root barrier to preserve the integrity of the waterproof membrane, a separation/filter layer to stabilize fine particles, capillary mats and mulch/mats to retain moisture and prevent surface erosion due to rain and wind scour.

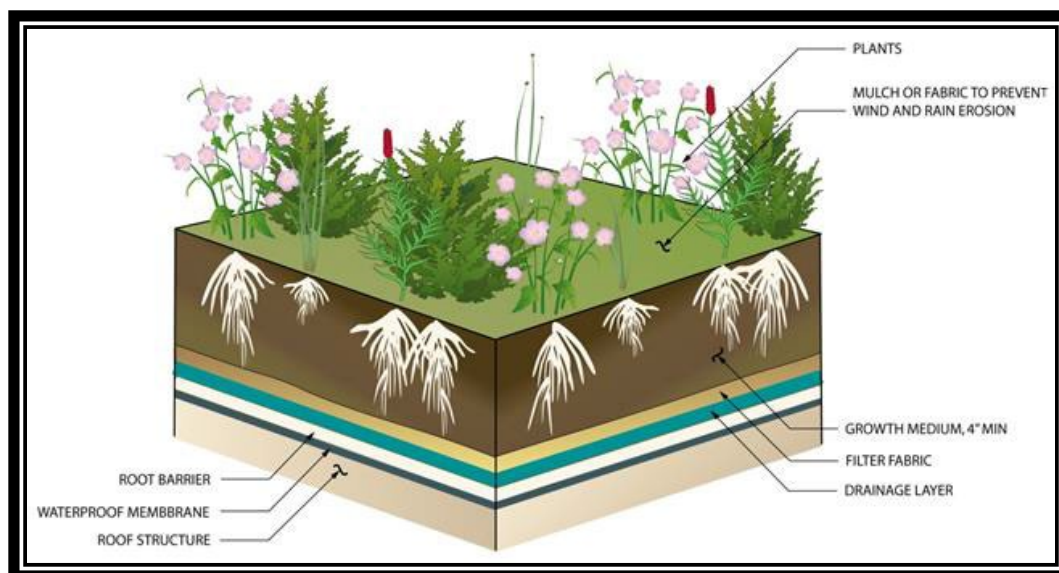


Figure V - 2.17 Typical Vegetated Roof Section

2.2.10.1 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. These are the easiest to install and generally provide the greatest stormwater storage capacity per inch of growth medium.

While vegetated roofs can be installed on slopes up to 40 degrees, slopes between 5 and 20 degrees (1:12 and 5:12) are most suitable and can provide natural drainage by gravity. Roofs with slopes greater than 10 degrees (2:12) require an analysis of engineered slope stability.

2.2.10.2 Limitations

Vegetated roofs are not included as an option in The List Approach within Core Requirement #5: Onsite Stormwater Management. However, they are an option available to project designers who want to use other methods to meet the LID Performance Standard within Core Requirement #5 or the Flow Control Performance Standard within Core Requirement #7: Flow Control

2.2.10.3 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.

2.2.10.4 Hydrologic and Hydraulic Design Considerations

2.2.10.4.1 Runoff Model Representation

When modeling the project using an approved continuous runoff model, use the element intended by the modeling software to represent a vegetated roof. If using WWHM2012, this is the "green roof" element. The user specifies the media thickness, vegetation type, roof slope, and length of drainage within the model.

2.2.10.5 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 V – 2.18 Vegetated Roof).

See the Low Impact Development Technical Guidance Manual for Puget Sound (Hinman and Wulkan, 2012) for a more detailed description of the components of and design criteria for vegetated roofs. It also includes references to other sources of information and design guidance.

Note that the Low Impact Development Technical Guidance Manual for Puget Sound (Hinman and Wulkan, 2012) is for additional informational purposes only. You must follow the guidance within this manual if there are any discrepancies between this manual and the Low Impact Development Technical Guidance Manual for Puget Sound (Hinman and Wulkan, 2012)

2.2.10.5.1 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.

2.2.10.5.1.a 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.

2.2.10.5.1.b 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.

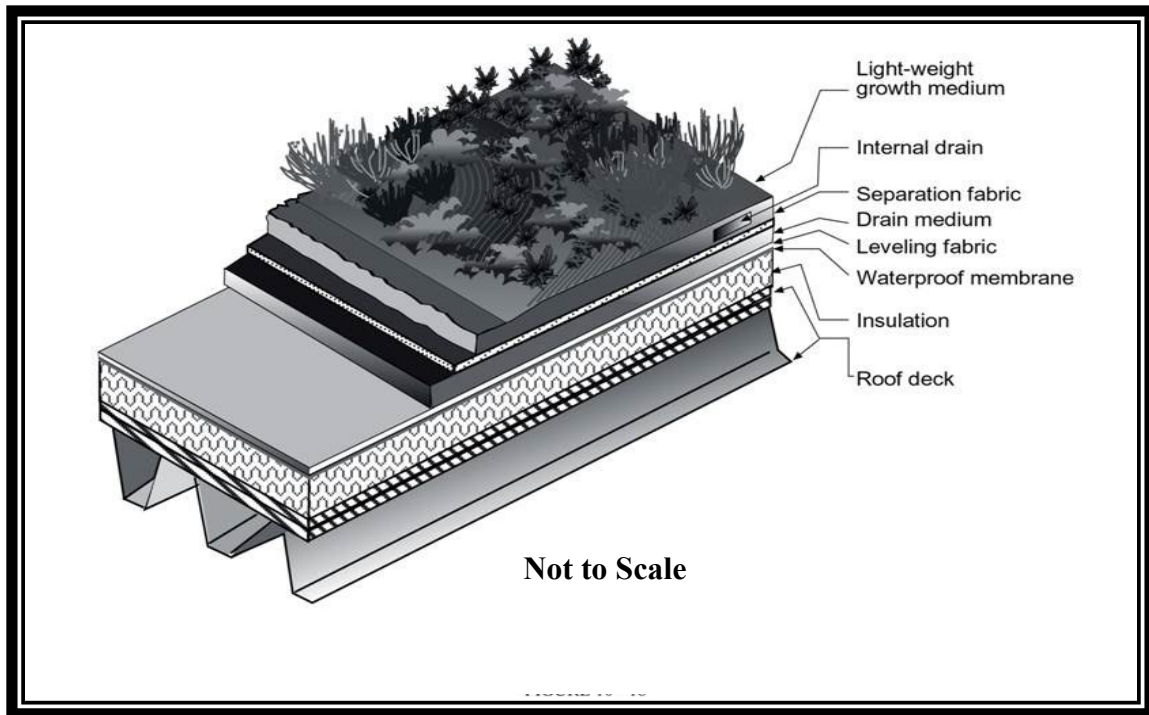


Figure V – 2.18 Vegetated Roof

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.

2.2.10.5.1.c 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.

2.2.10.5.1.d 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.

2.2.10.5.1.e 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 shall have the following characteristics:

- Must be a minimum of 3 inches deep,
- 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 and must be approved by a licensed landscape architect.
- Mulch, mat, or other measures to control erosion of growth media shall be maintained until 90 percent vegetation coverage is achieved.

2.2.10.5.1.f 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. Refer to the *LID Technical Guidance Manual for Puget Sound* for additional vegetation guidance for vegetated roofs.

Minimum requirements associated with vegetation design include the following:

- Plans must specify that vegetation coverage of selected plants must achieve 90 percent coverage within 2 years or additional plantings must be provided until this coverage requirement is met
- Plant spacing and plant size must be designed to achieve specified coverage by a licensed landscape architect

Vegetation must be suitable for rooftop conditions (e.g., hot, cold, dry, and windy). Plants must not require fertilizer, pesticides, or herbicides after 2-year establishment period. 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).

2.2.10.5.2 Drain System and Overflow

Vegetated roofs must be equipped with a roof drainage system capable of collecting subsurface and surface drainage and conveying it safely to a downstream BMP or an approved discharge. To facilitate subsurface drainage, interceptor drains are often installed at a regular spacing to prevent excessive moisture build up in the media and convey water to the roof drain.

Roof outlets must be protected from encroaching plant growth and loose gravel, and must be constructed and located so that they are permanently accessible.

2.2.10.6 Structural Design Considerations

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).

2.2.10.7 Construction and Maintenance

2.2.10.7.1 Construction Criteria

The growth medium must be protected from over compaction during construction.

2.2.10.7.2 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.

2.2.10.7.3 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.

2.2.11 LID.11 Full Dispersion

2.2.11.1 Purpose and Definition

This BMP allows for “fully dispersing” runoff from impervious surfaces and cleared areas of project sites into areas preserved as forest, native vegetation, or cleared area.

Ecology Full Dispersion as meeting Core Requirement #5: Onsite Stormwater Management, Core Requirement #6: Runoff Treatment, and Core Requirement #7: Flow Control. Sites that can fully disperse are not required to provide additional Runoff Treatment or Flow Control BMPs. Hard surfaces that are not fully dispersed should be partially dispersed to the maximum extent practicable

2.2.11.2 Applications and Limitations

The site (or area of the site) that is applying full dispersion per this BMP must be laid out to allow the runoff from the impervious (or cleared) surface to fully disperse into the preserved dispersion area. (i.e. Have full access to and not be intercepted by pipe(s), ditch(es), stream(s), river(s), pond(s), lake(s), or wetland(s)).

Projects that successfully apply this BMP on all or a portion of their site will decrease effective impervious surfaces, and may avoid triggering the TDA Thresholds in Core Requirement #7: Flow Control.

A site (or an area of a site) that applies full dispersion per this BMP consists of the following elements:

- **An impervious (or cleared) area.** The impervious (or cleared) area is the area that the design is mitigating for by using this BMP.
- **A flow spreader.** Runoff from the impervious (or cleared) area may need to be routed through a flow spreader (see Appendix V-A Flow Spreading Options), depending on the site layout and type of impervious surface, as further described below.
- **A dispersion area.** This area defines the limits of the Full Dispersion BMP. The impervious (or cleared) area must disperse into the preserved dispersion area.
 - The dispersion area must be forest, native vegetation, or a cleared area depending on the site type. Details are provided below for what amount of vegetation the dispersion area must contain based on site type.
 - If the dispersion area must be preserved as forest or native vegetation, it may be a previously cleared area that has been replanted in accordance with Native Vegetation Landscape Specifications in section 2.2.11.4 below.

- The dispersion area should be situated to minimize the clearing of existing forest cover, to maximize the preservation of wetlands (though the wetland area and any streams and lakes do not count as part of the dispersion area), and to buffer stream corridors.
- The dispersion area should be placed in a separate tract or protected through recorded easements for individual lots.
- The dispersion areas should be shown on all property maps and should be clearly marked during clearing and construction on the site.
- All trees within the dispersion area at the time of permit application shall be retained, aside from:
 - dangerous or diseased trees, and
 - approved timber harvest activities regulated under [WAC Title 222](#). Class IV General Forest Practices that are conversions from timberland to other uses are not acceptable for the preserved area.
- The dispersion 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. Cleared areas and areas of compacted soil associated with these areas and facilities must not exceed eight percent of the dispersion area.
- The dispersion area may contain utilities and utility easements, but not septic systems. For the purpose of this BMP, utilities are defined as potable and wastewater underground piping, underground wiring, and power and telephone poles.
- The dispersion area is not allowed in critical area buffers or on slopes steeper than 20%. Dispersion areas proposed on slopes steeper than 15% or within 50 feet of a geologically hazardous area ([RCW 36.70A.030\(5\)](#)) must be approved by a geotechnical engineer or engineering geologist.
- For sites with on-site sewage disposal systems, the discharge of runoff from the dispersion area must be located downslope of the primary and reserve drainfield areas. This requirement may be waived by the permitting jurisdiction if site topography clearly prevents discharged flows from intersecting the drainfield.
- **A flow path through the dispersion area.** The length of the flow path from the impervious (or cleared) area through the dispersion area varies based on the site layout and type of impervious surface, as further described below. Regardless of the site layout and type of impervious surface, the flow path must meet the following criteria:
 - The slope of the flow path must be no steeper than 15% for any 20-foot reach of the flow path. Slopes up to 20% are allowed where flow spreaders

are located upstream of the dispersion area and at sites where vegetation can be established.

- The flow paths from adjacent flow spreaders must be sufficiently spaced to prevent overlap of flows in the flow path areas.

The dispersion of runoff must not create flooding or erosion impacts.

2.2.11.3 Design Guidelines

2.2.11.3.1 Minimum Design Requirements for Residential Projects

Rural single family residential developments should use this BMP wherever possible to minimize effective impervious surfaces.

Full Dispersion from Impervious Surfaces in Residential Projects

Impervious surfaces within residential projects may be "fully dispersed" if they are within a TDA that is less than 10% impervious. If the TDA has more than 10% impervious area, the design may still fully disperse up to 10% of the TDA's area. The impervious areas that are beyond the 10% cannot drain to the dispersion area, and are subject to the thresholds in Core Requirement #6: Runoff Treatment and Core Requirement #7: Flow Control.

The lawn and landscaping areas associated with the impervious area being mitigated may be dispersed into the dispersion area. The lawn and landscaped area must comply with BMP LID.02: Post-Construction Soil Quality and Depth.

The dispersion area must be preserved as forest or native vegetation.

The dispersion area shall have a minimum area 6.5 times the area of the impervious surface draining to it.

The flow path from the impervious surface through the area preserved as forest or native vegetation must be at least 100 feet in length, or 25 feet for sheet flow from lawn and landscaping areas associated with the impervious area being mitigated.

The following additional guidelines must be followed for the following types of impervious surfaces within residential projects:

- **Full dispersion from roof surfaces:** Runoff from roof surfaces must either:
 - Provide dispersion as described in BMP LID.05: Downspout Dispersion Systems prior to the runoff entering the dispersion area. The dispersion area and flow path must meet the criteria described in this BMP.
- or
- Combine the roof runoff with the road runoff, and follow the guidance for full dispersion from roadway surfaces (below).

- **Full dispersion from driveway surfaces:** Runoff from driveway surfaces must either:
 - Provide dispersion as described in BMP LID.07: Concentrated Flow Dispersion and BMP LID.06: Sheet Flow Dispersion prior to the runoff entering the dispersion area. The dispersion area and flow path must meet the criteria described in this BMP.

or

 - Combine the driveway runoff with the road runoff, and follow the guidance for full dispersion from roadway surfaces (below).
- **Full dispersion from roadway surfaces:** Runoff from roadway surfaces must comply with all of the following requirements:
 - The road section shall be designed to minimize collection and concentration of roadway runoff. Sheet flow over roadway fill slopes (i.e., where roadway subgrade is above adjacent right-of-way) should be used 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. 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 into the dispersion area. 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 into the dispersion area. See Volume III, section 3.8 Outfalls for details on rock pads and dispersion trenches.
 - 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 V - 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.

- 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.

Full Dispersion from Cleared Areas in Residential Projects

The runoff from cleared areas of residential projects that are comprised of bare soil, non-native landscaping, lawn, and/or pasture is "fully dispersed" if it meets all of the following criteria:

- Cleared areas must comply with BMP LID.02: Post-Construction Soil Quality and Depth.
- The dispersion area must be preserved as forest or native vegetation.
- The flow path through the cleared area (and leading to the dispersion area) must not be greater than 25 feet.
- If the cleared area has a width of up to 25 feet:
 - The minimum flow path length from the cleared area through the dispersion area must be at least 25 feet.
- If the cleared area has a width of 25 to 250 feet:
 - The minimum flow path length from the cleared area through the dispersion area must be 25 feet, plus an additional 1 foot for every 3 feet of width of the cleared area (beyond the initial 25 feet) up to a maximum width of 250 feet.
- The topography of the cleared area must be such that runoff will not concentrate prior to discharge to the dispersion area.
- The width of the dispersion area must equal the width of the cleared area.

2.2.11.3.2 Minimum Design Requirements for Public Road Projects

These criteria apply to the construction of public roads not within the context of residential, commercial, or industrial site development. They will likely only be implementable on roads outside of the urban growth areas where roadside areas are not planned for urban density development.

Full dispersion can be applied to public road projects that meet the following requirements:

- The dispersion area must be outside of the urban growth area; or if inside the urban growth area, in legally protected areas (easements, conservation tracts, public parks).
- If the dispersion area is outside urban growth areas, legal agreements should be reached with the owner(s) of the property(ies) that contain the dispersion area.
- An agreement with the property owner(s) is advised for any dispersion areas that represent a continuation of past practice. If not a continuation of past practice, an agreement should be reached with the property owner.

Full Dispersion by Sheet Flow from Uncollected, Unconcentrated Runoff into the Dispersion Area

The runoff from public road projects that sheet flow into the dispersion area is "fully dispersed" if it meets all of the following criteria:

- The dispersion area must be preserved as forest or native vegetation.
- Depth to the average annual maximum groundwater elevation should be at least 3 feet.
- The flow path through any impervious area leading to the dispersion area must not be greater than 75 feet.
- The flow path through any pervious area leading to the dispersion area must not be greater than 150 feet. Pervious flow paths include up-gradient road side slopes that run onto the road and down-gradient road side slopes that precede the dispersion area.
- The width of the dispersion area should be equivalent to the width of impervious surface sheet flowing into it.
- Flow path length through the dispersion area:
 - For outwash The following criteria apply to sites (or areas of sites) with outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands). The outwash soils must have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The saturated hydraulic conductivity must be based on a Pilot Infiltration Test or the Soil Grain Size Analysis method as identified in Appendix III-A.

- If the impervious area has a flow path length of up to 20 feet, the flow path length through the dispersion area must be at least 10 feet.
- If the impervious area has a flow path length greater than 20 feet, the flow path length through the dispersion area must be 10 feet, plus an additional 0.25 feet for every 1 foot of impervious flow path length beyond the initial 20 feet.
- For other soils: The following criteria apply to sites (or areas of sites) with soils other than those described in the bullet above (Types C and D and some Type B not meeting the criterion in the bullet above).
 - For every 1 foot of flow path length across the impervious surface, the flow path length through the dispersion area must be 6.5 feet.
 - The minimum flow path length through the dispersion area is 100 feet.
- The lateral slope of the impervious area should be less than 8%.
- Road side slopes must be less than 25%. Road side slopes do not count as part of the dispersion area unless native vegetation is re-established and slopes are less than 15%. Road shoulders that are paved or graveled to withstand occasional vehicle loading count as impervious surface.
- Longitudinal slope of road should be $\leq 5\%$.
- The average longitudinal (parallel to road) slope of dispersion area should be less than or equal to 15%.
- The average lateral slope of dispersion area should be less than or equal to 15%.

Full Dispersion of Channelized (Collected and Re-dispersed) Stormwater into the Dispersion Area

The runoff from public road projects that is collected and re-dispersed is "fully dispersed" if it meets all of the following criteria:

- The dispersion area may be either:
 - preserved as forest or native vegetation, or

- cleared land. This cleared land option may only be used if the site is outside of the Urban Growth Area and does not have a natural or man-made drainage system.
- Depth to the average annual maximum groundwater elevation should be at least 3 feet.
- Channelized flow must be re-dispersed to produce the longest possible flow path.
- Flows must be evenly dispersed across the dispersion area.
- 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 into the dispersion area. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use dispersion trenches to disperse flows into the dispersion area. See Volume III, section 3.8 Outfalls for details on rock pads and dispersion trenches.
 - Dispersion trenches shall be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flow path, and shall have a minimum 2 feet by 2 cross section, 50 feet in length, filled with 3/4-inch to 1 1/2-inch washed rock, and provided with a level notched grade board. Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to 4 trenches. Dispersion trenches shall have a minimum spacing of 50 feet between centerlines.
- Approved energy dissipation techniques may be used.
- Limited to on-site (associated with the road) flows.
- The width of the dispersion area should be equivalent to length of the road from which runoff is collected.
- The average longitudinal and lateral slopes of the dispersion area should be $\leq 8\%$.
- The slope of any flow path segment within the dispersion area must be no steeper than 15% for any 20-foot reach of the flow path segment.
- Flow path length through the dispersion area:
 - For outwash soils: The following criteria apply to sites (or areas of sites) with outwash soils (Type A – sands and sandy gravels,

possibly some Type B – loamy sands) that have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The saturated hydraulic conductivity must be based on field results using procedures (Pilot Infiltration Test or Soil Grain Size Analysis Method) identified in Appendix III-A.

- The dispersion area should be at least ½ of the impervious drainage area.
- For other soils: The following criteria apply to sites (or areas of sites) with soils other than those described in the bullet above (Types C and D and some Type B not meeting the criterion in the bullet above).
 - For every 1 foot of flow path length across the impervious surface, the flow path length through the dispersion area must be 6.5 feet.
 - The minimum flow path length through the dispersion area is 100 feet.

Full Dispersion by Engineered Dispersion

The runoff from public road projects is "fully dispersed" if it meets all of the following criteria:

- Stormwater can be dispersed via sheet flow or via collection and re-dispersion in accordance with the techniques for Full Dispersion of Channelized (Collected and Re-dispersed) Storm- water into the Dispersion Area (above).
- The dispersion area should be planted with native trees and shrubs.
- For outwash soils: The following criteria apply to sites (or areas of sites) with outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The saturated hydraulic conductivity must be based on field results using procedures (Pilot Infiltration Test or Soil Grain Size Analysis Method) identified in Appendix III-A.
 - The dispersion area must be compost amended in accordance with guidelines in BMP LID.02: Post-Construction Soil Quality and Depth. The guidance document Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington

(Stenn et al., 2016) can be used, or an approved equivalent soil quality and depth specification approved by Ecology.

- If impervious area has a flow path length of up to 20 feet, the flow path length through the dispersion area must be at least 10 feet.
- If the impervious area has a flow path length greater than 20 feet, the flow path length through the dispersion area must be 10 feet, plus an additional 0.25 feet for every 1 foot of impervious flow path length beyond the initial 20 feet.
- For other soils: The following criteria apply to sites (or areas of sites) with soils other than those described in the bullet above (Types C and D and some Type B not meeting the criterion in the bullet above).
- If the dispersion area has Type C or D soils, it
 - The dispersion area must be compost-amended following guidelines in BMP T5.13: Post-Construction Soil Quality and Depth. The guidance document Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington (Stenn et al., 2016) can be used, or an approved equivalent soil quality and depth specification approved by Ecology.
 - The dispersion area must be 6.5 times the area of the surface(s) draining to it.
- The average longitudinal (parallel to road) slope of the dispersion area should be $\leq 15\%$.
- The average lateral slope of the dispersion area should be $\leq 15\%$.
- The depth to the average annual maximum groundwater elevation should be at least three feet.

2.2.11.4 Native Vegetation Landscape Specifications

These specifications may be used in situations where an applicant wishes to convert a previously developed surface to a native vegetation landscape for purposes of meeting full dispersion requirements or code requirements for forest retention. Native vegetation landscape is intended to have the soil, vegetation, and runoff characteristics approaching that of natural forestland.

Conversion of a developed surface to native vegetation landscape requires the removal of impervious surface, 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) 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. Species must be selected as appropriate for site shade and moisture conditions, and in accordance with the following requirements:
 - 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 a spacing recommended by a professional landscaper or in accordance with local requirements.
 - b. Shrubs: a minimum of two species of shrubs should 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 should be planted. Space plants so as to cover the entire landscape area, excluding points where trees or shrubs are planted.

For landscaped 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 two years.

7. The plantings must be well established on at least 90% of the converted area. A minimum of 90% plant survival is required after 3 years.

Conversion of an area that was under cultivation to native vegetation landscape requires a different treatment. Elimination of cultivated plants, grasses and weeds is required before planting and will be required on an on-going basis until native plants are well-established. The soil should be tilled to a depth of 18 inches. A minimum of 8 inches of soil having an organic content of 6 to 12 percent is required, or a four inch layer of compost may be placed on the surface before planting, or 4 inches of clean wood chips may be tilled into the soil, as recommended by a landscape architect or forester. After soil preparation is complete, continue with steps 4 through 7 above. Placing 4 inches of compost on the surface may be substituted for the hog fuel or mulch. For large areas where frequent watering is not practical, bare-root stock may be substituted at a variable spacing from 10 to 12 feet o.c. (with an average of 360 trees per acre) to allow for natural groupings and 4 to 6 feet o.c. for shrubs. Allowable bare-root stock types are 1-1, 2-1, P-1 and P-2. Live stakes at 4 feet o.c. may be substituted for willow and red-osier dogwood in wet areas.

2.2.11.5 Runoff Model Representation

Areas that are fully dispersed do not have to use approved runoff models to demonstrate compliance. They are presumed to fully meet the Runoff Treatment and Flow Control requirements in Core Requirement #6: Runoff Treatment and Core Requirement #7: Flow Control.

2.2.12 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 Core Requirement #5 (On-site Stormwater Management), basic and enhanced treatment targets of Core Requirement #6 (Runoff Treatment), and Core Requirement #7 (Flow Control).

The key to natural dispersion is that flows from the impervious area must 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.

Using natural dispersion on projects will result in benefits when determining applicable core 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.

2.2.12.1 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.

2.2.12.2 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 are additional limitations for sites 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 3.8.1 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.

2.2.12.3 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 dissipaters, 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.

2.2.12.4 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 core requirements (Volume I, Section 2.3), but not towards the individual thresholds of Core Requirement #6 (Runoff Treatment) or Core 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.

2.2.12.5 Design Criteria

2.2.12.5.1 Sheet Flow

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

The contributing impervious surface flow path must be less than 75 feet. The contributing pervious flow path must be less than 150 feet. Pervious flow paths may include up-gradient road side slopes that run onto the road and down-gradient road side slopes that precede the dispersion area. The sheet flow path is measured in the direction of flow and generally represents the width of the pavement area.

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. Road side slopes do not count as part of the dispersion area unless native vegetation is re-established and slopes are less than 15 percent. Road shoulders that are paved or graveled count as impervious surface.

The average longitudinal (parallel to road) slope of the dispersion area must be less than 15 percent.

The average lateral slope of the dispersion area must be less than 15 percent.

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 outwash soils (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 V - 2.12 illustrates the configuration of a typical natural dispersion area relative to the roadway.

2.2.12.5.2 Channelized Flow

Channelized stormwater can be re-disbursed, per the guidance below, into areas with (a) native vegetation or (b) cleared land in areas outside of urban growth areas that do not have a natural or manmade drainage system.:

Full dispersion credit (i.e., no other treatment or flow control required) is given to projects that meet the following criteria:

- Outwash soils that have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The saturated hydraulic conductivity must be based on a Pilot Infiltration Test or other methods outlined in Volume III, Appendix III-A.

- The dispersion area flow path must be at least half the width of the contributing impervious drainage area.
- Other soils: (Types C and D and some Type B not meeting the criterion in above)
 - The dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.

Other criteria applicable to all soil types:

- Depth to the average annual maximum groundwater elevation should be at least three feet.
- Channelized flow must be re-dispersed to produce longest possible flow path.
- 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.

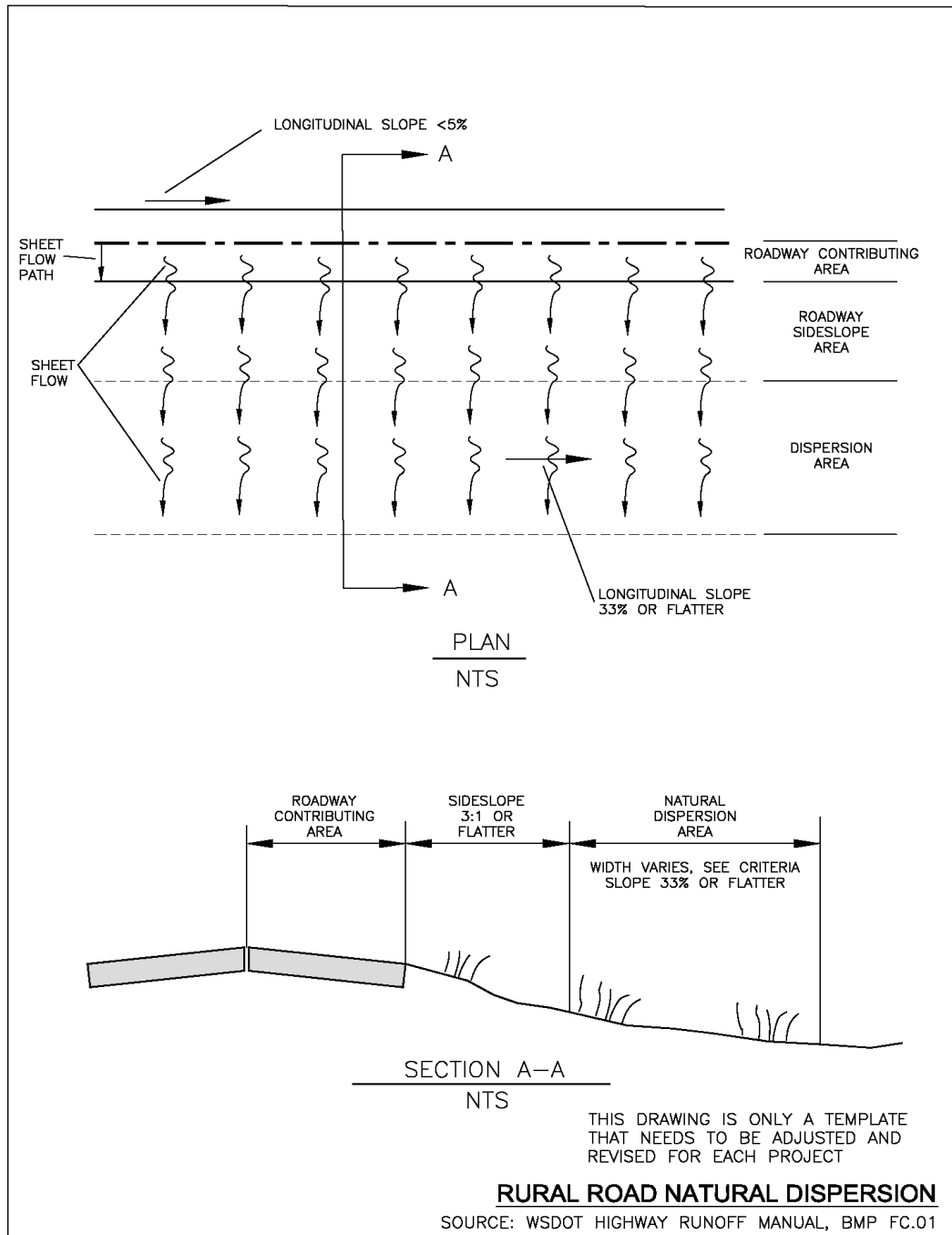


Figure V - 2.129 Natural Dispersion

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 (WSDOT Standard Specifications 9-03.12(5) or equivalent); and provided with a level notched grade board (see Figure III – 3.6, 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 intersect 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 wetlands, streams, or slopes steeper than 40 percent with a vertical change of at least 10 feet.

Where the Administrator or designee 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.

2.2.12.5.3 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.

2.2.12.6 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 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. 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.

2.2.12.6.1 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.

2.2.12.6.2 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.

2.2.12.7 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.

2.2.12.8 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 dissipaters 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.

2.2.13 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 Core Requirement #5 (On-site Stormwater Management), basic and enhanced treatment targets of Core Requirement #6 (Runoff Treatment), and Core Requirement #7 (Flow Control).

2.2.13.1 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.

2.2.13.2 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.

Depth to the average annual maximum groundwater elevation shall be at least three feet.

2.2.13.3 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.

2.2.13.4 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.

2.2.13.5 Design Criteria

2.2.13.5.1 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).

2.2.13.5.2 Sizing Criteria

Figure V - 2.13 illustrates a typical engineered dispersion area relative to the adjacent roadway.

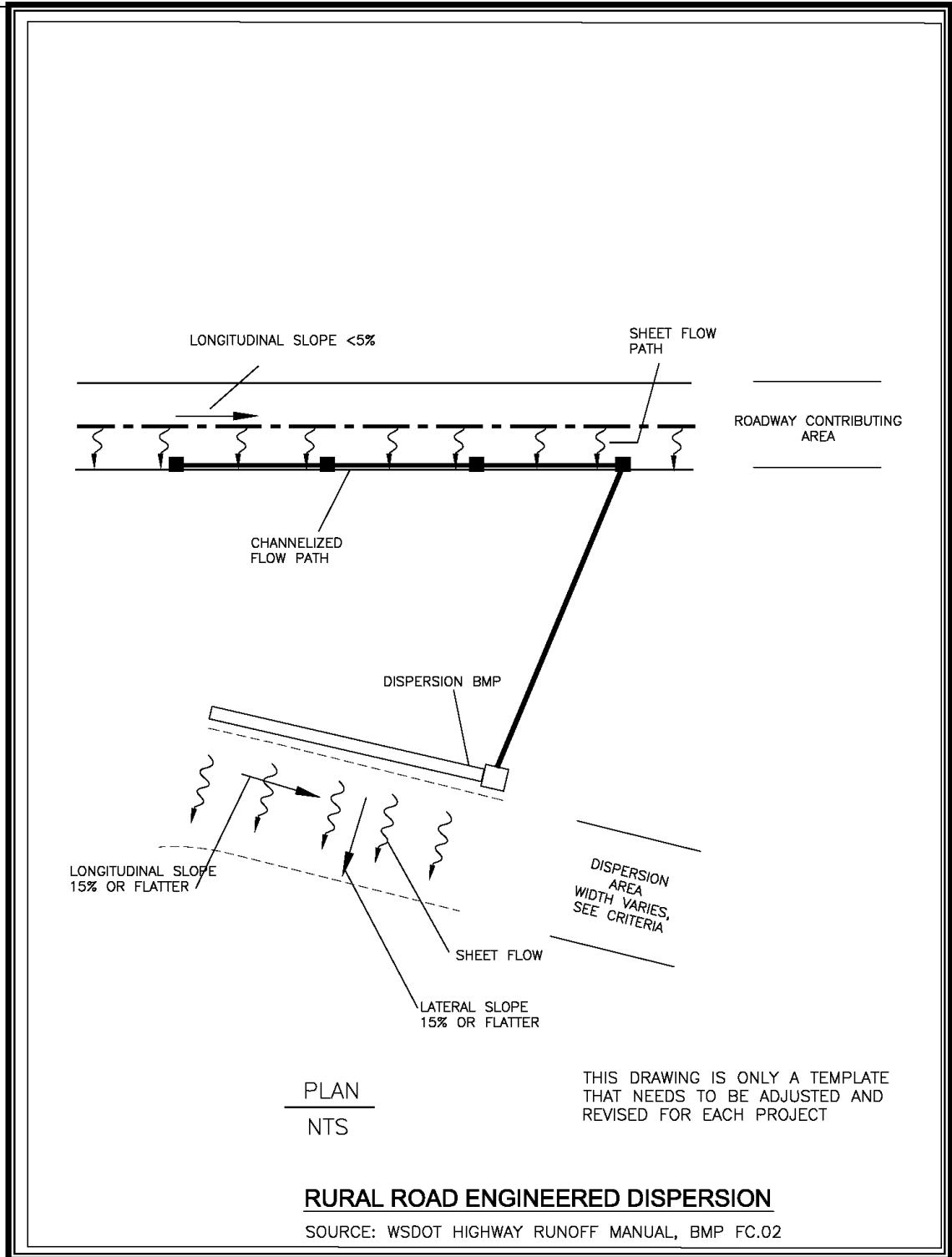


Figure V - 2.13 Engineered Dispersion

2.2.10.6 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 foot 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.

2.2.13.6 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 V - 2.7. 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.

2.2.13.7 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.

2.2.13.7.1 Materials

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

2.2.13.8 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.

2.2.13.8.1 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.

2.2.13.8.2 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.

2.2.13.9 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.

2.2.13.10 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.

2.2.14 LID.14 Tree Planting and Tree Retention (for Flow Control Credit)

2.2.14.1 Description

Trees provide flow control via interception, transpiration, and increased infiltration. Additional environmental benefits include improved air quality, carbon sequestration, reduced heat island effect, pollutant removal, and habitat preservation or formation.

2.2.14.2 Applications and Limitations

When implemented in accordance with the criteria outlined below, retained and newly planted trees receive credits toward meeting the LID Performance Standard within Core Requirement #5 and/or the Flow Control Performance Standard of Core Requirement #7. The degree of flow control provided by a tree depends on the tree type (i.e., evergreen or deciduous), canopy area, and proximity to hard surfaces. Flow control credits may be applied to project sites of all sizes.

Site considerations specific to retained and newly planted trees are provided below.

2.2.14.3 Retained Trees

Setbacks of proposed infrastructure from existing trees are critical considerations. Tree protection requirements limit grading and other disturbances in proximity to the tree.

2.2.14.4 Newly Planted Trees

Mature tree height, size, and rooting depth must be considered to ensure that new tree planting locations are appropriate given adjacent above- and below-ground infrastructure. Although setbacks will vary by species, some general recommendations include:

- Minimum 5 foot setback from structures
- Minimum 2 foot setback from edge of any paved surface.

2.2.14.5 Modeling and Sizing

2.2.14.5.1 Retained Trees

Flow control credits for retained trees are provided in Table V - 2.2 by tree type. These credits can be applied to reduce impervious or other hard surface area requiring flow control. Credits are given as a percentage of the existing tree canopy area. The minimum credit for existing trees ranges from 50 to 100 square feet.

The total tree credit for retained and newly planted trees shall not exceed 25 percent of impervious or other hard surface requiring mitigation.

Table V - 2.2 Flow Control Credits for Retained Trees

Tree Type	Credit
Evergreen	20% of canopy area (minimum of 100 sq. ft./tree)
Deciduous	10% of canopy area (minimum of 50 sq. ft./tree)

$$\text{Impervious/Hard Surface Area Mitigated} = (\Sigma \text{Evergreen Canopy Area} \times .2) + (\Sigma \text{Deciduous Canopy Area} \times 0.1)$$

Tree credits are not applicable to trees in native vegetation areas used for flow dispersion or other flow control credit. Credits are also not applicable to trees in planter boxes.

2.2.14.5.2 Newly Planted Trees

Flow Control credits for newly planted trees are provided in Table V - 2.3 by tree type. These credits can be applied to reduce the impervious or other hard surface area requiring flow control. Credits range from 20 to 50 square feet per tree.

Table V - 2.3 Flow Control Credits for Newly Planted Trees

Tree Type	Credit
Evergreen	50 sq. ft. per tree
Deciduous	20 sq. ft. per tree

$$\text{Impervious/Hard Surface Area Mitigated} = \Sigma \text{Number of Trees} \times \text{Credit (sq. ft.)}$$

Flow Control credits are not applicable to newly planted trees in native vegetation areas used for flow dispersion or other flow control credit. Credits are also not applicable to new trees in planter boxes.

2.2.14.6 Tree Planting and Tree Retention Design Criteria

2.2.14.6.1 Retained Trees

The following design criteria are specific to projects proposing to retain onsite trees for flow control credits:

2.2.14.6.2 Tree Species and Condition

Existing tree species and location must be clearly shown on submittal drawings.

Trees must be viable for long-term retention (i.e., in good health and compatible with proposed construction).

2.2.14.6.3 Tree Size

To receive flow control credit, retained trees shall have a minimum 6 inches diameter

at breast height (DBH). DBH is defined as the outside bark diameter at 4.5 feet above the ground on the uphill side of a tree. For existing trees smaller than this, the newly planted tree credit may be applied as presented below.

2.2.14.6.4 Tree Canopy Area

The retained tree canopy area shall be measured as the area within the tree drip line. A drip line is the line encircling the base of a tree, which is delineated by a vertical line extending from the outer limit of a tree's branch tips down to the ground (see also Figure 2.14). If trees are clustered, overlapping canopies are not double counted.

2.2.14.6.5 Tree Location

Flow control credit for retained trees depends upon proximity to ground level impervious or other hard surfaces. To receive a credit, the existing tree must be on the development site and within 20 feet of new and/or replaced ground level impervious or other hard surfaces (e.g., driveway or patio) on the development site. Distance from impervious or other hard surfaces is measured from the tree trunk center.

An arborist report shall be required if impervious surface is proposed within the critical root zone of the existing tree. The critical root zone is defined as the line encircling the base of the tree within half the diameter of the dripline (see also Figure 2.14). If the arborist report concludes that impervious surface should not be placed within 20 feet of the tree, and canopy overlap with impervious surface is still anticipated given a longer setback, the tree flow control credit may still be approved.

Minimize the installation of any impervious surfaces in critical root zone areas. Where road or sidewalk surfaces are needed under a tree canopy, un-mortared permeable pavers or flagstone (rather than concrete or asphalt) or bridging techniques should be used (see Figure V - 2.).

2.2.14.7 Newly Planted Trees

The following design criteria are specific to projects proposing to plant new onsite trees for flow control credits.

2.2.14.7.1 Tree Species

Consult a landscape architect or other trained professional to guide the plant selection for each unique location and/or application. An example list of tree species is provided in Ecology's 2019 SWMMWW, Volume V, Table 11.3: Recommended Newly Planted Tree Species for Flow Control Credit.

2.2.14.7.2 Tree Size

To receive flow control credit, new deciduous trees at the time of planting shall be at least 1.5 inches in diameter measured 6 inches above the ground. New evergreen trees shall be at least 4 feet tall.

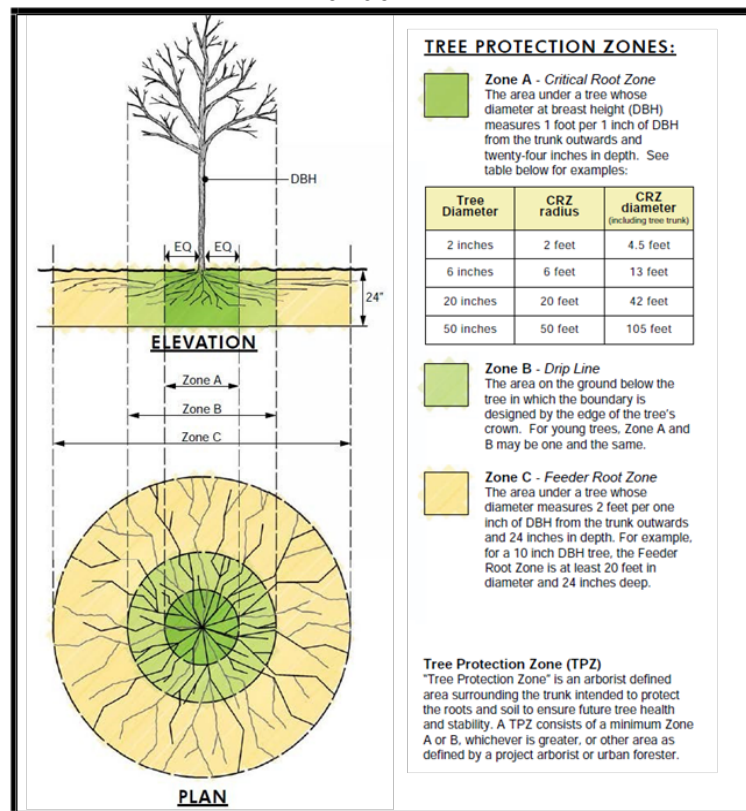
2.2.14.7.3 Tree Location

Similar to retained trees, flow control credit for newly planted trees depends upon proximity to ground level hard surfaces. To receive a credit, the tree must meet tree location requirements listed in retained tree design criteria above. Distance from hard surfaces is measured from the edge of the surface to the center of the tree at ground level.

Trees shall be sited according to sun, soil, and moisture requirements. Planting locations shall be selected to ensure that sight distances and appropriate setbacks are maintained given mature height, size, and rooting depths.

To help ensure tree survival and canopy coverage, the minimum tree spacing for newly planted trees shall accommodate mature tree spread. Onsite stormwater management and/or flow control credit must not be given for new trees with on-center spacing less than 10 feet.

Figure V - 2.21 Critical Root Zone, Source: Pierce County Stormwater Management Manual



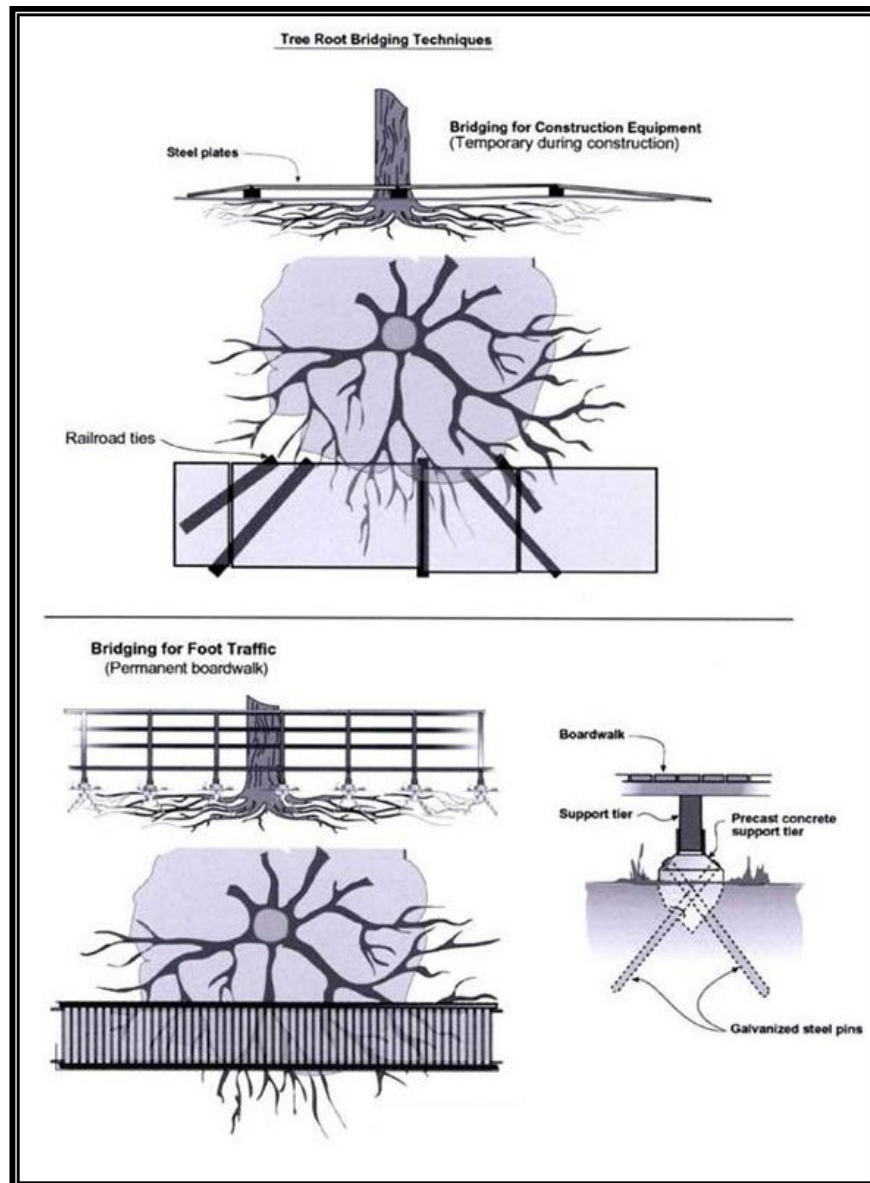


Figure V - 2.22 Root Bridge, Source: Pierce County Stormwater Management Manual

2.2.14.8 Plant Material and Planting Specifications

Standard practices for planting materials and methods are provided in the WSDOT Standard Specifications Sections 8-02 and 9-14 and WSDOT Standard Plan H-10.10-00.

2.2.14.9 Runoff Model Representation

If the design criteria for this BMP are followed, the total impervious/hard surface areas entered into the runoff model may be reduced by the amount indicated in the design criteria above.

2.2.14.10 Construction Criteria

Protect trees and tree root systems utilizing the following methods:

- The existing tree roots, trunk, and canopy shall be fenced and protected during construction activities.
- Trees that are removed or die shall be replaced with like species during the next planting season (typically in fall). Trees shall be pruned according to industry standards (ANSI A 300 standards).
- Reduce soil compaction during the construction phase by protecting critical tree root zones that usually extend beyond the trees canopy or drip line. The critical tree root zone should be factored using the tree's diameter breast height (see Figure 2.1421).
- Prohibit any excavation within the critical tree root zone.
- Prohibit the stockpiling or disposal of excavated or construction materials in the tree planting areas to prevent contaminants from damaging vegetation and soils.
- Avoid excavation or changing the grade near trees that have been designated for protection. If the grade level around a tree is to be raised, a dry rock wall or rock well shall be constructed around the tree. The diameter of this wall or well should be at least equal to the diameter of the tree canopy plus 5 feet.
- Prevent wounds to tree trunks and limbs during the construction phase.
- Tree root systems tend to overlap and fuse among adjacent trees. Trees or woody vegetation that will be removed and that are next to preserved trees should be cut rather than pushed over with equipment. Where construction operations unavoidably require temporary access over tree root zones or other soil protection areas, provide protection as follows:
 - For foot access or similar light surface impacts, apply a 6-inch layer of arborist wood chip mulch and water regularly to maintain moisture, control erosion and protect surface roots.
 - For any vehicle or equipment access, apply a minimum 1-inch steel plate or 4-inch thick timber planking over 2-3 inches of arborist wood chip

mulch, or a minimum 0.75-inch plywood over 6-8 inches of arborist wood chip mulch to protect roots and root zone soil from disturbance or compaction.

- Prep tree conservation areas to better withstand the stresses of the construction phase by pruning and applying a 1 inch layer of compost covered with a 2 inch layer of mulch around them well in advance of construction activities.

2.2.14.11 Operations and Maintenance Criteria

Trees shall be retained, maintained and protected on the site after construction and for the life of the development or until any approved redevelopment occurs in the future. Replace trees that are removed or die with like species during the next appropriate planting season (typically in the fall).

Prune, when necessary for compatibility with other infrastructure and/or to preserve the health and longevity of trees. Meet industry standards for pruning (ANSI A300 standards).

For newly planted trees, provide supplemental irrigation during the first three growing seasons after installation to help ensure tree survival.

See Core Requirement #9 in Volume I; Volume I, Section 3.8.4; and Volume I, Appendix I-E for information on maintenance requirements.

2.2.15 LID.15 Minimal Excavation Foundation Systems

Minimal excavation foundation systems are those techniques that minimize disturbance to the natural soil profile within the footprint of the structure. This preserves most of the hydrologic properties of the native soil. Pin foundations are an example of a minimal excavation foundation. For more information see Ecology's 2019 *Stormwater Manual for Western Washington* BMP T5.19: Minimal Excavation Foundations.

2.2.15.1 Applicability and Limitations

- To minimize soil compaction, heavy equipment, including pile driving equipment that would degrade the natural soil profile's ability to retain, drain and/or filter stormwater cannot be used within or immediately surrounding the building. Tracked equipment weighing 650 psf or less is acceptable

2.2.15.2 Design Criteria

Runoff Model Representation

- Where residential roof runoff is dispersed on the up-gradient side of a structure in accordance with the design criteria and guidelines in BMP LID.05: Downspout Dispersion Systems, the tributary roof area may be modeled as pasture on the native soil, provided the dispersed runoff is not cut off by an embedded grade beam, wall, or skirt structure from reaching the preserved permeable soils below the building.
- If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in BMP LID.05: Downspout Dispersion Systems, AND there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP LID.02: Post-Construction Soil Quality and Depth, the tributary roof areas may be modeled as lawn/landscaped area.
- Where terracing on a slope below the building or vegetated flow path, as defined above, is necessary for construction, the square footage of roof that can be modeled as pasture or lawn/landscaped area must be reduced to account for lost permeable soils. The roof area modeled as pasture or lawn/landscape shall be reduced by the same percentage as that of the intact permeable soils in the slope below the structure or within the down gradient flow path that are removed by the terracing.

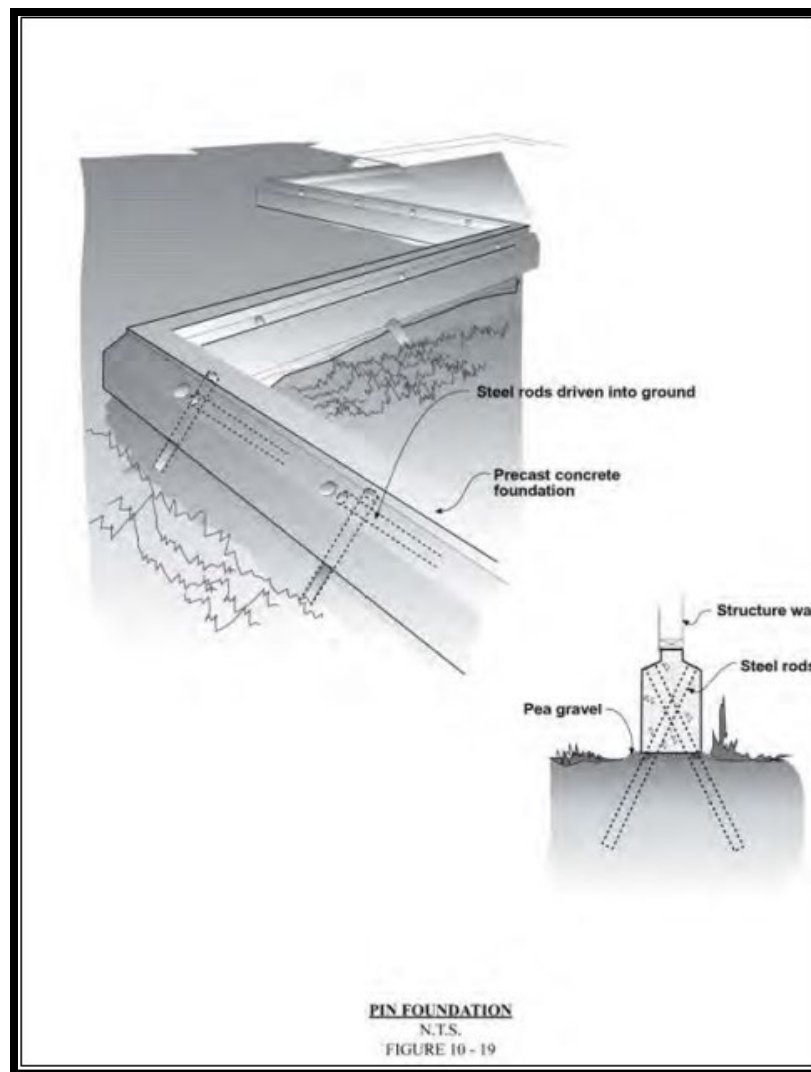


Figure V - 2.15 Pin Foundations

2.2.16 LID.16 Rainwater Harvesting

Rainwater harvesting is the capture and storage of rainwater for beneficial use. Roof run-off may be routed to cisterns for storage and nonpotable uses such as irrigation, toilet flushing, and cold water laundry. Rainwater harvesting can help reduce peak stormwater flows, durations, and volumes. The amount of reduction achieved with cistern storage is a function of contributing area, storage volume, and rainwater use rate.

2.2.16.1 Design Criteria

In order to use the guidance below for Runoff Model Representation, the design must show 100% reuse of the annual average runoff volume. The designer must use an approved continuous runoff model to calculate the annual average for drainage area.

System designs involving interior uses must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually.

Restrict the use of this BMP to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.

2.2.16.2 Runoff Model Representation

If the design criteria for this BMP are followed, the area draining to the rainwater harvesting BMP is not entered into the runoff model.

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 groundwater, as needed to protect water uses. Frequently infiltration will be used in combination with detention and release to meet Core 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 of stormwater through Underground Injection Control (UIC) wells is regulated by the Washington State Department of Ecology (Ecology) and the Underground Injection Control (UIC) Program (Washington Administrative Code [WAC] 173-218).

The UIC Program guidance has been incorporated into Ecology's 2019 Stormwater Management Manual for Western Washington (SWMMWW). See Volume I, Section I-4: UIC Program in the 2019 SWMMWW for requirements and information pertaining to the design, construction, operation and maintenance, and management of new and existing UIC wells. Where Ecology's SWMMWW Minimum Requirements or BMPs are referenced, refer to the equivalent Core Requirements and BMPs in this Manual. In instances where no equivalent DDECM section or guidance exists, apply Ecology's SWMMWW. Note that UIC BMPs in the 2019 SWMMWW supersedes the 2006 Ecology Guidance for UIC wells that manage stormwater.

Due to Thurston County's reliance on groundwater as a primary source for drinking water, the County may impose additional, more stringent requirements than Ecology for deep UICs (UIC wells that extend below an upper confining layer and discharge into the underlying vadose zone). These requirements normally include, but are not limited to a hydrogeologic investigation and/or assessment, UIC installation to be completed by a Washington State licensed well driller, additional treatment BMPs, restrictions on appropriate land use, or other protective measure as determined by the Manual Administrator or designee.

Note: Project proponents are highly encouraged to explore alternative approaches to stormwater management before deciding to use a deep UIC well.

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. Per WAC 173-218-030, a UIC well is a well that is used to discharge fluids into the subsurface. A UIC well is one of the following: (1) A bored, drilled or driven shaft, or dug hole whose depth is greater than the largest surface dimension; (2) an improved sinkhole; or (3) a subsurface fluid distribution system.

UIC systems may include drywells, perforated 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 UIC wells at single-family homes (or duplexes) receiving only residential roof runoff used to collect stormwater runoff from roof surfaces on an individual home (or duplex) or for basement flooding 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.

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 groundwater are not endangered by pollutants in the discharge (non-endangerment standard).

To operate, all shallow UIC wells must:

1. Be rule-authorized or covered by a state waste discharge permit to operate.
2. If a UIC well is rule-authorized, a permit is not required.
3. Rule-authorization can be rescinded if a UIC well no longer meets the non-endangerment standard.
4. 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: <https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Underground-injection-control-program>.

To operate, all deep UIC wells must be permitted (i.e., are not rule-authorized) and:

1. Be deeper than 20 feet or pierce a confining layer.
2. Designs must be accompanied by a hydrogeologic investigation identifying downgradient receptors within a 2-year time-of-transport for a conservative solute. Data and modeling to support this evaluation may be available from Thurston County.
3. Waivers from this requirement may be considered if accompanied by a written request sealed by a Washington-licensed hydrogeologist certifying that the proposed deep UIC(s) do not pose a threat to any drinking water supplies

within a 2-year time-of-transport for a conservative solute, and accompanied by sufficient support information.

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 Groundwater 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 III, 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

The project engineer or designee shall inspect infiltration facilities before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place. If an engineered or bioretention soil mix will be placed to provide treatment in an infiltration facility, prior to placement of the engineered or bioretention soil mix, the project engineer shall verify that the finished subgrade is scarified and meets the designed infiltration rate. The project engineer shall notify Thurston County at (360) 754-4681 two days before placement of treatment soils, if any, to verify subgrade.

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 groundwater 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 3.1.5, 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 Basins
- IN.02 Infiltration Trenches
- IN.03 Infiltration Vaults and Drywells

3.2.1 IN.01 Infiltration Basins

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

If this BMP is proposed to be used for Runoff Treatment, the design must show that the criteria for Runoff Treatment in Volume III, Site Suitability Criteria (SSC) are met. Refer to the guidance in Volume III for information pertinent to all infiltration BMPs.

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

3.2.1.1 Applicability

Infiltration basins for flow control are used to convey stormwater runoff from new development or redevelopment to the ground and groundwater after appropriate treatment. Infiltration basins designed to meet runoff treatment criteria of Core 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, Core 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 groundwater resources, and
- Will not cause a violation of groundwater 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.

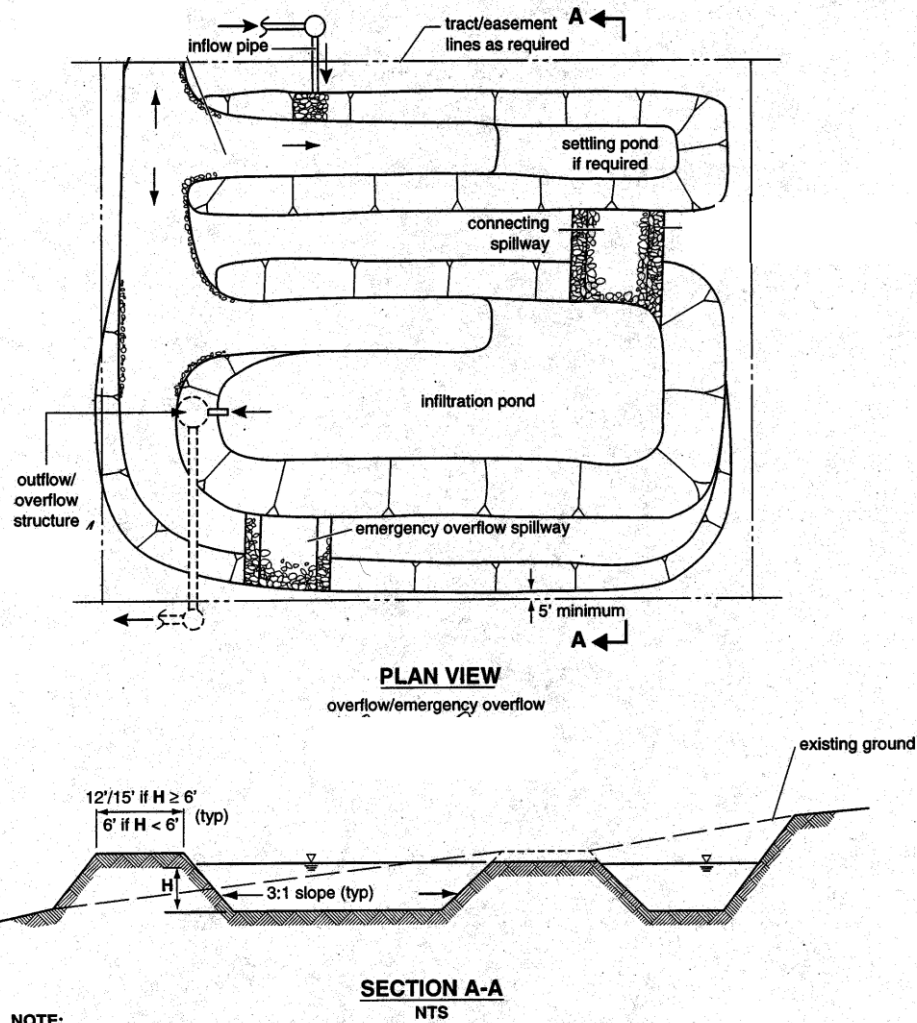


Figure V - 3.1 Typical Infiltration Pond/Basin

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.

3.2.1.2 Limitations

See Volume III for soil testing and site suitability criteria.

3.2.1.3 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 core 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.

3.2.1.4 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 pretreatment BMP or basic treatment BMP 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.

3.2.1.5 Hydrologic and Hydraulic Design Considerations

See Volume III for detailed guidance on modeling infiltration basins.

3.2.1.5.1 100-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).

3.2.1.6 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 Core 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.

3.2.1.7 Design Criteria

3.2.1.7.1 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.

- Infiltration basins with a maximum depth of 4 feet or more and a minimum storage volume of 5,000 cubic feet are required to include a crest gage that will record maximum basin water surface elevation after a storm event. The designer may submit alternative crest recording device for county acceptance. See WSDOT Standard Plan H-30.10-00, Crest Gage for crest gage details. In addition, project submittals must include a table that identifies the design stage/storage/discharge expected for the 2-, 5-, 10-, 25-, 50, and 100-year recurrence interval flows.

3.2.1.7.2 Materials

Lining material: Infiltration 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-B). 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 Core 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 V – 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 groundwater pollution. Consult the local extension agency for appropriate fertilizer types and application rates.

3.2.1.8 Site Design Elements

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

3.2.1.8.1 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.

3.2.1.9 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 track hoes 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.

3.2.1.10 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.

Figure V - 3.2 through Figure V - 3.7 provide different configurations for infiltration trenches. Infiltration trenches are 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.

3.2.2.1 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.

Infiltration trenches can be used to meet the flow control standards of Core Requirement #7.

When used in combination with other onsite stormwater management BMPs, they can also help achieve compliance with the Performance Standard option of Core Requirement #5.

Infiltration trenches can be used to meet some of the water quality treatment requirements of Core Requirement #6 if the underlying soil meets the requirements provided in Volume III, Section 2.3.1.

3.2.2.2 Limitations

See Volume III for soil testing and site suitability criteria.

3.2.2.3 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).

3.2.2.4 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 basic treatment BMP or pretreatment BMP 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.

3.2.2.5 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.

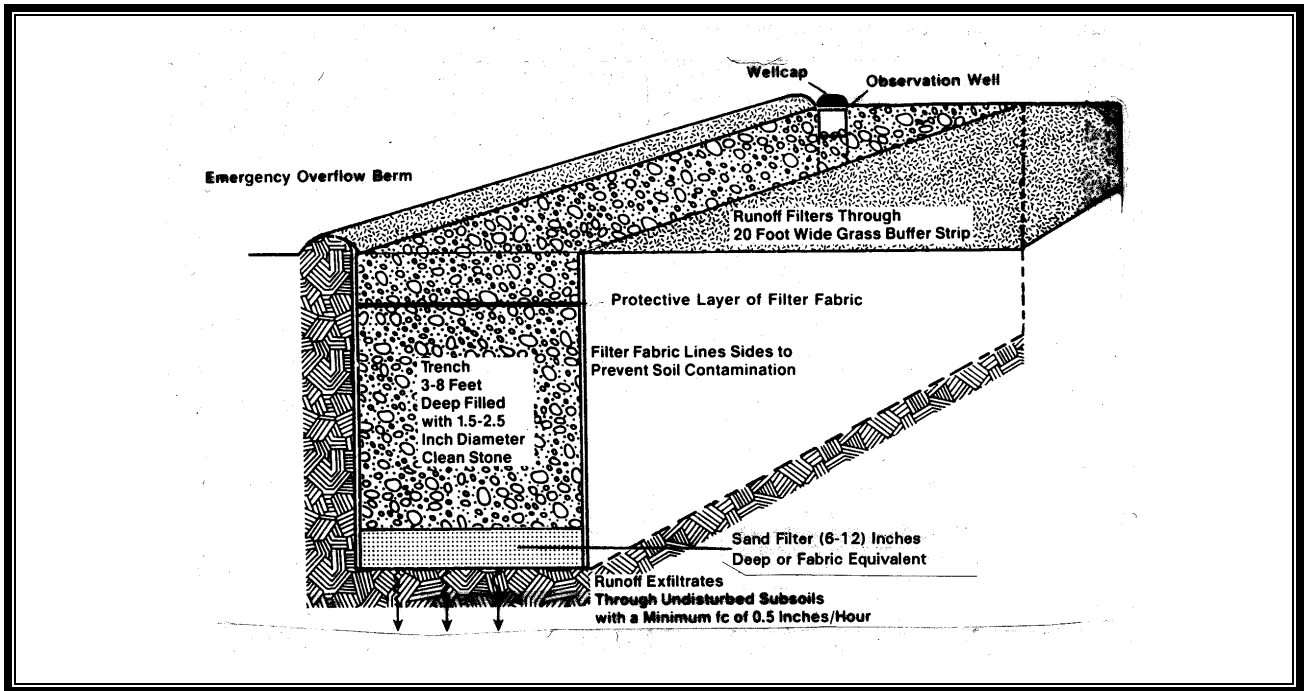


Figure V - 3.2 Schematic of an Infiltration Trench

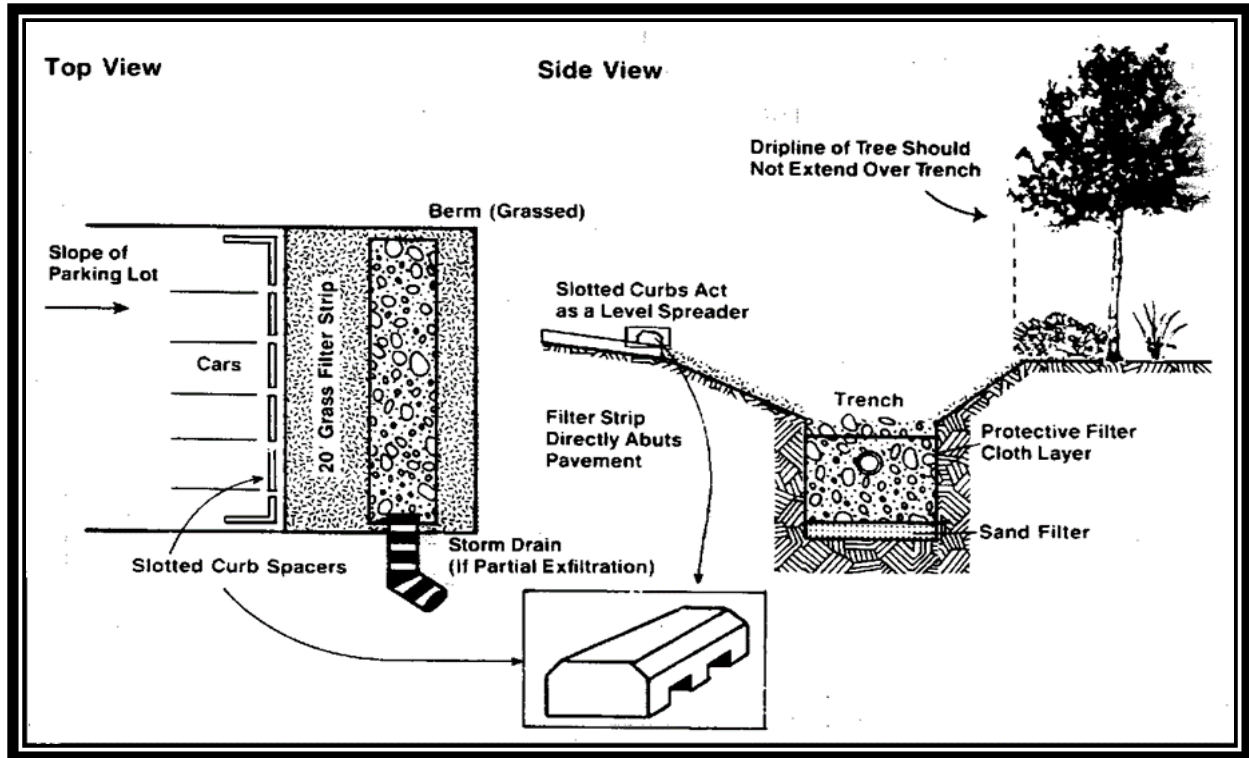
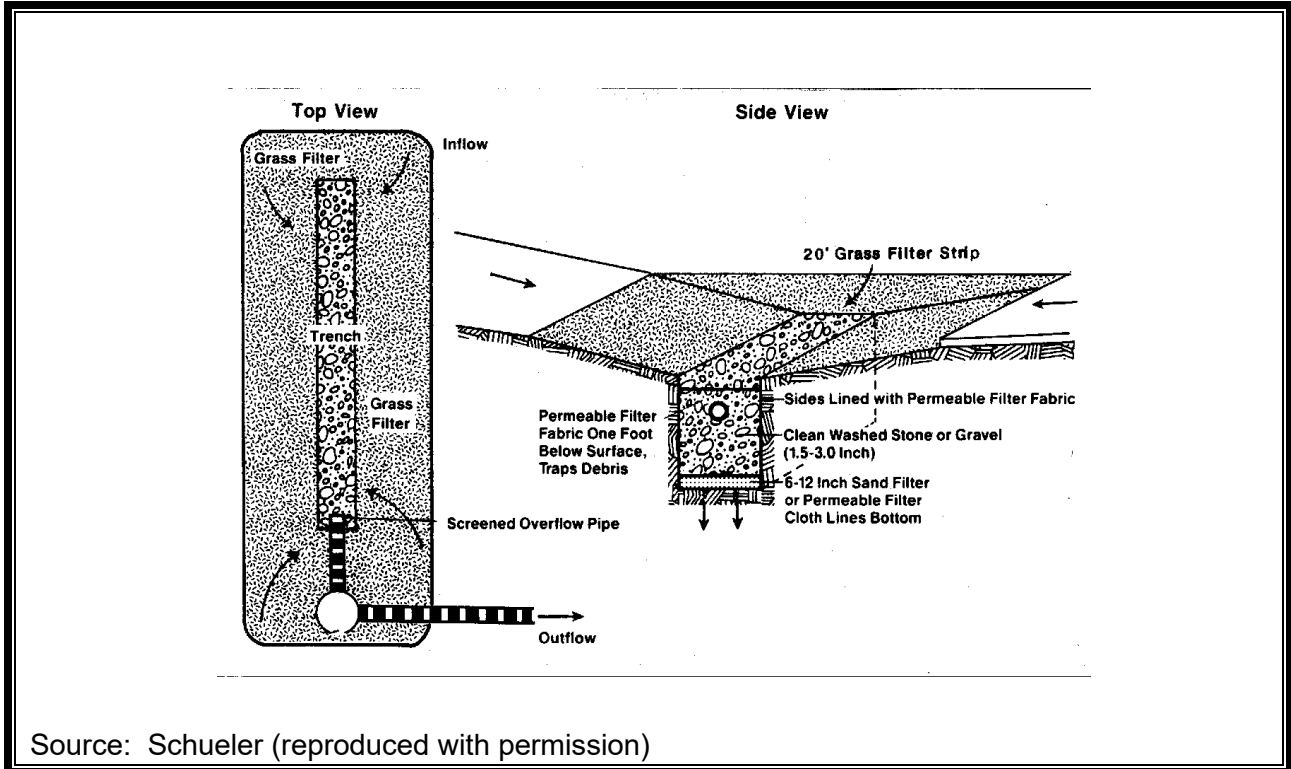


Figure V - 3.3 Parking Lot Perimeter Trench Design



Source: Schueler (reproduced with permission)

Figure V - 3.4 Median Strip Trench Design

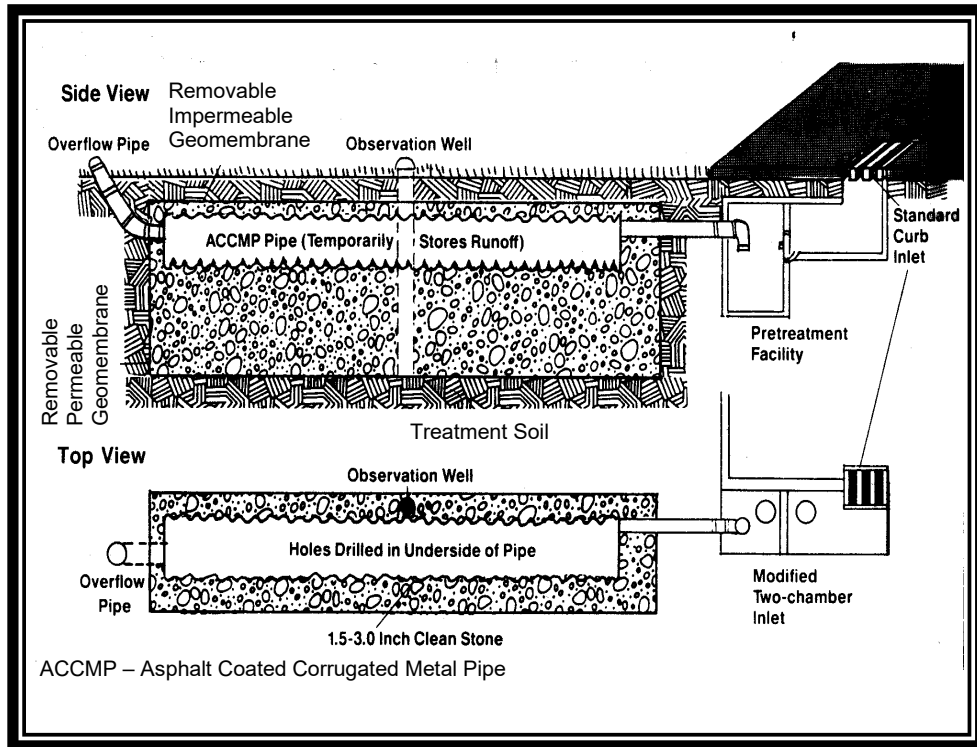


Figure V - 3.5 Oversized Pipe Trench Design

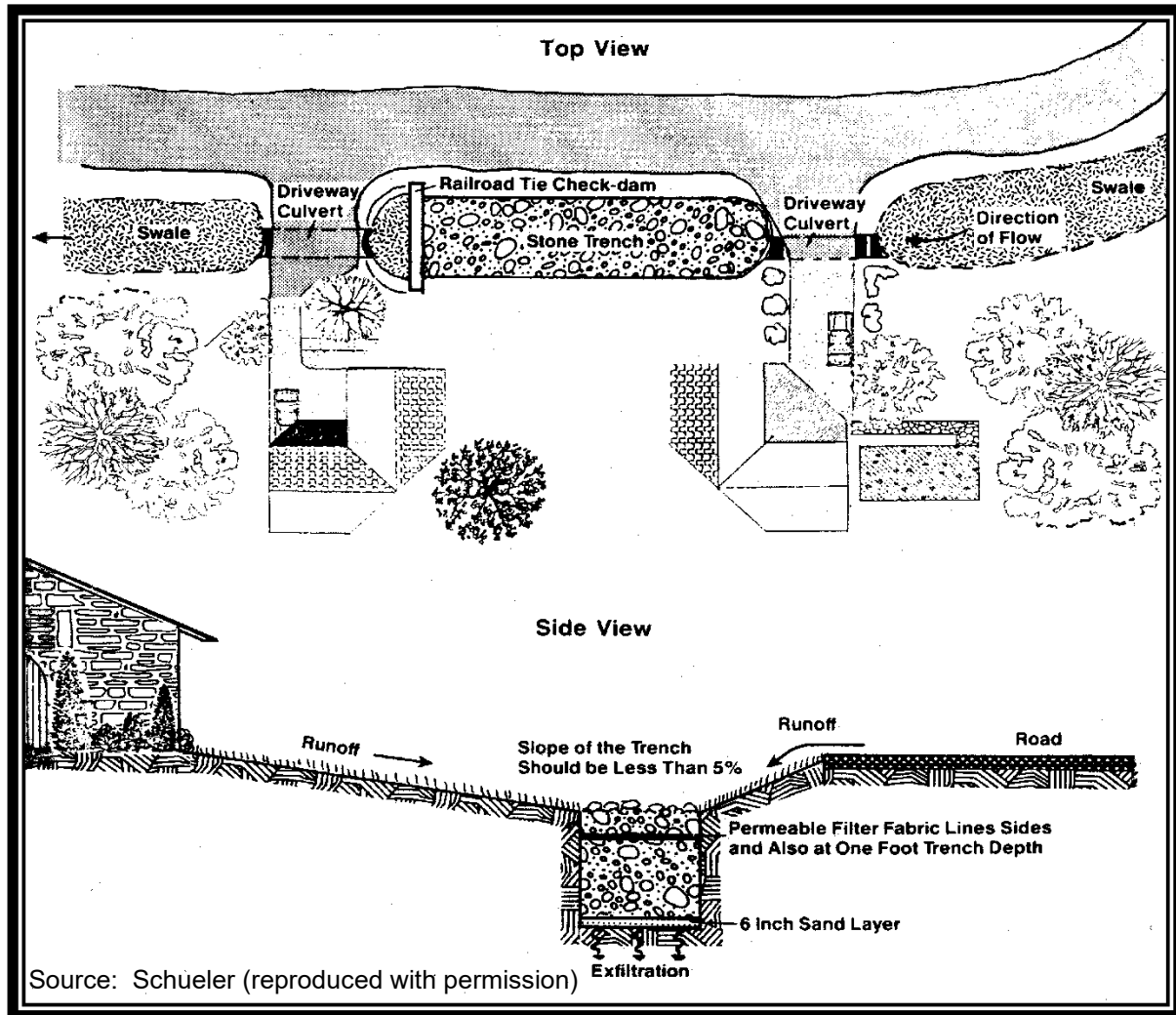


Figure V - 3.6 Swale/Trench Design

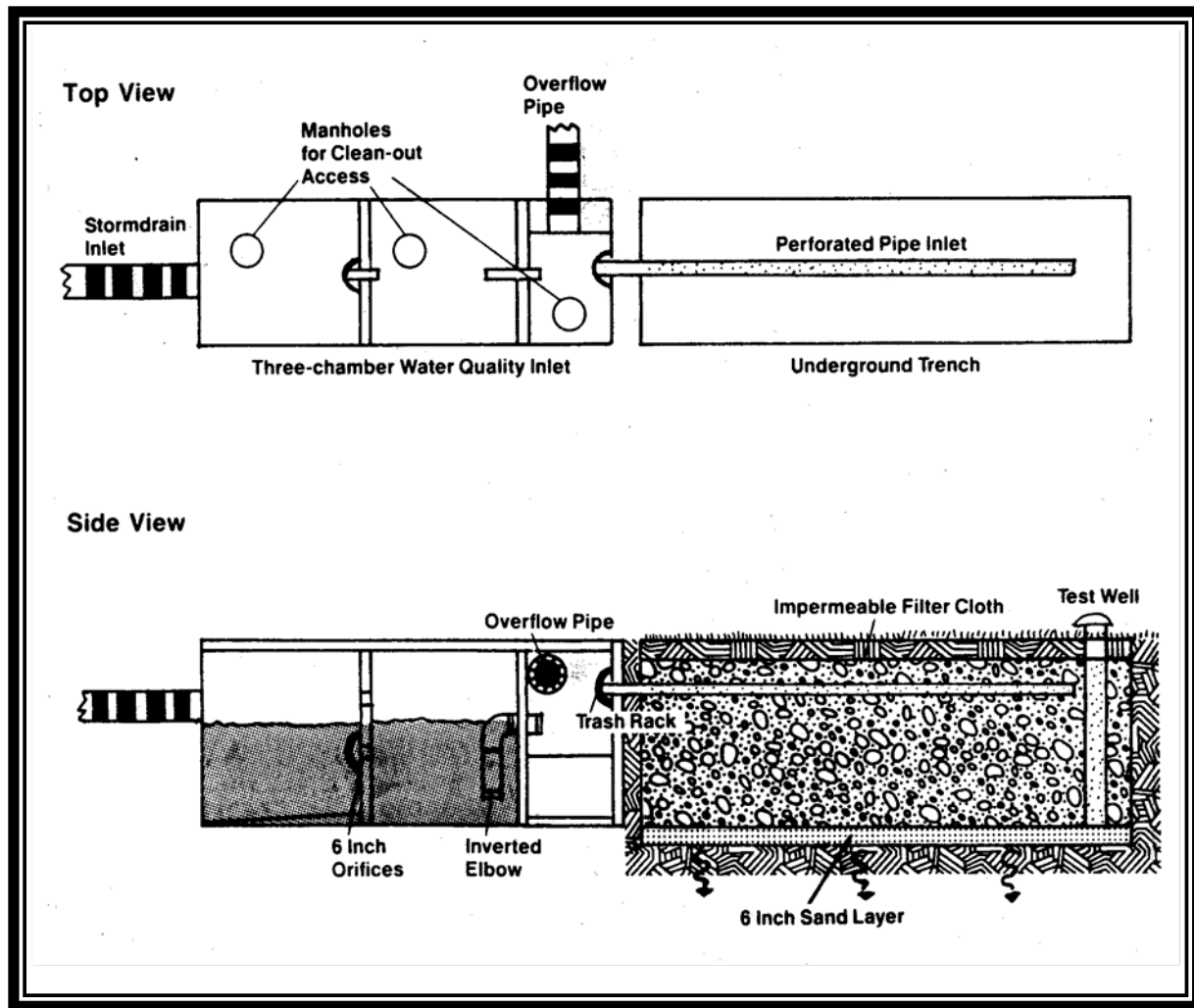


Figure V - 3.7 Underground Trench with Oil/Grit Chamber Source: Schueler (reproduced with permission)

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 V - 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.

3.2.2.6 Design Criteria

3.2.2.6.1 Trench Cover

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

3.2.2.6.2 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). Where perforated pipe is not used, UIC regulations do not apply.

3.2.2.6.3 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.

3.2.2.6.4 Materials

Backfill Material:

The aggregate material for the infiltration trench must consist of a clean aggregate and meet WSDOT Specification 9-03.12(5) that nominally ranges from 0.75-inch to 1.5-inch diameter. A maximum diameter of 3 inches and a minimum diameter of 1.5 inches may be approved if void space is maintained. 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-B of Volume V).²

A 6-inch minimum layer of sand may be used as a filter media at the bottom of the trench instead of geotextile.

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

3.2.2.7 Construction and Maintenance

Initial trench excavation shall be conducted to within 2 feet of the final elevation of the trench 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 silt 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.

² Refer to the Federal Highway Administration Manual "Geosynthetic Design and Construction Guidelines," Publication No. FHWA HI-95-038, May 1995 for design guidance on geotextiles in drainage applications. Refer to the NCHRP Report 367, "Long-Term Performance of Geosynthetics in Drainage Applications," 1994, for longterm performance data and background on the potential for geotextiles to clog, blind, or to allow piping to occur and how to design for these issues.

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 Vaults and Drywells

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

Infiltration vaults and drywells are typically underground structures that convey stormwater runoff into the soil matrix. They can be used as standalone structures, or as part of a larger drainage system. These types of underground infiltration facilities can be a useful alternative for sites with constraints that make siting an infiltration pond difficult.

Infiltration vaults and drywell are subject to UIC regulations; see 3.1.3 Underground Injection Control.

3.2.4 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 Core Requirement 6.

3.2.4.1 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.

Drywells and infiltration vaults should not be built on slopes greater than 25% (4:1).

Drywells and infiltration vaults shall not be placed on or above a landslide hazard area or slopes greater than 15% without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or licensed geologist and acceptance from Thurston County's DDECM Administrator.

3.2.4.2 Submittals and Approval

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

3.2.4.3 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 pretreatment BMP or basic treatment BMP 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.

3.2.4.4 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 for infiltration vaults to bypass flows over the 100-year post developed peak flow to the infiltration vault.

3.2.4.5 Design Criteria

3.2.4.5.1 Geometry

Infiltration Vaults:

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.

Drywells:

Drywell bottoms should be a minimum of 5 feet above the seasonal high groundwater level or impermeable soil layers.

Drywell are typically a minimum of 48 inches in diameter and approximately 5 to 10 feet deep, or more.

Drywells should be no closer than 30 feet center to center or twice the depth, whichever is greater.

3.2.4.6 Structural Design Considerations

3.2.4.6.1 Materials

Infiltration Vaults:

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 V - 3.8), or plastic 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.

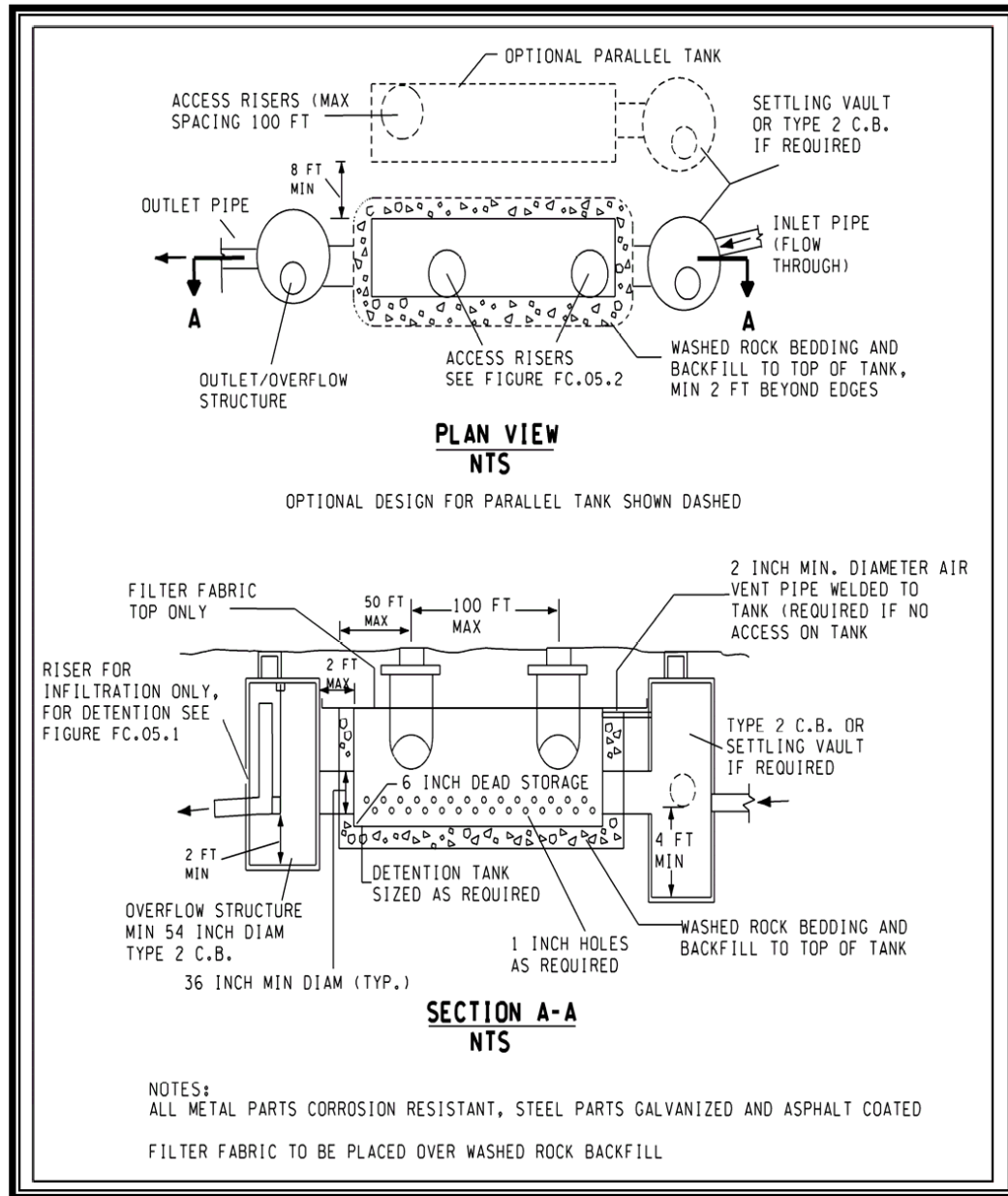


Figure V - 3.8 Infiltration Vault

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.

Open bottom stormwater chamber systems may also be used with the construction criteria shown above.

Drywells:

Filter fabric (geotextile) should be placed on top of the drain rock and on trench or drywell sides prior to backfilling to prevent migration of fines into the drain rock, depending on local soil conditions.

3.2.4.6.2 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.

3.2.4.6.3 Access

Access for infiltration vaults 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 V - 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.

3.2.4.7 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 track hoes should be considered. The infiltration area should be flagged or marked to keep equipment away.

See Appendix V-C for information on maintenance requirements.

Chapter 4 - Detention BMPs

4.1 Detention Facility BMPs

Detention facilities temporarily store increased surface runoff from development, meeting performance standards described in Core 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.

4.1.1.1 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.

4.1.1.2 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.

4.1.1.3 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 (Core 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.

4.1.1.4 Pretreatment

Pretreatment is not required.

4.1.1.5 Hydrologic and Hydraulic Design Considerations

4.1.1.5.1 General Hydraulic Design Considerations

Detention ponds must be designed as flow-through systems (however, parking lot storage may be utilized through a back up system). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximize the distance between the inlet and outlet to promote sedimentation.

4.1.1.5.2 Detention Volume and Outflow

The volume and outflow design for detention ponds must comply with both Core 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.

4.1.1.5.3 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.

4.1.1.5.4 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.

4.1.1.5.5 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.

4.1.1.5.6 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 V - 4.2).

Design the emergency overflow spillway to allow a minimum of 1 foot of freeboard above the design water surface elevation.

4.1.1.5.6.a 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).

4.1.1.6 Design Criteria

See Figure V - 4.1 and Figure V - 4.2 for typical detention pond layout.

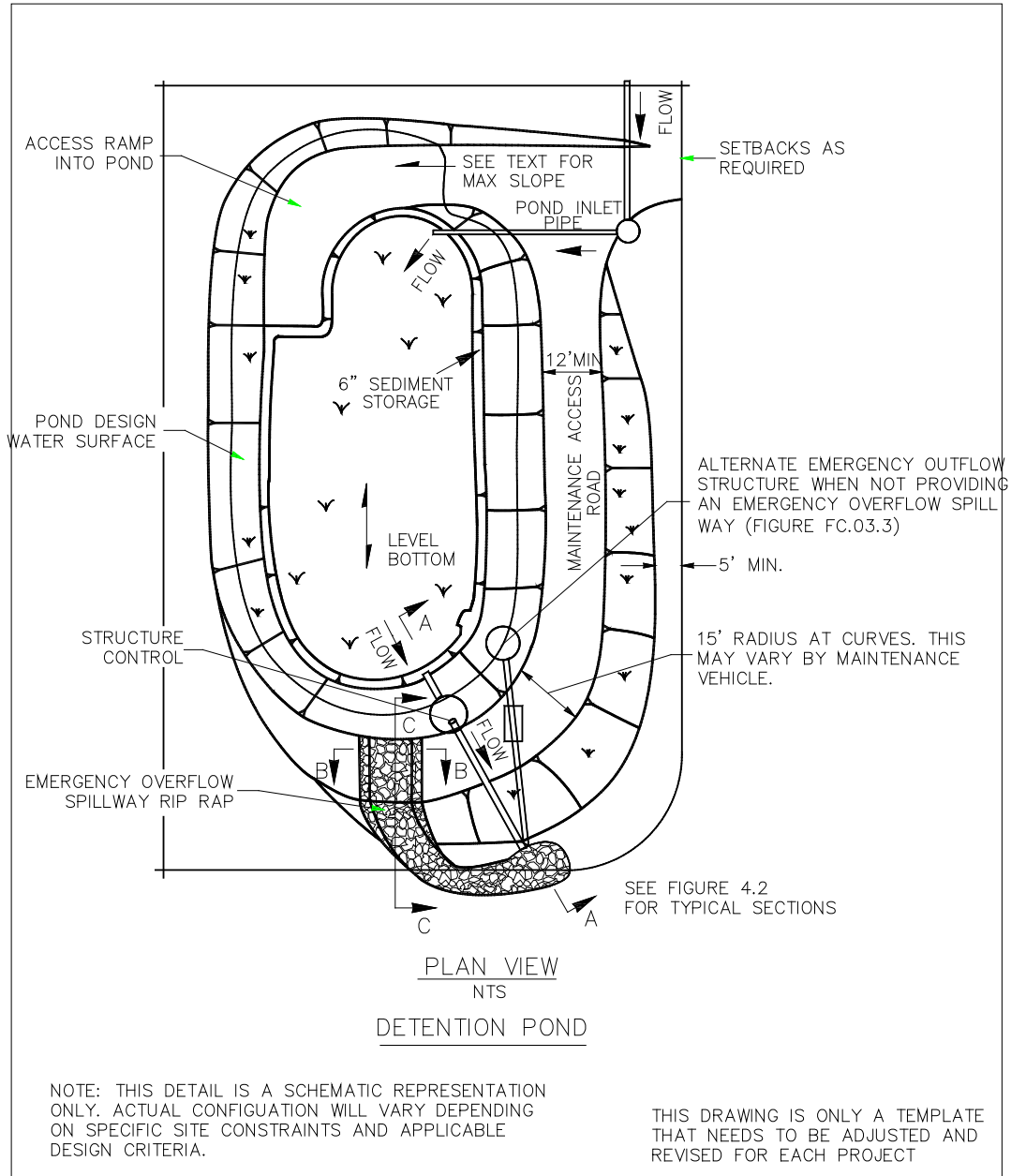


Figure V - 4.1 Typical Detention Pond

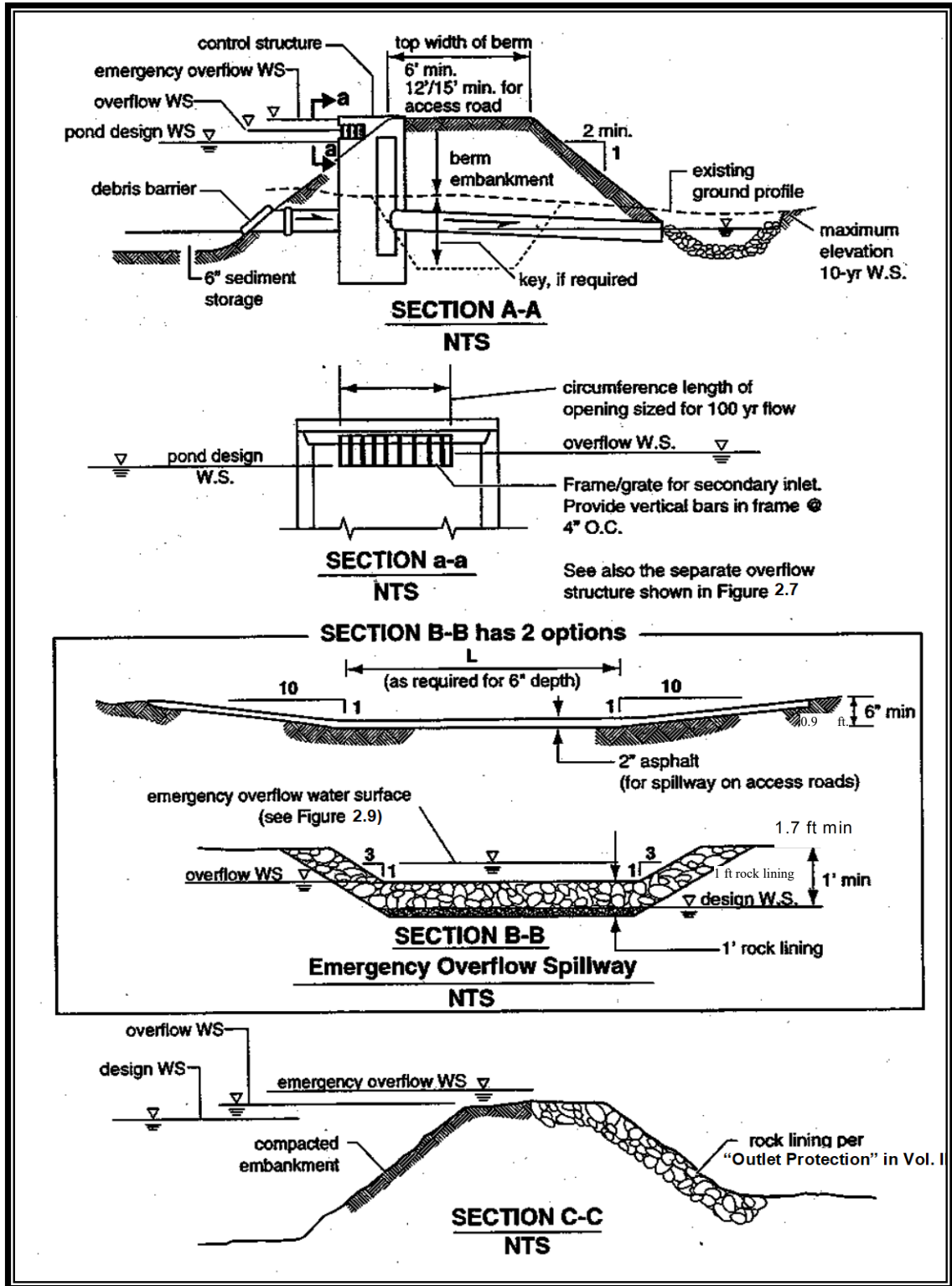


Figure V - 4.2 Typical Detention Pond Sections

4.1.1.6.1 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.

4.1.1.7 Structural Design Considerations

4.1.1.7.1 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.

4.1.1.7.2 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.

4.1.1.7.3 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 70 to 73) of the Dam Safety Guidelines Part 4 – Dam Design and Construction (Ecology 1993). An electronic version of the Dam Safety Guidelines is available in PDF format at <https://ecology.wa.gov/Water-Shorelines/Water-supply/Dams/Construction-maintenance/Guidance..>

4.1.1.7.4 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>.

4.1.1.8 Site Design Elements

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

4.1.1.9 Construction and Maintenance

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

4.1.1.9.1 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 V - 4.3 and Figure V - 4.4.

4.1.2.1 Applicability

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

4.1.2.2 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.

4.1.2.3 Hydrologic and Hydraulic Design Considerations

4.1.2.3.1 General Hydraulic Design Considerations

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

4.1.2.3.2 Detention Volume and Outflow

Design volumes and outflows for detention tanks to meet the performance standards as required in Core Requirement #5: Onsite Stormwater Management, Core Requirement #7: Flow Control, and/or Core Requirement #8: Wetlands Protection, and the hydrologic analysis and design methods described in Volume III. Design guideline for control structures are given in Appendix V-A.

4.1.2.3.3 Control Structures

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

Tanks may be designed as flow-through systems with manholes in line to promote sediment removal and facilitate maintenance, or may be designed as backup systems if preceded by water quality treatment 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.

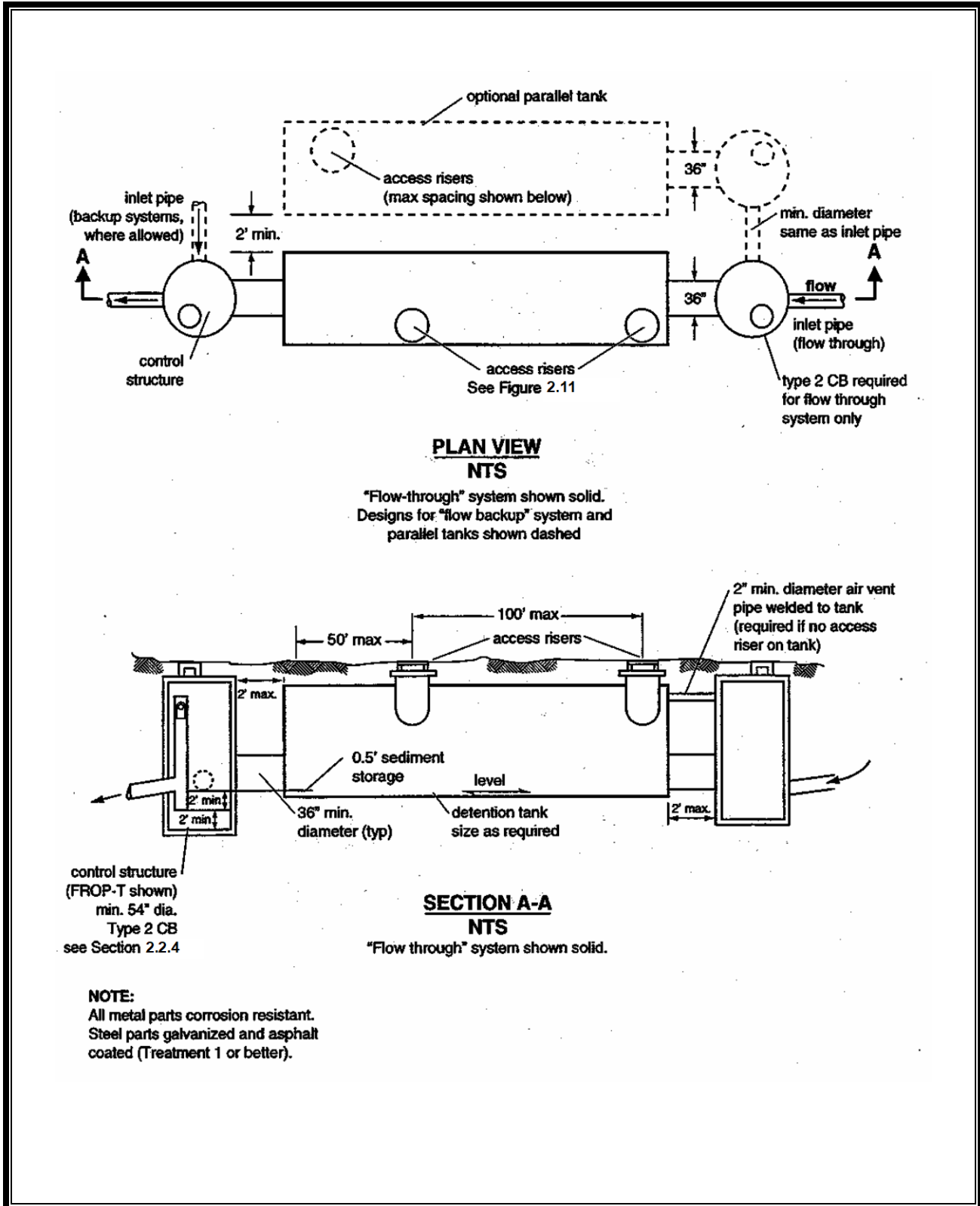
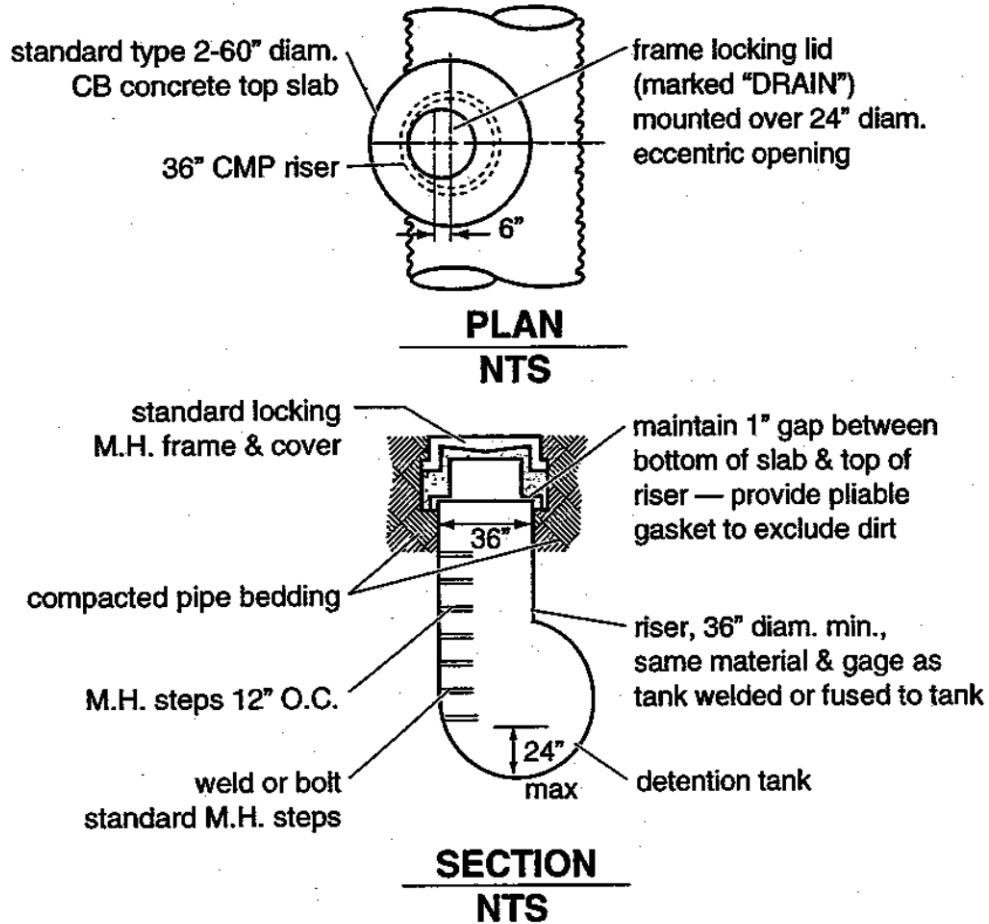


Figure V - 4.3 Typical Detention Tank



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 V - 4.4 Detention Tank Access Detail

4.1.2.4 Design Criteria

4.1.2.4.1 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.

4.1.2.4.2 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

- Steel reinforced polyethylene (SRPE)

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. Where other metals (such as aluminum or stainless steel) or plastics are available, they should be used.

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.

4.1.2.5 Structural Design Considerations

4.1.2.5.1 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.

4.1.2.5.2 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.

4.1.2.5.3 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 V - 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.

Note: Control structures and access manholes should have additional ladder rungs to allow ready access to all detention tank access pipes when the catch basin sump is filled with water.

4.1.2.6 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.

4.1.2.7 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.

4.1.2.8 Construction and Maintenance

4.1.2.8.1 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.

4.1.2.8.2 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

4.1.3.1 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.

4.1.3.2 Hydrologic and Hydraulic Design Considerations

4.1.3.2.1 Detention Volume and Outflow

Design the volumes and outflows for detention vaults to meet the performance standards as required in Core Requirement #5: Onsite Stormwater Management, Core Requirement #7: Flow Control, and/or Core Requirement #8: Wetlands Protection, and the hydrologic analysis and design methods described in Volume III. Design guideline for control structures are given in Appendix V-A.

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

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

4.1.3.3 Design Criteria

A standard detention vault detail is shown in Figure V - 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.

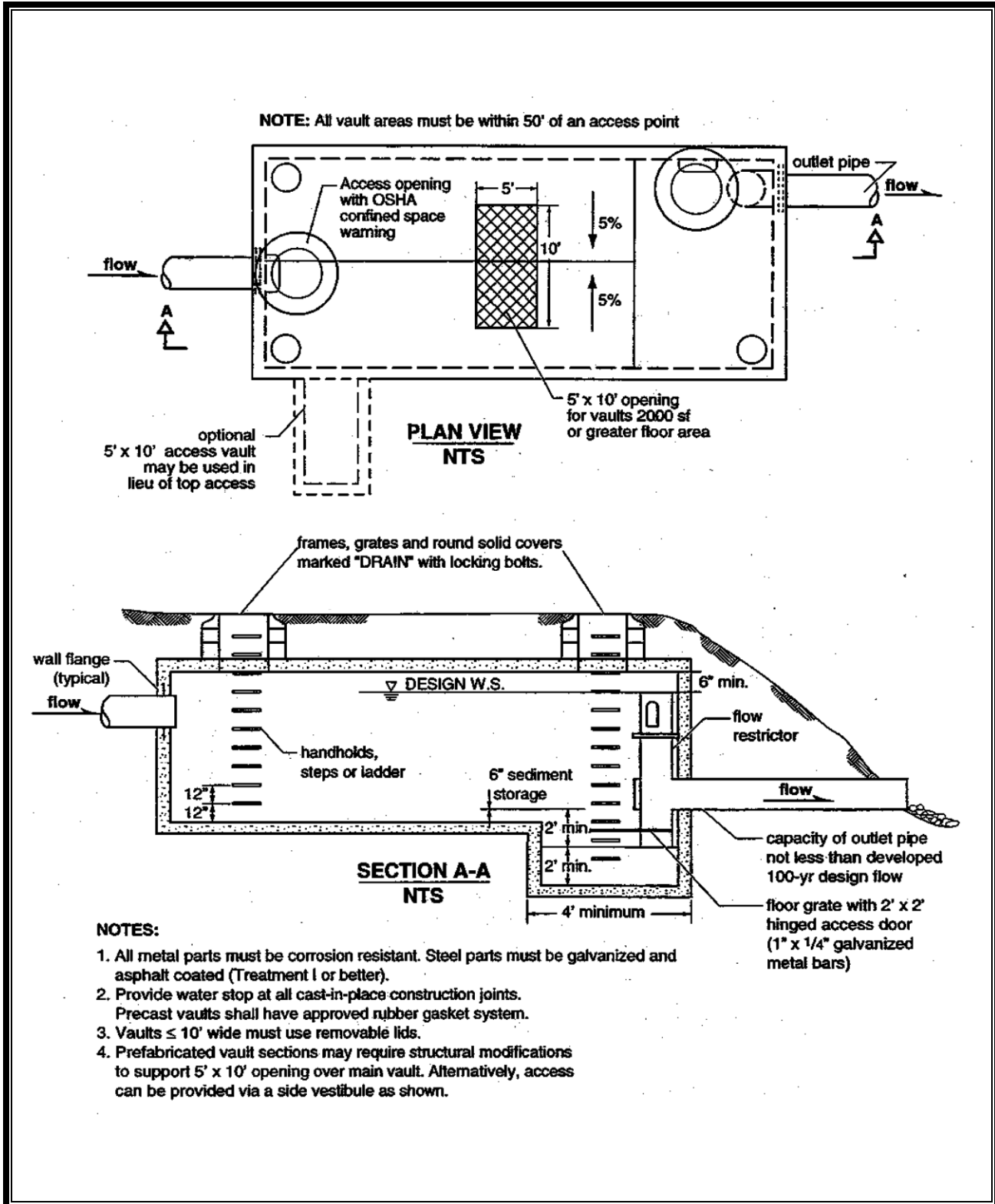


Figure V - 4.5 Typical Detention Vault

4.1.3.3.1 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.

4.1.3.4 Structural Design Considerations

4.1.3.4.1 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.

4.1.3.4.2 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.

4.1.3.4.3 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 V - 4.5.

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.

4.1.3.5 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.

4.1.3.5.1 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.

4.1.3.6 Construction and Maintenance

4.1.3.6.1 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.

4.1.3.6.2 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.

Biofiltration BMPs remove low concentrations and quantities of total suspended solids, heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater.

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. In cases where hydrocarbons, high TSS, or debris would be present in the runoff, as such as high-use sites, a pretreatment system for those components would be necessary. 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. Consider biofiltration BMPs in retrofit situations where appropriate (Center for Watershed Protection, 1998).

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.

- Target pollutants are amenable to biofiltration treatment

If the biofilter within the biofiltration BMP can be impacted by snowmelts and ice, refer to (Caraco and Claytor, 1997) for additional design criteria. 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 Compost-Amended Vegetated Filter Strips (CAVFS)

5.1.1 BF.01 Basic Biofiltration Swale



Biofiltration swale with check dams at Ecology headquarters

5.1.1.1 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.

5.1.1.2 Limitations

Data suggests that the performance of biofiltration swales is highly variable from storm to storm. It is therefore recommended that treatment methods that perform more consistently, such as BMP MF.01: Sand Filter Basin and BMP WP.02: Wetponds, before using a biofiltration swale. Biofiltration swales downstream of Runoff Treatment BMPs of equal or greater effectiveness can convey runoff, but the designer should not consider them to offer additional Runoff Treatment benefit (Horner, 2000).

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 to 15 inches.

Maintenance access to the biofiltration swale inlet, outlet, and to mowing.

5.1.1.3 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.

5.1.1.4 Pretreatment

Pretreatment is not required.

5.1.1.5 Hydrologic and Hydraulic Design Considerations

- Table V - 5.1 specifies design criteria. Use a 9 minute hydraulic residence time at a multiple of the peak 15 minute Water Quality Design Flow Rate (Q) representing 91% runoff volume as determined by an Ecology approved continuous runoff model.
- Check the hydraulic capacity/stability for inflows greater than design flows. Bypass high flows, or control release rates into the biofiltration swale, if necessary.
- Install flow spreaders (minimum 1 inch gravel) at the head and every 50 feet in swales of 4 feet width. Include sediment cleanouts (weir, settling basin, or equivalent) at the head of the biofilter as needed.
- Use energy dissipators (riprap) for increased downslopes.

Table V - 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) 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 4.)
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 side slope	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. Below the design water depth install an erosion control blanket, at least 4" of topsoil, and the selected biofiltration mix. Above the water line use a straw mulch or sod.
3. This range of Manning's n can be used in the equation; $b = Qn/1.49y^{1.67} s^{0.5} - Zy$ with bottom width b, and lower depth, y, at the same flow. This provides the designer with the option of varying the bottom width of the swale depending on space limitations. Designing at the higher n within this range at the same flow decreases the hydraulic design depth, thus placing the pollutants in closer contact with the vegetation and the soil.
4. 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.

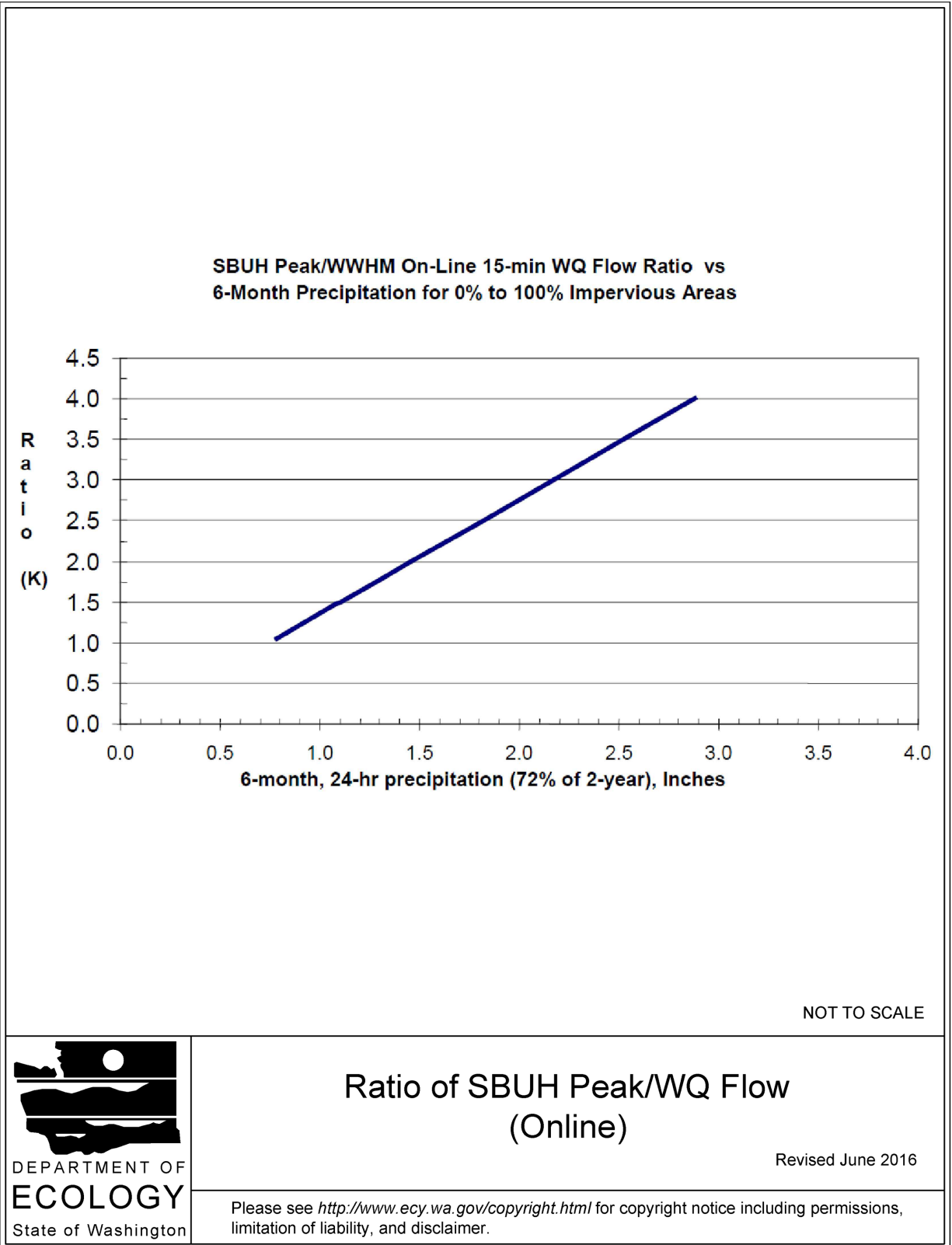


Figure V – 5.1 Ratio of SBUH Peak/WQ Flow (Online)

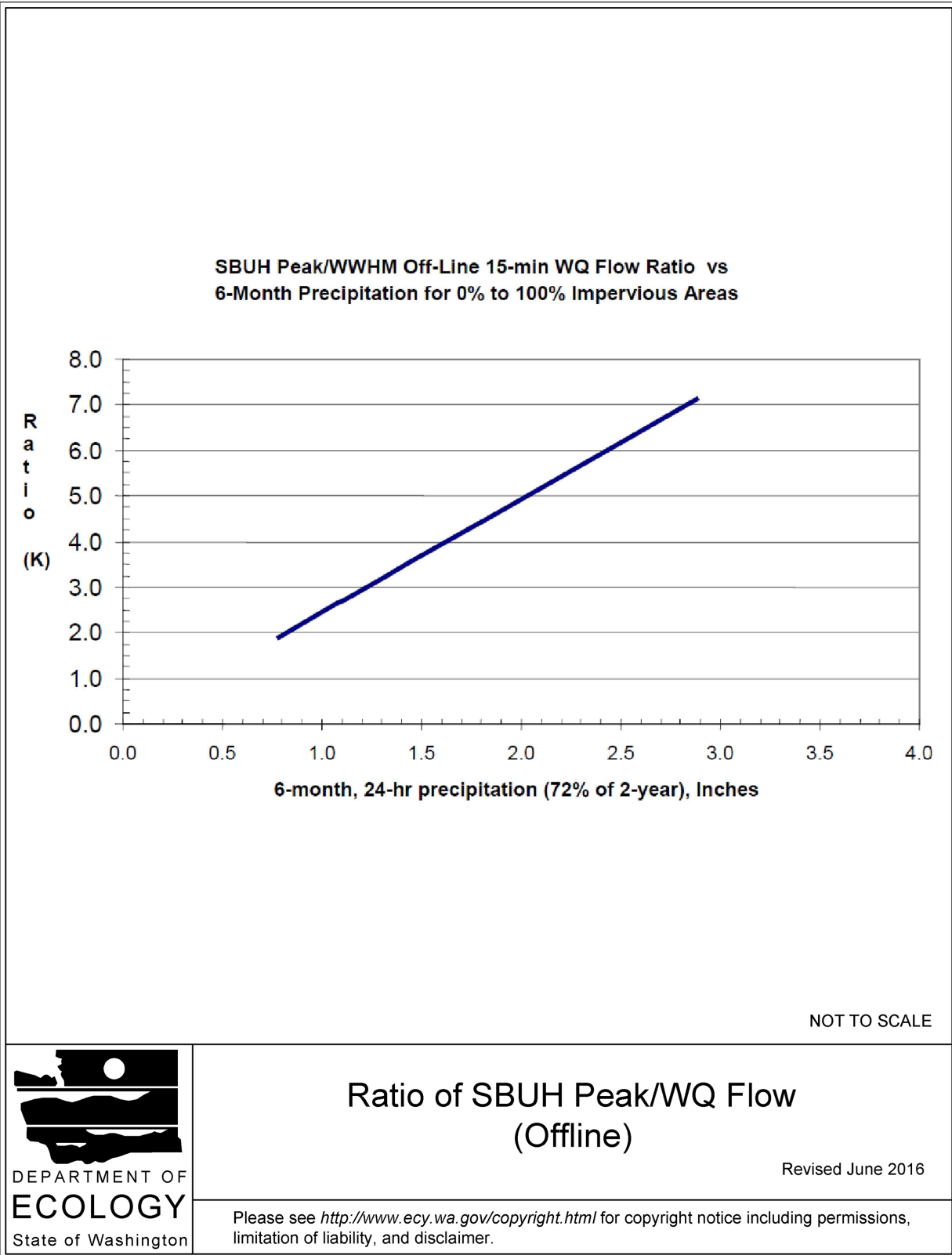


Figure V – 5.2 Ratio of SBUH Peak/WQ Flow (Offline)

5.1.1.5.1 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. Swales designed in an off-line mode should not engage a bypass until the flow rate exceeds a value determined by multiplying Q , the off-line water quality design flow rate predicted by an approved continuous runoff model, by the ratio determined in Figure V - 5.2. This modified design flow rate is an estimate of the design flow rate determined by using Santa Barbara Urban Hydrograph (SBUH) procedures. When designing a swale to be off-line, the stability check described under *Sizing Procedure for Biofiltration Swales* is not required.

5.1.1.5.2 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).

5.1.1.5.3 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.

5.1.1.5.4 Sizing Procedure for Biofiltration Swales

This guide provides biofilter swale design procedures in full detail, along with examples.³

5.1.1.5.4.a 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.

P-2. Establish the longitudinal slope of the proposed biofilter.

P-3. Select vegetation cover suitable for the site. Refer to Tables V – 5.2, 5.5, and 5.6 to select vegetation for western Washington.

5.1.1.5.4.b Design Calculations for Biofiltration Swale

The procedure recommended here is an adaptation from the design procedure originated by Chow (Chow, 1959) for biofiltration applications in Puget Sound,

This procedure reverses Chow's order, designing first for capacity and then for stability. The capacity analysis emphasizes the promotion of biofiltration, rather than transporting

³ WSDOT has developed a biofiltration swale design spreadsheet that available at <http://www.wsdot.wa.gov/Environment/WaterQuality/Runoff/HighwayRunoffManual.htm>

flow with the greatest possible hydraulic efficiency. Therefore, it is based on criteria that promote sedimentation, filtration, and other pollutant removal mechanisms. Because these criteria include a lower maximum velocity than permitted for stability, the biofilter dimensions usually do not have to be modified after a stability check

Design Steps (D)

D-1. Select the type of vegetation, and design depth of flow(based on frequency of mowing and type of vegetation) (Table V – 5.1).

D-2. Select a value of Manning's n. See Table V – 5.1.

D-3. Select the biofiltration swale shape. The shape is typically trapezoidal or parabolic.

D-4. Use Manning's equation and first approximations relating to hydraulic radius and dimensions for the selected biofiltration swale shape to obtain a working value of the biofiltration swale width dimension;

(equation 1):

$$Q = \frac{1.49AR^{0.67}s^{0.5}}{n}$$

(equation 2):

$$A_{rectangle} = Ty$$

(equation 3):

$$R_{rectangle} = \frac{Ty}{T + 2y}$$

Where:

Q = Water Quality Design Flow Rate in 15-minute time steps (ft³/s, cfs)

n = Manning's n (dimensionless)

s = Longitudinal slope as a ration of vertical rise/horizontal run (dimensionless)

A = Cross-sectional area (ft²)

R = Hydraulic radius (ft)

T = top width of trapezoid or width of a rectangle (ft)

Y = depth of flow (ft)

b = bottom width of trapezoid (ft)

If equations 2 and 3 are substituted into equation 1 and solved for T, complex equations result that are difficult to solve manually. However, approximate solutions can be found by recognizing that $T \gg y$ and $Z^2 \gg 1$, and that certain terms are nearly negligible. The approximation solutions for rectangular and trapezoidal shapes are:

$$R_{\text{rectangle}} \approx y, R_{\text{trapezoid}} \approx y, R_{\text{parabolic}} \approx 0.67y, R_v \approx 0.5y$$

Substitute $R_{\text{trapezoid}}$ and $A_{\text{trapezoid}} = by + Zy^2$ into Equation 1, and solve for the bottom width b (trapezoidal swale):

$$b \approx \frac{2.5Qn}{1.49v^{1.67}s^{0.5}} - Zy$$

For a trapezoid For a trapezoid, select a side slope Z of at least 3. Compute b and then top width T, where $T = b + 2yZ$. Note: an adjustment factor of 2.5 accounts for the difference between Water Quality Design Flow Rate (Q) and the SBUH design flow. This equation is used to estimate an initial cross-sectional area. It does not affect the overall biofiltration swale size.

If b for a swale is greater than 10 feet, either investigate how Q can be reduced, divide the flow by installing a low berm, or arbitrarily set b = 10 feet and continue with the analysis. For other swale shapes, refer to Figure V - 5.3.

D-5. Compute A:

$$A_{\text{rectangle}} = Ty$$

$$A_{\text{trapazoid}} = by + Zy^2$$

$$A_{\text{filter strip}} = Ty$$

D-6. Compute the SBUH design flow velocity (V) at the Water quality Design Flow Rate (Q):

$$V = K \frac{Q}{A}$$

Where:

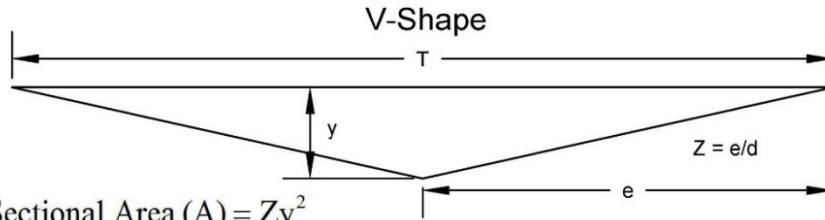
K = A ratio of the peak 10-minute flow predicted by SBUH to the water quality design flow rate estimated using an approved continuous runoff model. The value of K is determined from Figure V - 5.1 for on-line facilities, or Figure V - 5.2 for off-line facilities.

If $V > 1.0$ feet/sec (or $V > 0.5$ feet/sec for a filter strip), repeat steps D-1 to D-6 until the condition is met. A velocity greater than 1.0 feet/sec was found to flatten grasses, thus reducing filtration. A velocity lower than this maximum value will allow a 9-minute hydraulic residence time criterion in a shorter biofilter. If the value of V suggests that a longer biofilter will be needed than space permits, investigate how Q can be reduced (e.g., use of low impact development [LID] BMPs), or increase y and/or T (up to the allowable maximum values) and repeat the analysis.

Source: Livingston, et al, 1984

Channel Geometry

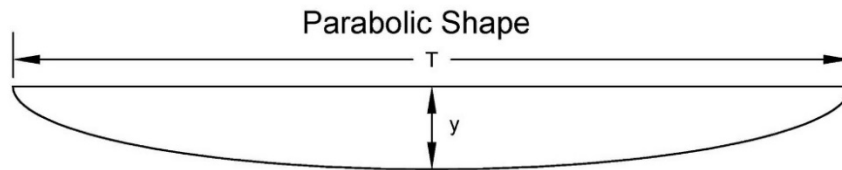
NOT TO SCALE



$$\text{Cross - Sectional Area (A)} = Zy^2$$

$$\text{Top Width (T)} = 2yZ$$

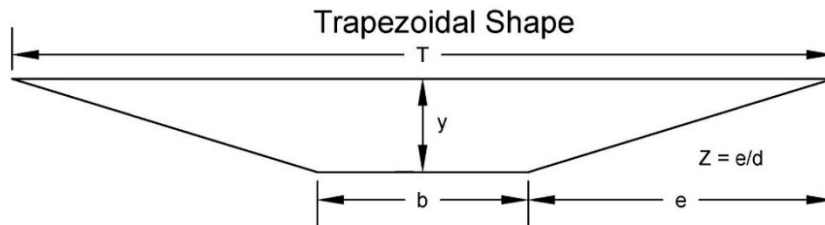
$$\text{Hydraulic Radius (R)} = \frac{Zy}{2\sqrt{Z^2 + 1}}$$



$$\text{Cross - Sectional Area (A)} = \frac{2}{3}Ty$$

$$\text{Top Width (T)} = \frac{1.5A}{y}$$

$$\text{Hydraulic Radius (R)} = \frac{T^2y}{1.5T^2 + 4y^2}$$



$$\text{Cross - Sectional Area (A)} = by + Zy^2$$

$$\text{Top Width (T)} = b + 2yz$$

$$\text{Hydraulic Radius (R)} = \frac{by + Zy^2}{b + 2y\sqrt{Z^2 + 1}}$$



DEPARTMENT OF
ECOLOGY
State of Washington

Geometric Formulas for Common Swale Shapes

Revised June 2016

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Figure V - 5.3 Geometric Formulas for Common Swale Shapes

D-7. Compute the swale length (L, feet)

$$L = Vt \text{ (60 sec/min)}$$

Where: t = hydraulic residence time (min)

Use t = 9 minutes for this calculation (use t = 18 minutes for a continuous inflow biofiltration swale). If a biofilter length is greater than the space permits, follow the advice in Step D-6.

If a length less than 100 feet results from this analysis, increase it to 100 feet, the minimum allowed. In this case, it may be possible to save some space in width and still meet all criteria. This possibility can be checked by computing V in the 100 feet biofilter for t = 9 minutes, recalculating A (if V less than 1 foot/sec) and recalculating T.

D-8. If there is still not sufficient space for the biofilter, consider the following solutions:

1. Divide the site drainage to flow to multiple biofiltration BMPs.
2. Use infiltration to provide lower discharge rates to the biofiltration swale (only if the conditions for infiltration in Volume III are met).
3. Reduce the developed surface area to gain space for the biofiltration swale.
4. Increase the longitudinal slope.
5. Increase the side slopes.
6. Nest the biofiltration swale within or around another Runoff Treatment BMP.

5.1.1.5.4.c *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 swale capacity analysis above.

SC-1. Perform the stability check for the 100-year, return frequency flow using 15-minute time steps using an approved continuous runoff model.

SC-2. Estimate the vegetation coverage (“good” or “fair”) and height on the first occasion that the biofiltration swale 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 V - 5.2. When uncertain, be conservative by selecting a relatively low degree.

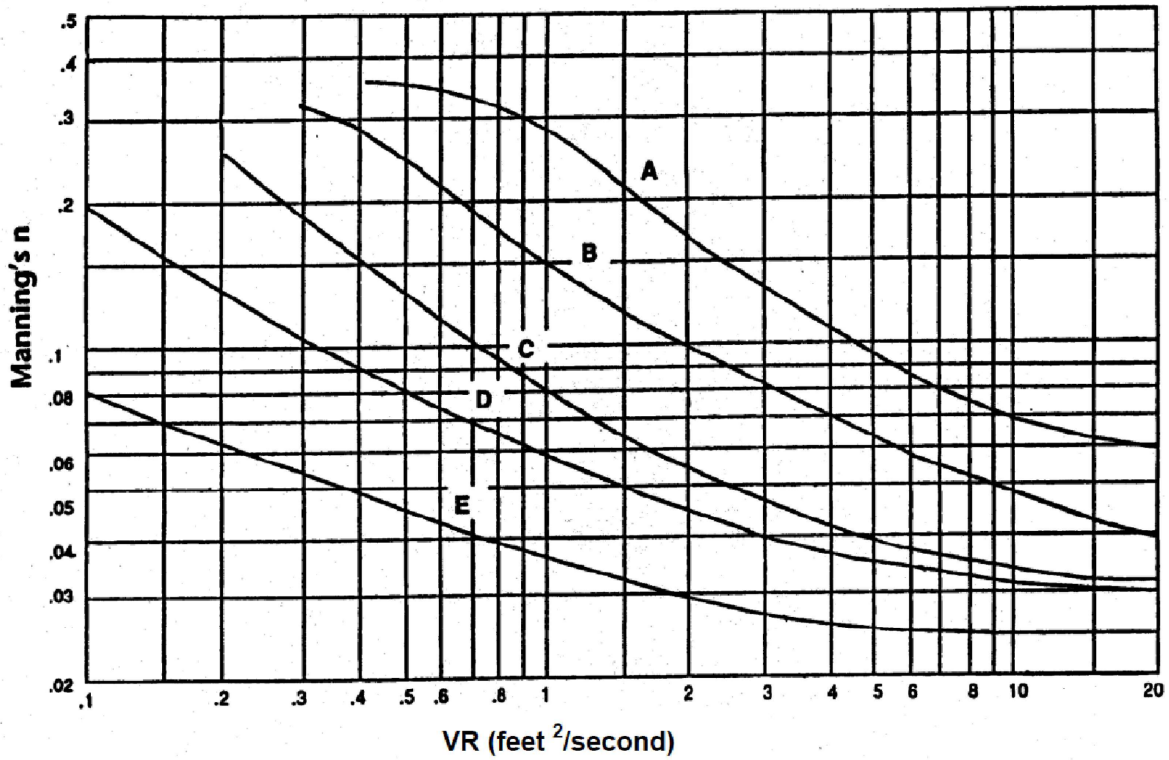
The maximum permissible velocity for erosion prevention (V_{max}) is 3 feet per second.

Table V - 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.



Note: VR is the product of velocity and hydraulic radius

Source: Livingston, et al, 1984

NOT TO SCALE



The Relationship of Manning's n with VR for Various Degrees of Flow Retardance (A-E)

Revised June 2016

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Figure V – 5.4 The Relationship of Manning's n with VR for Various Degrees of Flow Retardance (A-E)

SC-5. See Figure V - 5.4 to obtain a first approximation for VR of 3 feet/second.

SC-6. Compute the hydraulic radius, R, from VR in Figure V - 5.4 and a Vmax.

SC-7. Use Manning's equation to solve for the actual VR.

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 feet/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 (the A from SC-10) than is provided for capacity (the A from D-5), the capacity design is acceptable. If not, use A from Step SC-10 of the stability analysis and recalculate the biofiltration swale 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 swale 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 biofiltration 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 the biofiltration swale 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.

5.1.1.5.4.d Completion Step (CO)

CO-1. Review all of the criteria and guidelines for biofiltration swale planning, design, installation, and operation above and specify all of the appropriate features for the application.

For an example of sizing calculations for biofiltration swales see Ecology's 2019 SWMMMWW, Volume 5, Chapter 7.

5.1.1.6 Design Criteria

Figure V - 5.5, **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.** provide details of biofiltration swales.

5.1.1.6.1 Geometry

5.1.1.6.1.a 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).

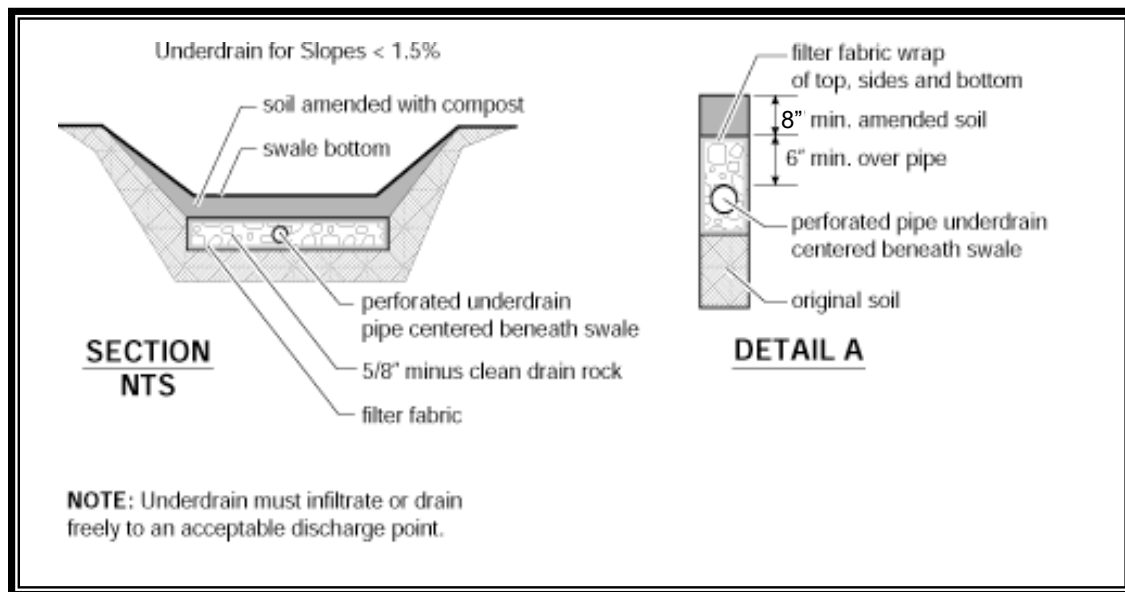


Figure V - 5.5 Biofiltration Swale Underdrain Detail

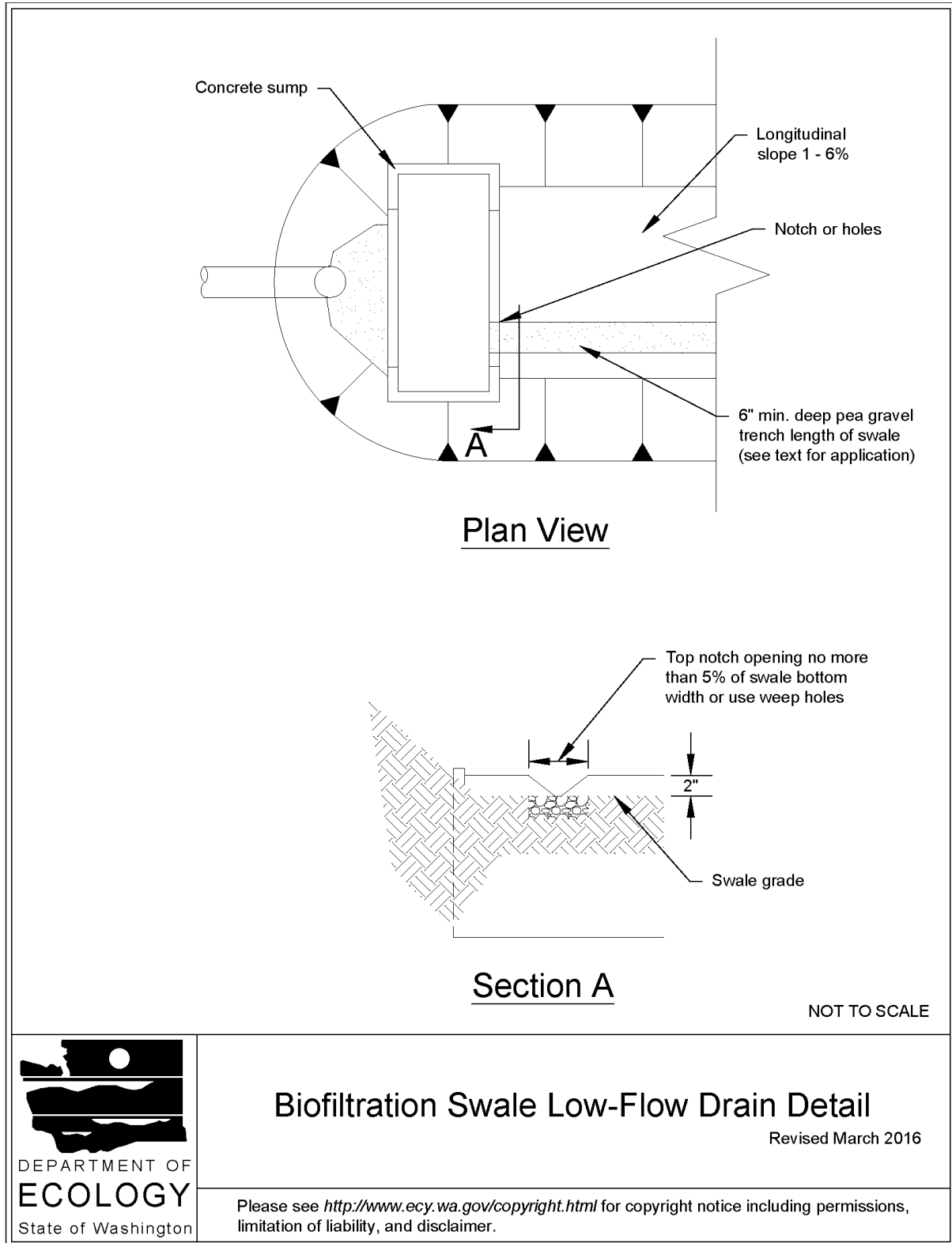


Figure V – 5.6 Biofiltration Swale Low-Flow Drain Detail

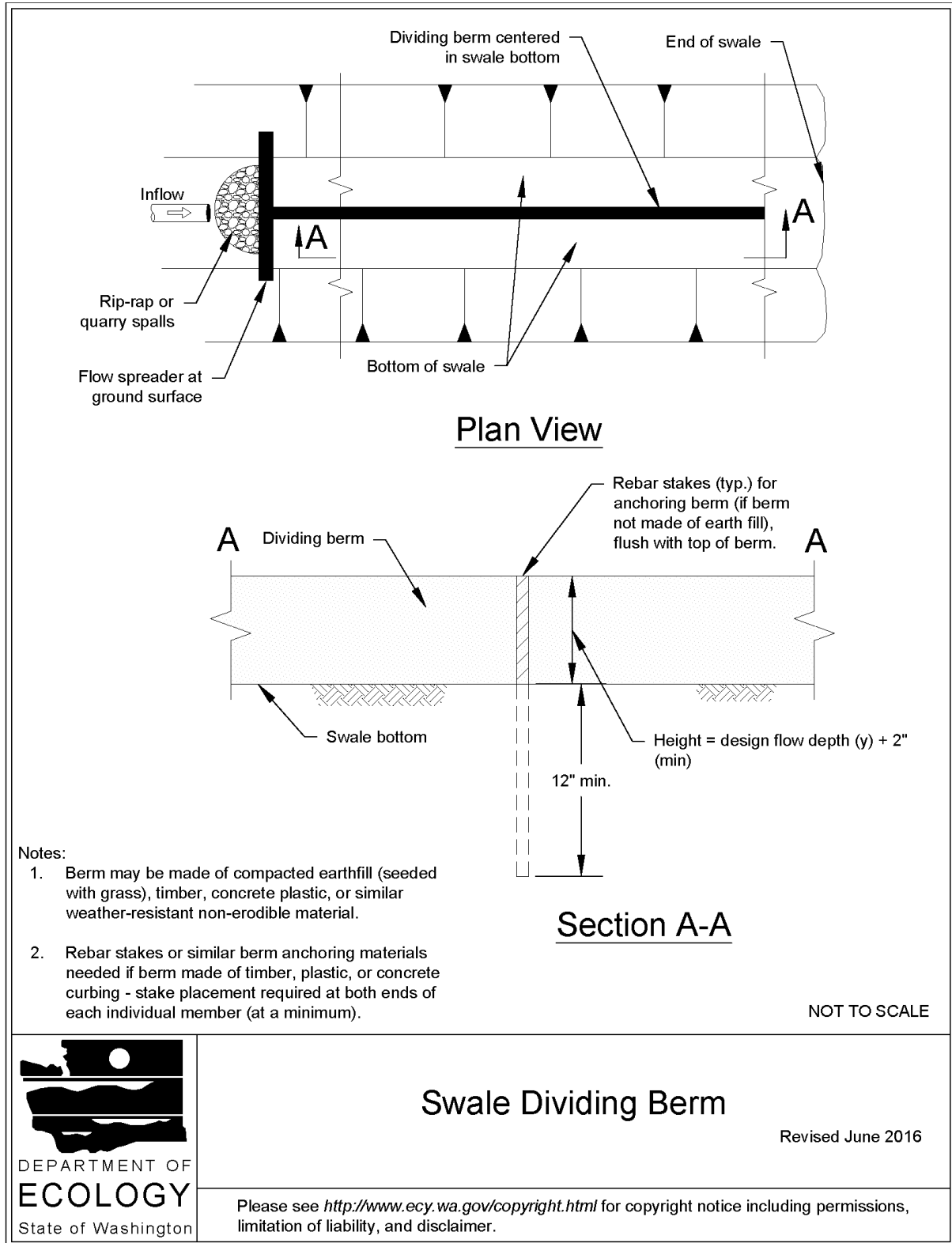


Figure V – 5.7 Swale Dividing Berm

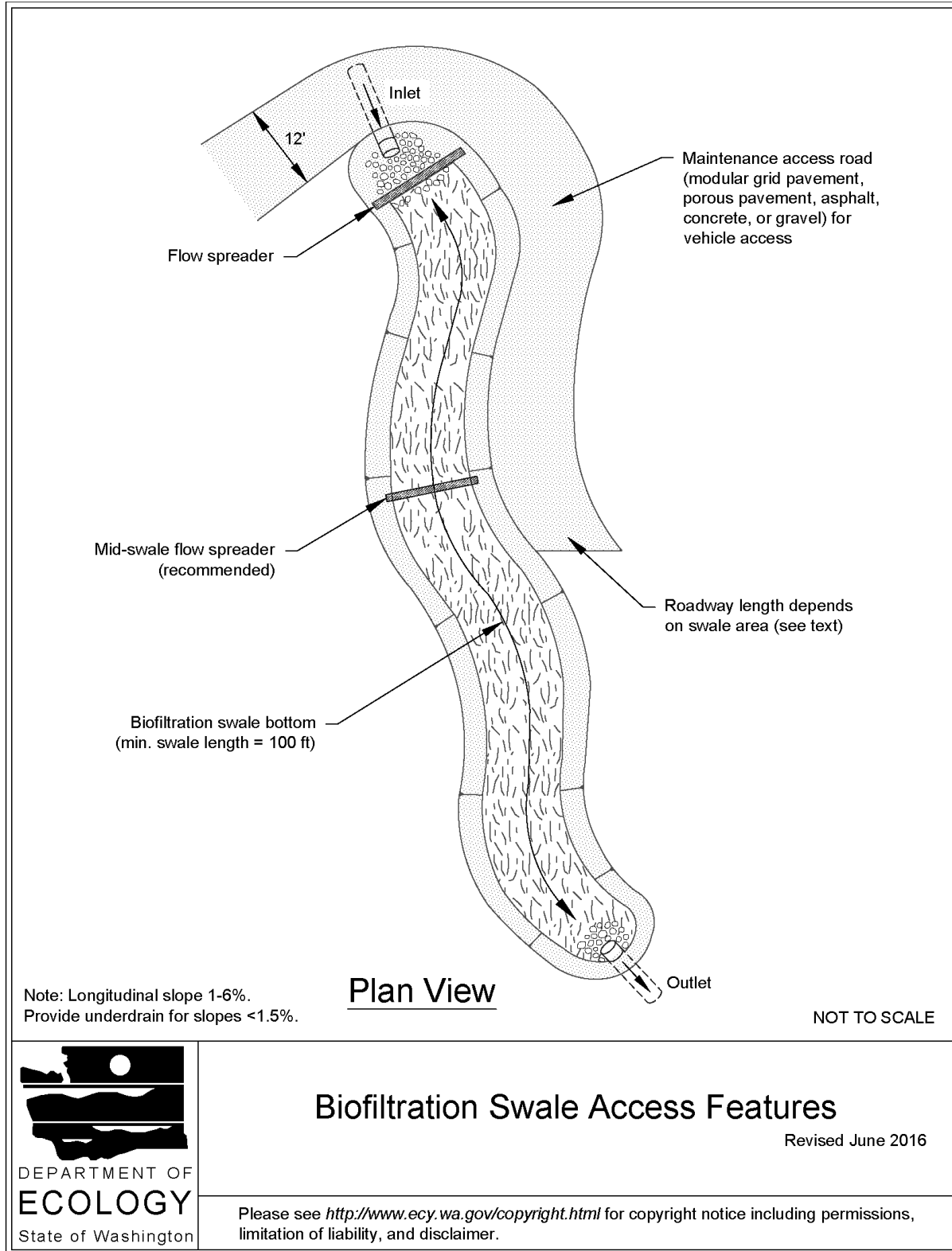


Figure V – 5.8 Biofiltration Swale Access Feature

5.1.1.6.1.b 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 V - 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.

5.1.1.6.1.c 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 (**Error! Reference source not found.**).

5.1.1.6.2 Materials

5.1.1.6.2.a Soil Criteria

The swale shall have a minimum 8 inches of topsoil that conforms to the following:

Table V - 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).

5.1.1.6.2.b Vegetation Criteria

Table V - 5.4, Table V - 5.5, and Table V - 5.7 present recommended grasses, wetland plants, and groundcovers. The following invasive species shall not be used:

Phalaris arundinaceae (reed canary grass)

Lythrum salicaria (purple loosestrife)

Phragmites spp. (reeds)

Iris pseudocorus (yellow iris)

Typha spp (Cattails).

Table V - 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 V - 5.5 Groundcovers and Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington

Groundcovers	
kinnikinnick*	<i>Arctostaphylos uva-ursi</i>
Epimedium	<i>Epimedium grandiflorum</i>
creeping forget-me-not	<i>Omphalodes verna</i>
--	<i>Euonymus lanceolata</i>
yellow-root	<i>Xanthorhiza simplissima</i>
--	<i>Genista</i>
white lawn clover	<i>Trifolium repens</i>
white sweet clover*	<i>Melilotus alba</i>
-----	<i>Rubus calycinoideis</i>
strawberry*	<i>Fragaria chiloensis</i>
broadleaf lupine*	<i>Lupinus latifolius</i>

Grasses (drought-tolerant, minimum mowing)	
dwarf tall fescues	<i>Festuca</i> spp. (e.g., Many Mustang, Silverado)
hard fescue	<i>Festuca ovina duriuscula</i> (e.g., Reliant, Aurora)
tufted fescue	<i>Festuca amethystine</i>
buffalo grass	<i>Buchloe dactyloides</i>
red fescue*	<i>Festuca rubra</i>
tall fescue grass*	<i>Festuca arundinacea</i>
blue oatgrass	<i>Helictotrichon sempervirens</i>

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.

Consider sun/shade conditions for adequate vegetative growth and avoid prolonged shading of any portion not planted with shade tolerant vegetation.

5.1.1.7 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 V - 5.4 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 V - 5.8).

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. Thus, use vegetation specifically adapted to withstand saturated soil conditions. Different vegetation in turn requires modification of several of the design parameters for BMP BF.01: Basic Biofiltration Swale.

Wet biofiltration swales are Runoff Treatment BMPs that remove low concentrations of pollutants such as TSS, heavy metals, nutrients, and petroleum hydrocarbons.



Wet swale example

5.1.2.1 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).

5.1.2.2 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.

5.1.2.3 Submittals and Approval

As part of submittals made as required in Volume I, include information described under BF.01 for a basic biofiltration swale.

5.1.2.4 Pretreatment

Pretreatment is not required.

5.1.2.5 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: Wet biofiltration swales must be designed as off-line facilities.

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 V - 5.2. 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.

5.1.2.6 Design Criteria

5.1.2.6.1 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 minimum 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.**

5.1.2.6.2 Materials

5.1.2.6.2.a Soil Criteria

Same as for basic biofiltration swales (see Table V - 5.3).

5.1.2.6.2.b Vegetation Criteria

A list of acceptable plants and recommended spacing is shown in Table V - 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 V - 5.6 Recommended Plants for Wet Biofiltration Swale

Common Name	Scientific Name	Spacing (on center)
Shortawn foxtail	<i>Alopecurus aequalis</i>	seed
Water foxtail	<i>Alopecurus geniculatus</i>	seed
Spike rush	<i>Eleocharis spp.</i>	4 inches
Slough sedge*	<i>Carex obnupta</i>	6 inches or seed
Sawbeak sedge	<i>Carex stipata</i>	6 inches
Sedge	<i>Carex spp.</i>	6 inches
Western mannagrass	<i>Glyceria occidentalis</i>	seed
Velvetgrass	<i>Holcus mollis</i>	seed
Slender rush	<i>Juncus tenuis</i>	6 inches
Watercress*	<i>Rorippa nasturtium-aquaticum</i>	12 inches
Water parsley*	<i>Oenanthe sarmentosa</i>	6 inches
Hardstem bulrush	<i>Scirpus acutus</i>	6 inches
Small-fruited bulrush	<i>Scirpus microcarpus</i>	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.

5.1.2.7 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.

5.1.2.8 Construction and Maintenance

Construction considerations are the same as for basic biofiltration swales except mowing of wetland vegetation 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. Many native *Juncus* species remain green throughout the winter; therefore, fall harvesting of *Juncus* species is not recommended.

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.

5.1.3.1 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.

5.1.3.2 Limitations

In general, no inlet port should carry more than about 10 percent of the flow

A continuous inflow biofiltration 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.

5.1.3.3 Submittals and Approval

As part of submittals made as required in Volume I, include information described under BF.01 for a basic biofiltration swale.

5.1.3.4 Pretreatment

Pretreatment is not required.

5.1.3.5 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 continuous inflow biofiltration swale of 9 minutes as calculated using the online water quality design flow rate multiplied by the ratio, K, in Figure V - 5.1. Assuming an even distribution of inflow along the side of the swale, double the hydraulic residence time to a minimum of 18 minutes.

5.1.3.6 Design Criteria

5.1.3.6.1 Geometry

Same as basic biofiltration swale.

5.1.3.6.2 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.

Intent: 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. Contaminated stormwater is distributed as sheet flow across the inlet width of a biofilter strip. Runoff treatment is provided by passage of water over the surface and through grass.



Vegetated Filter Strip in Median Along I-5 in Snohomish County

5.1.4.1 Applicability

A basic filter strip is typically used online, adjacent, and parallel to paved areas like parking lots, driveways, and roadways.

5.1.4.2 Limitations

Filter strips shall only receive sheet flow. The maximum permissible tributary flow path is 150 feet.

5.1.4.3 Submittals and Approval

No additional submittals (except those described in Volume I as applicable to your project) are required.

5.1.4.4 Pretreatment

Pretreatment is not required.

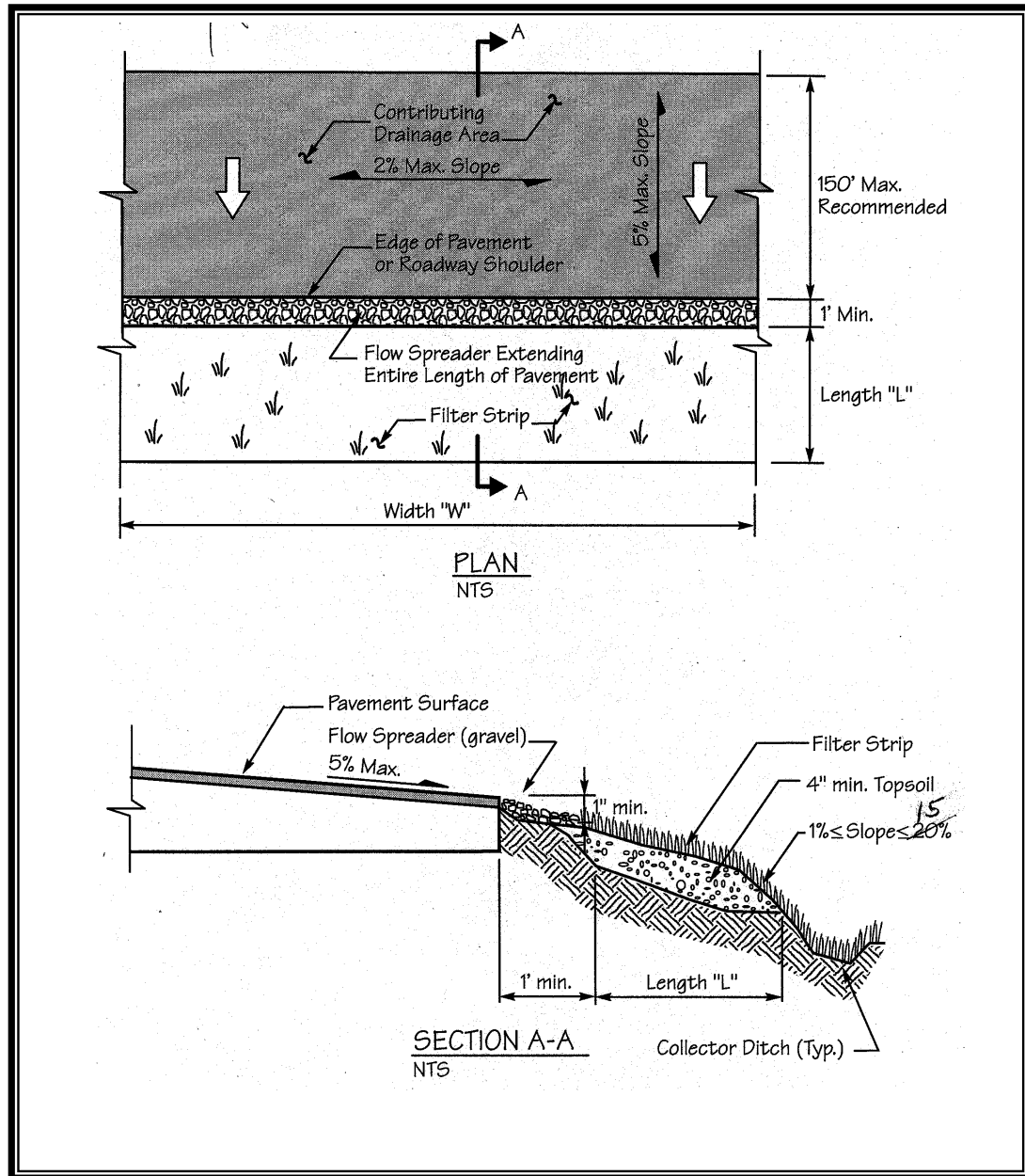


Figure V - 5.9 Typical Filter Strip

Hydrologic and Hydraulic Design Considerations

5.1.4.4.1 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 V - 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.

5.1.4.4.2 Maximum Water Depth

1 inch. (Below the design water depth install an erosion control blanket, at least 4" of topsoil, and the selected biofiltration seed mix. Above the water line use a straw mulch or sod.)

5.1.4.4.3 Maximum Velocity

0.5 feet per second @ K multiplied by the WQ Design Flow Rate.

5.1.4.4.4 Manning Coefficient

0.35

5.1.4.4.5 Hydraulic Residence Time

9 minutes.

5.1.4.4.6 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:

$$Ty = A_{\text{rectangle}}, \text{ ft}^2$$

$$y \approx R_{\text{rectangle}}, \text{ design depth of flow, ft. (1 inch maximum)}$$

$$Q = \text{peak Water Quality design flow rate based on an approved continuous runoff model, ft}^3/\text{sec}$$

K = The ratio determined by using Figure V - 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), ft²

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 Water Quality Design Flow Rate calculated by an approved continuous simulation model and the SBUH design flow rate.

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:

$$L = tV = 540V$$

5.1.4.5 Design Criteria

5.1.4.5.1 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 V - 5.6). 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.

If flow spreading and energy dissipation is included in the design (see Figure V - 5.6), a minimum 1-foot wide strip of crushed rock or gravel should be placed between the contributing drainage area and filter strip.

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.

5.1.5 BF.05 Compost-Amended Vegetated Filter Strip (CAVFS)

The compost-amended vegetated filter strip (CAVFS) is a variation of BMP BF.04: Basic Filter Strip that adds soils amendments to the roadside embankment. The soil amendments improve infiltration characteristics, increase surface roughness, and improve plant sustainability. Once permanent vegetation is established, the advantage of the CAVFS are higher surface roughness; greater retention and infiltration capacity; improved removal of soluble cationic contaminants through sorption; improved overall vegetative health; and a reduction of invasive weeds.

5.1.5.1 Applicability

CAVFS can be used to meet basic runoff treatment and enhanced runoff treatment objectives. It has practical application in areas where there is space for roadside embankments that can be built to the CAVFS specifications

5.1.5.2 Limitations

CAVFS have somewhat higher construction costs than BMP BF.04: Basic Filter Strip due to more expensive materials, but require less land area for Runoff Treatment, which can reduce overall costs.

5.1.5.3 Submittals and Approval

No additional submittals (except those described in Volume I as applicable to your project) are required.

5.1.5.4 Pretreatment

Pretreatment is not required.

5.1.5.5 Hydrologic and Hydraulic Design Considerations

The CAVFS design incorporates composed material into the native soils per the criteria in BMP LID.02: Post-Construction Soil Quality and Depth for turf areas. However, as noted below, the compost should not contain biosolids or manure. The goal is to create a healthy soil environment for a lush growth of turf.

5.1.5.6 Design Criteria

5.1.5.6.1 Materials

Soil/Compost Mix

- *Presumptive approach:* Place and rototill 1.75 inches of composted material into 6.25 inches of soil (a total amended depth of about 9.5 inches), for a settled depth of 8 inches. Water or roll to compact soil to 85 percent maximum. Plant grass.

- *Custom Approach:* Place and rototill the calculated amount of composted material into a depth of soil needed to achieve 8 inches of settled soil at 5 percent organic content. Water or roll to compact soil to 85 percent maximum. Plant grass.

The amount of compost or other soil amendments used varies by soil type and organic matter content. If there is a good possibility that site conditions may already contain a relatively high organic content, then it may be possible to modify the pre-approved rate described above and still be able to achieve the 5 percent organic content target.

- The final soil mix (including compost and soil) should have an initial saturated hydraulic conductivity less than 12 inches per hour, and a minimum long-term hydraulic conductivity of 1 inch per hour, per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 85 percent compaction per ASTM Designation D 1557 (Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort).

Infiltration rate and hydraulic conductivity are assumed to be approximately the same in a uniform mix soil. The long term saturated hydraulic conductivity of the soil mix is determined by applying the appropriate infiltration correction factor as explained in 2.2.5.5.1 Determining Design Infiltration Rates within BMP LID.08: Bioretention Cells, Swales, and Planter Boxes.

- The final soil mix should have a minimum organic content of 5 percent by dry weight per ASTM Designation D 2974 (Standard Test Method for Moisture, Ash and Organic Matter of Peat and Other Organic Soils) (Tackett 2004).
- Achieving the above recommendations will depend on the specific soil and compost characteristics. In general, the recommendation can be achieved with 60 percent to 65 percent loamy sand mixed with 25 percent to 30 percent compost or 30 percent sandy loam, 30 percent coarse sand, and 30 percent compost.
- The final soil mixture should be tested prior to installation for fertility, micronutrient analysis, and organic material content.
- Clay content for the final soil mix should be less than 5 percent.
- Compost must not contain biosolids, manure, any street or highway sweepings, or any catch basin solids.
- The pH for the soil mix should be between 5.5 and 7.0 (Stenn 2003). If the pH falls outside the acceptable range, it may be modified with lime to increase the pH or iron sulfate plus sulfur to lower the pH. The lime or iron sulfate must be

mixed uniformly into the soil prior to use in LID areas (Low-Impact Development Center 2004).

- The soil mix should be uniform and free of stones, stumps, roots, or other similar material larger than 2 inches.
- When placing topsoil, it is important that the first lift of topsoil is mixed into the top of the existing soil. This allows the roots to penetrate the underlying soil easier and helps prevent the formation of a slip plane between the two soil layers.

Soil Component

- The texture for the soil component of the LID BMP soil mix should be loamy sand (USDA Soil Textural Classification).

Compost Component

- Follow the specifications for compost in BMP LID.08: Bioretention Cells, Swales, and Planter Boxes.

5.1.5.6.2 Runoff Model Representation

The CAVFS will have an “Element” in the approved continuous runoff model that must be used for determining the amount of water that is treated by the CAVFS. To fully meet Runoff Treatment requirements, 91 percent of the influent runoff file must pass through the soil profile of the CAVFS. Water that merely flows over the surface is not considered treated. Approved continuous runoff models should be able to report the amount of water that it estimates will pass through the soil profile.

5.1.5.6.3 Maintenance

Compost, as with other filter mediums, can become plugged with fines and sediment, which may require removal and replacement. Including vegetation with compost helps prevent the medium from becoming plugged with sediment by breaking up the sediment and creating root pathways for stormwater to penetrate into the compost. It is expected that soil amendments will have a removal and replacement cycle; however, this time from has not yet been established.

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	Presetting 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 Figure V - 6.1 and Figure V - 6.2).

Wetlands created to mitigate disturbance impacts (e.g., filling) may not be used as stormwater treatment BMPs. This is because of the different, incompatible functions of the two kinds of wetlands. Mitigation wetlands are intended to function as full replacement habitat for fish and wildlife, providing the same functions and harboring the same species diversity and biotic richness as the wetlands they replace. Stormwater treatment wetlands are used to capture and transform pollutants, just as wet ponds are, and over time pollutants will concentrate in the sediment. This is not a healthy environment for aquatic life. Stormwater treatment wetlands are used to capture pollutants in a managed environment so that they will not reach natural wetlands and other ecologically important habitats. In addition, vegetation must occasionally be harvested and sediment dredged in stormwater treatment wetlands, further interfering with use for wildlife habitat.

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.



Wm Bush Park wetland in Lacey

6.1.1.1 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. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. Since water depths are shallower than in wet ponds, water loss by evaporation is an important concern. Stormwater treatment wetlands are a good water quality facility choice in areas with high winter groundwater levels.

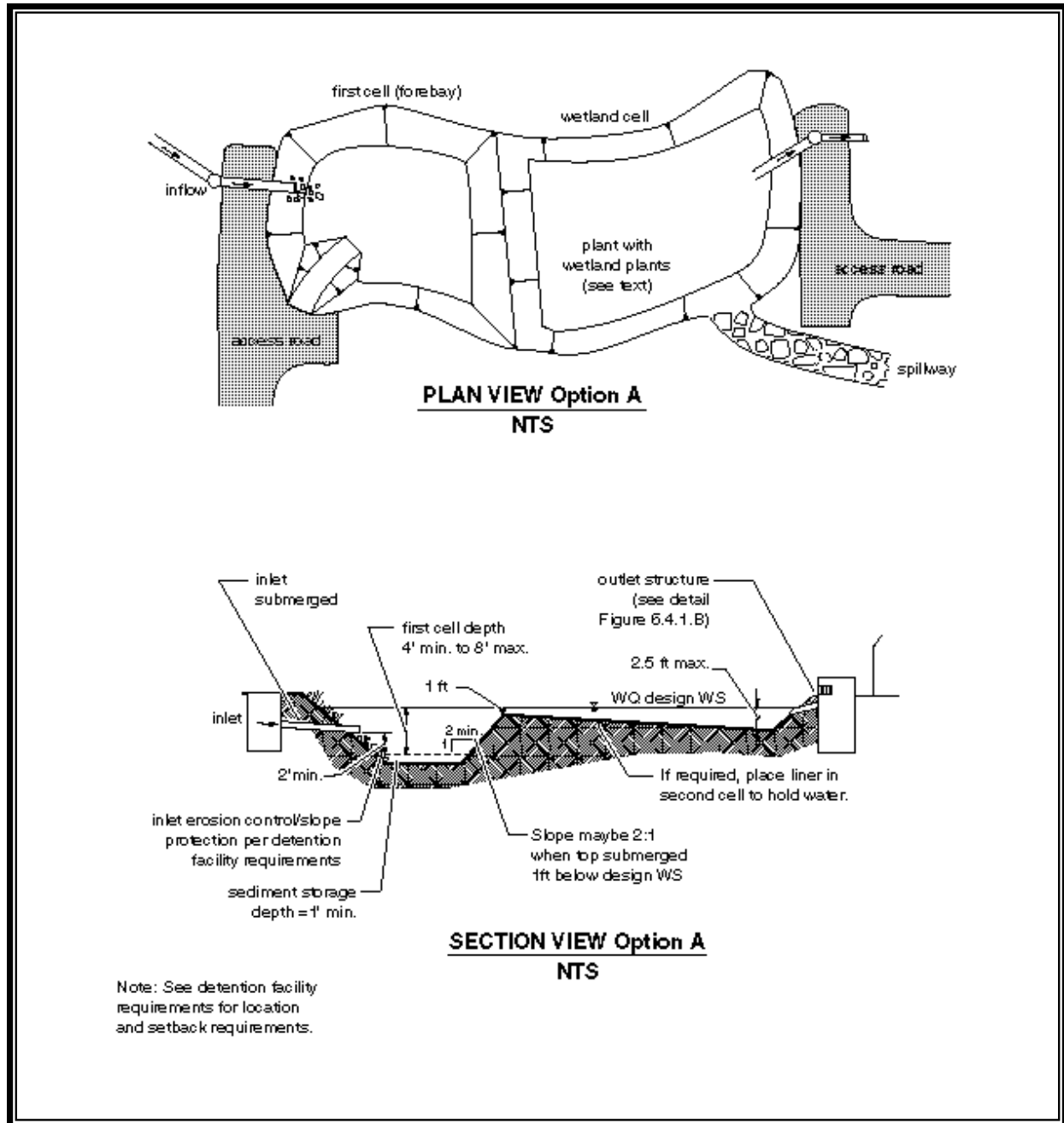


Figure V - 6.1 Stormwater Wetland – Option One

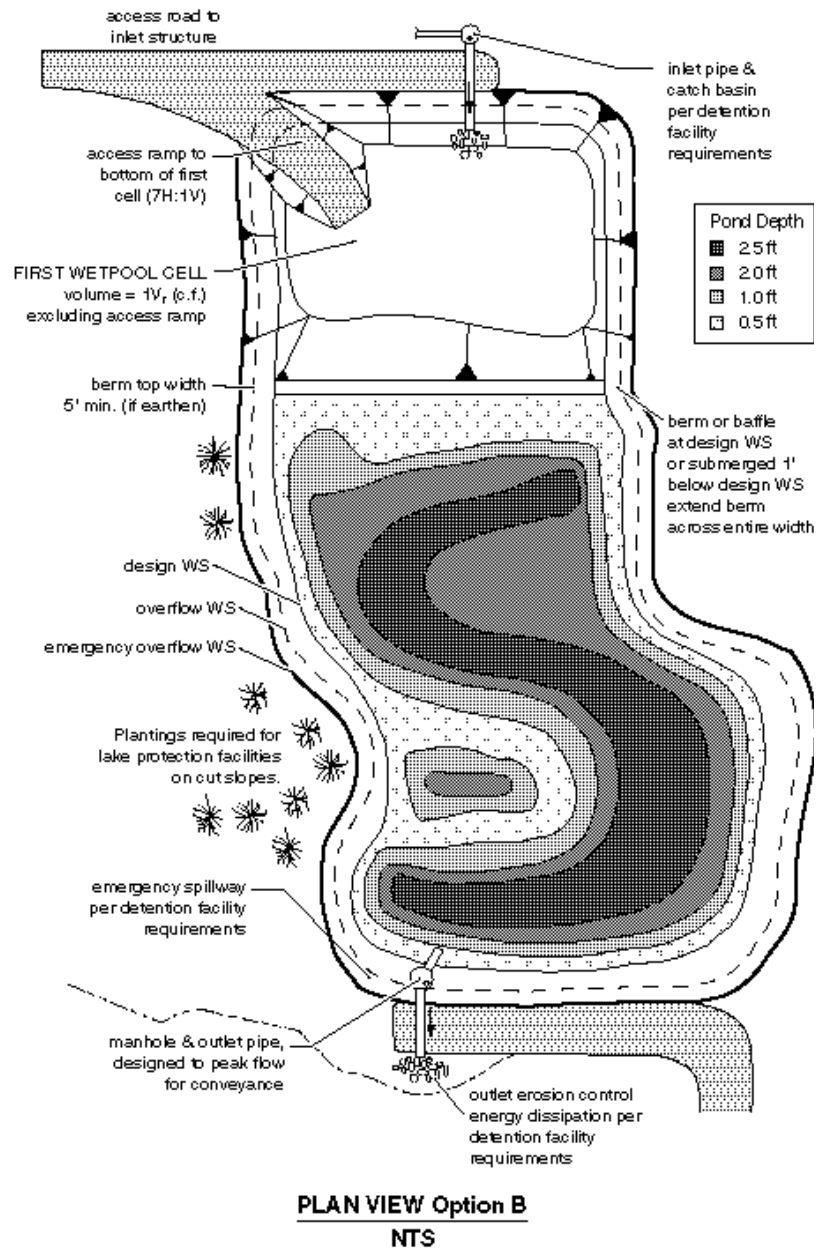


Figure V - 6.2 Stormwater Wetland — Option Two

6.1.1.2 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.

6.1.1.3 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.

6.1.1.4 Pretreatment

Pretreatment is accomplished in the presettling cell of the wetland, so a separate pretreatment facility is not required.

6.1.1.5 Hydrologic and Hydraulic Design Considerations

When used for Runoff 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.

6.1.1.5.1 Inlets and Outlets

Inlets and outlets shall be configured using the requirements of wet ponds (see BMP WP.02).

6.1.1.5.2 Sizing Procedure

Step 1: The volume of a basic wet pond is used as a template for sizing the stormwater wetland. The design volume Water Quality Design 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 (the presettling cell) of the stormwater treatment 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 second cell (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 V - 6.2 for a list of plants recommended for wet pond water depth zones, or consult a wetland scientist.

6.1.1.6 Design Criteria

6.1.1.6.1 Geometry

1. Stormwater wetlands shall consist of two cells, a presettling cell and a wetland cell.
2. The presettling cell shall contain approximately 33 percent of the wet pool volume calculated in Step 1 above.
3. The depth of the presettling cell shall be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage.
4. One foot of sediment storage shall be provided in the presettling cell.
5. The wetland cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches).
6. 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 V - 6.1). Alternatively, the second cell may be graded naturalistically from the top of the dividing berm (see Criterion 8 below).
7. 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:
 - a. If the top of berm is at the water quality design water surface, the berm side slopes shall be no steeper than 3H:1V.
 - b. 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.
8. 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 V - 6.1). The second example is a “naturalistic” alternative, with the specified range of depths intermixed throughout the second cell (see Figure V - 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 V – 6.1). 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.

TableV - 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

6.1.1.6.2 Materials

6.1.1.6.2a Lining Requirements

Stormwater treatment wetlands are not intended to infiltrate. In infiltrative soils, both cells of the stormwater treatment wetland shall be lined. To determine whether a low-permeability liner or a treatment liner is required, determine whether the following conditions will be met. If soil permeability will allow sufficient water retention, lining may be waived.

1. The second cell (the wetland cell) must retain water for at least 10 months of the year.
2. The first cell (the presettling cell) must retain at least three feet of water year-round.
3. A complete precipitation record shall be used when establishing these conditions. Evapotranspiration losses shall be taken into account as well as infiltration losses.

Intent: Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the second cell. This may allow a treatment liner rather than a low permeability liner to be used for the second cell. The first cell must retain water year-round in order for the presettling function to be effective.

If a low permeability liner is used, 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.

The criteria for liners given in Appendix V-B must be observed.

6.1.1.6.2b Vegetation

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Table V - 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 V - 6.2 Emergent Wetland Plant Species Recommended for Wet Ponds

Species	Common Name	Notes	Maximum Depth
<i>Agrostis exarata</i> ⁽¹⁾	Spike bent grass	Prairie to coast	to 2 ft
<i>Carex stipata</i>	Sawbeak sedge	Wet ground	
<i>Eleocharis palustris</i>	Spike rush	Margins of ponds, wet meadows	to 2 ft
<i>Glyceria occidentalis</i>	Western mannagrass	Marshes, pond margins	to 2 ft
<i>Juncus tenuis</i>	Slender rush	Wet soils, wetland margins	
<i>Oenanthe sarmentosa</i>	Water parsley	Shallow water along stream and pond margins; needs saturated soils all summer	
<i>Scirpus atrocinctus</i> (formerly <i>S. cyperinus</i>)	Woolgrass	Tolerates shallow water; tall clumps	
<i>Scirpus microcarpus</i>	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
<i>Sagittaria latifolia</i>	Arrowhead		
INUNDATION 1 TO 2 FT			
<i>Agrostis exarata</i> ⁽¹⁾	Spike bent grass	Prairie to coast	
<i>Alisma plantago-aquatica</i>	Water plantain		
<i>Eleocharis palustris</i>	Spike rush	Margins of ponds, wet meadows	
<i>Glyceria occidentalis</i>	Western mannagrass	Marshes, pond margins	
<i>Juncus effusus</i>	Soft rush	Wet meadows, pastures, wetland margins	
<i>Scirpus microcarpus</i>	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
<i>Sparganium emmersum</i>	Bur reed	Shallow standing water, saturated soils	
INUNDATION 1 TO 3 FT			
<i>Carex obnupta</i>	Slough sedge	Wet ground or standing water	1.5 to 3 ft
<i>Beckmania syzigachne</i> ⁽¹⁾	Western sloughgrass	Wet prairie to pond margins	
<i>Scirpus acutus</i> ⁽²⁾	Hardstem bulrush	Single tall stems, not clumping	to 3 ft
<i>Scirpus validus</i> ⁽²⁾	Softstem bulrush		
INUNDATION GREATER THAN 3 FT			
<i>Nuphar polysepalum</i>	Spatterdock	Deep water	3 to 7.5 ft
<i>Nymphaea odorata</i> ⁽¹⁾	White waterlily	Shallow to deep ponds	to 6 ft

Species	Common Name	Notes	Maximum Depth
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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 V - 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.

6.1.1.6.3 Site Design Elements

6.1.1.6.3.1 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.

6.1.1.6.3.2 Construction and Maintenance

See Appendix V-C for general maintenance guidelines.

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. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the “live storage” area above the permanent pool (see BMP WP.04). Figures V - 6.3 and V - 6.4 illustrate a typical wet pond BMP.

The following design criteria cover two wet pond applications – the basic wet pond and the large wet pond. Large wet ponds are designed for higher levels of pollutant removal.



Wetpond along Yelm Hwy in Lacey

6.1.2.1 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. Large wet ponds are designed for higher levels of pollutant removal.

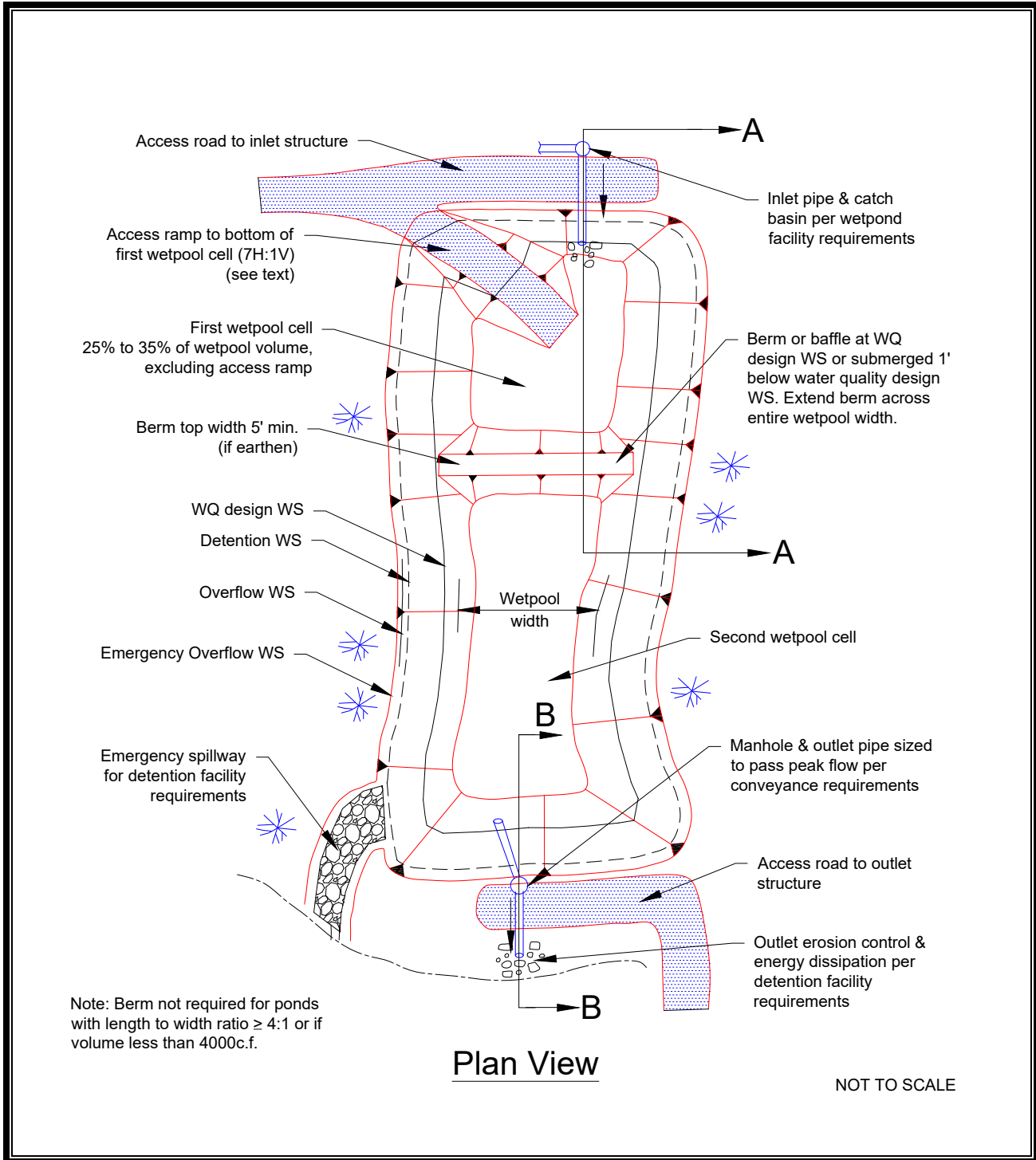


Figure V - 6.3 Wet Pond

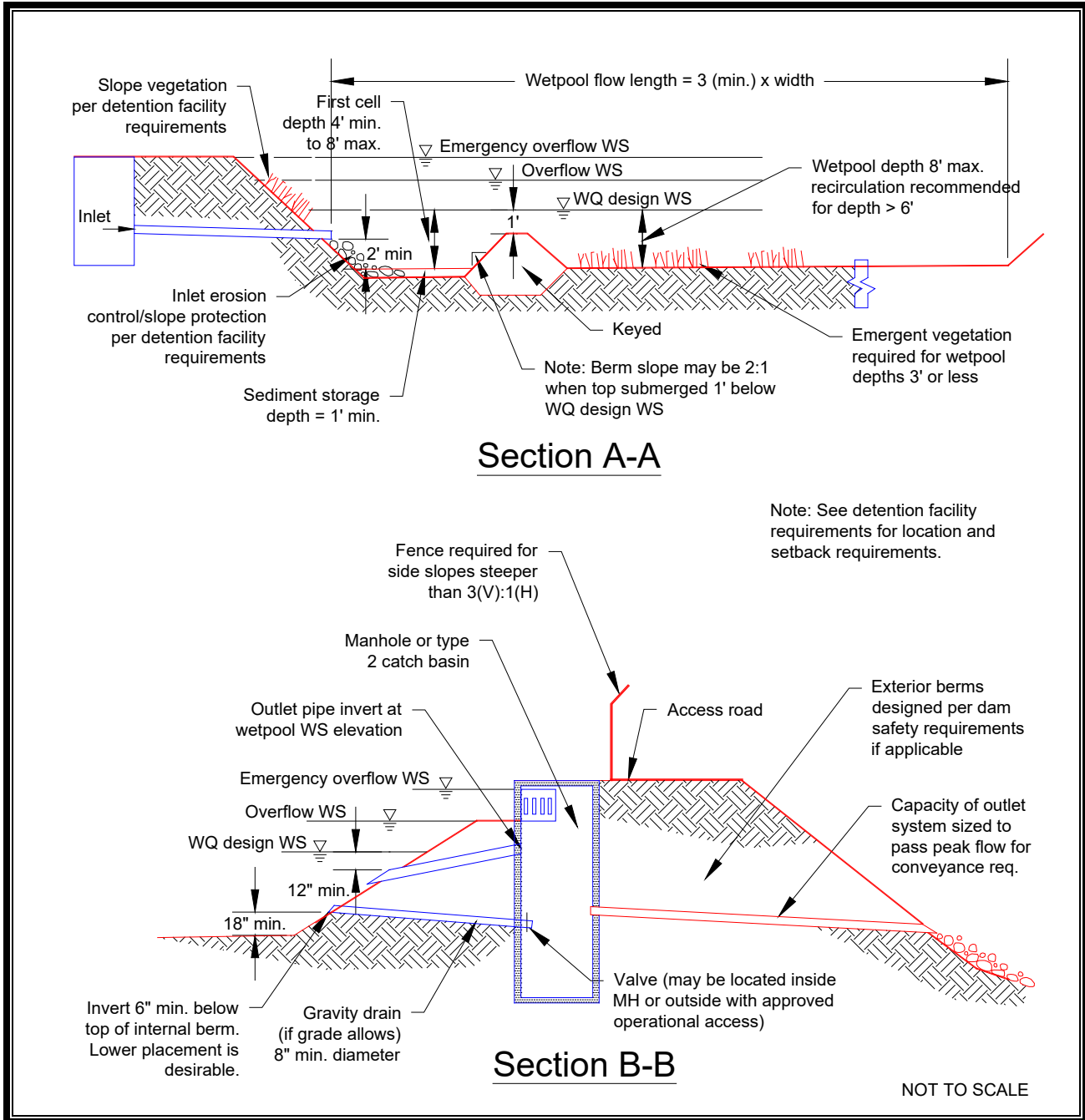


Figure V - 6.4 Wet Pond

6.1.2.2 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 0.5 inches per hour), the pond will be required to be lined to maintain a permanent wet pool. As long as the first cell retains a permanent pool of water, the pond will function as an effective Runoff Treatment BMP/

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.

Wet ponds can attract wild fowl that can be hazardous to air traffic. The Federal Aviation Administration has established perimeters around airports to exclude open water areas that could attract wildlife. See the *Airport Stormwater Guidance Manual* at <http://www.wsdot.wa.gov/aviation/AirportStormwaterGuidanceManual.htm> if the project is within 10,000 feet of an airport.

6.1.2.3 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 Core 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.

6.1.2.4 Pretreatment

Pretreatment is not required for this BMP.

6.1.2.5 Hydrologic and Hydraulic Design Considerations

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.

Also important are the avoidance of short-circuiting and the promotion of 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 and promote plug flow, the pond should be designed to force water 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:

- 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.

6.1.2.5.1 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 Step 3.

Step 4: Determine wet pond dimensions that include the dimensions for the two wet pool cells. General wet pond design criteria and concepts are shown in Figure V - 6.3 and Figure V - 6.4.

6.1.2.6.1 Design Criteria

6.1.2.6.1 Geometry

- The total wetpool volume shall be divided into two cells within the wet pond, separated by a baffle or berm. The first wet pool cell shall contain 25 to 35 percent of the total wet pool volume. 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, connect all the way to the bottom.

Intent: 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.

- Sediment storage shall be provided in the first cell. The sediment storage shall have a minimum depth of 1 foot. A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation unless an alternative gauging method is proposed.
- 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.
- The maximum depth of each cell shall not exceed 8 feet (exclusive of sediment storage in the first cell). Pool depths of 3 feet or shallower (second cell) shall be planted with emergent wetland vegetation (see Planting requirements).
- 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:

$$\text{Width} = (\text{average top width} + \text{average bottom width})/2$$

- 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). However, it is especially important in this case that the flow path length be maximized. 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.
- All inlets shall enter the first cell. If there are multiple inlets, the length-to-width ratio shall be based on the average flow path length for all inlets.
- The first cell must be lined in accordance with the liner requirements contained in Appendix V-B.

6.1.2.6.1a Inlet and Outlet

See Figure 6.3 and Figure 6.4 for details on the following requirements:

- 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.

- 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.

Intent: The inverted outlet pipe provides for trapping of oils and floatables in the wet pond.

- The pond outlet pipe shall be sized, at a minimum, to pass the on-line Water Quality Design Flow Rate. Note: The highest invert of the outlet pipe sets the WQ design water surface elevation.
- The overflow criteria for single-purpose (Runoff 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 Rate 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 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.
- 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 recommended, of grade allows.

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 gravity 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 gravity 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 should 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.

6.1.2.6.1b Baffles, Berms, and Slopes

- A berm or baffle shall extend across the full width of the wet pool, and tie into the wet pond side slopes. 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 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.

Intent: 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.
- 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.
- Requirements for wet pond side slopes are the same as for detention ponds (see BMP D.01: Detention Ponds).

6.1.2.6.1c Embankments

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. See Dam Safety for Detention BMPs in BMP D.01: Detention Ponds.

6.1.2.6.2 Materials

6.1.2.6.2a Vegetation

Planting requirements for detention ponds also apply to wet ponds.

- 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 V - 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.

6.1.2.6.3 Site Design Elements

The following design features should be incorporated to enhance aesthetics where possible:

- 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.

- For wet pool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.
- A flow length-to-width ration greater than the 3:1 minimum is desirable. If the ratio is 4:1 or greater, then the dividing berm is not required, and pond may consist of one cell rather than two. A one-cell pond must provide at least 6-inches of sediment storage depth. A one-cell pond must also provide a minimum depth of 4 feet for the volume equivalent to the first cell of a two-cell design.
- 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.
- A small amount of base flow is desirable to maintain circulation and reduce the potential for low oxygen conditions during late summer.
- 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.

Intent: Evergreen trees or shrubs are preferred to avoid problems associated with leaf drop. Columnar deciduous trees (e.g., hornbeam, Lombardy poplar) typically have fewer leaves than other deciduous trees.

- The number of inlets to the facility should be limited; ideally there should be only one inlet. The flow path length should be maximized from inlet to outlet for all inlets to the wetpond.

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.
- Provide side slopes that are sufficiently gentle to avoid the need for fencing (3H:1V or flatter).

- 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.

6.1.2.6.3.1 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.

6.1.2.6.3.2 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 track hoe (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.

6.1.2.6.4 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

6.1.3.1 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 Runoff 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.

6.1.3.2 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.

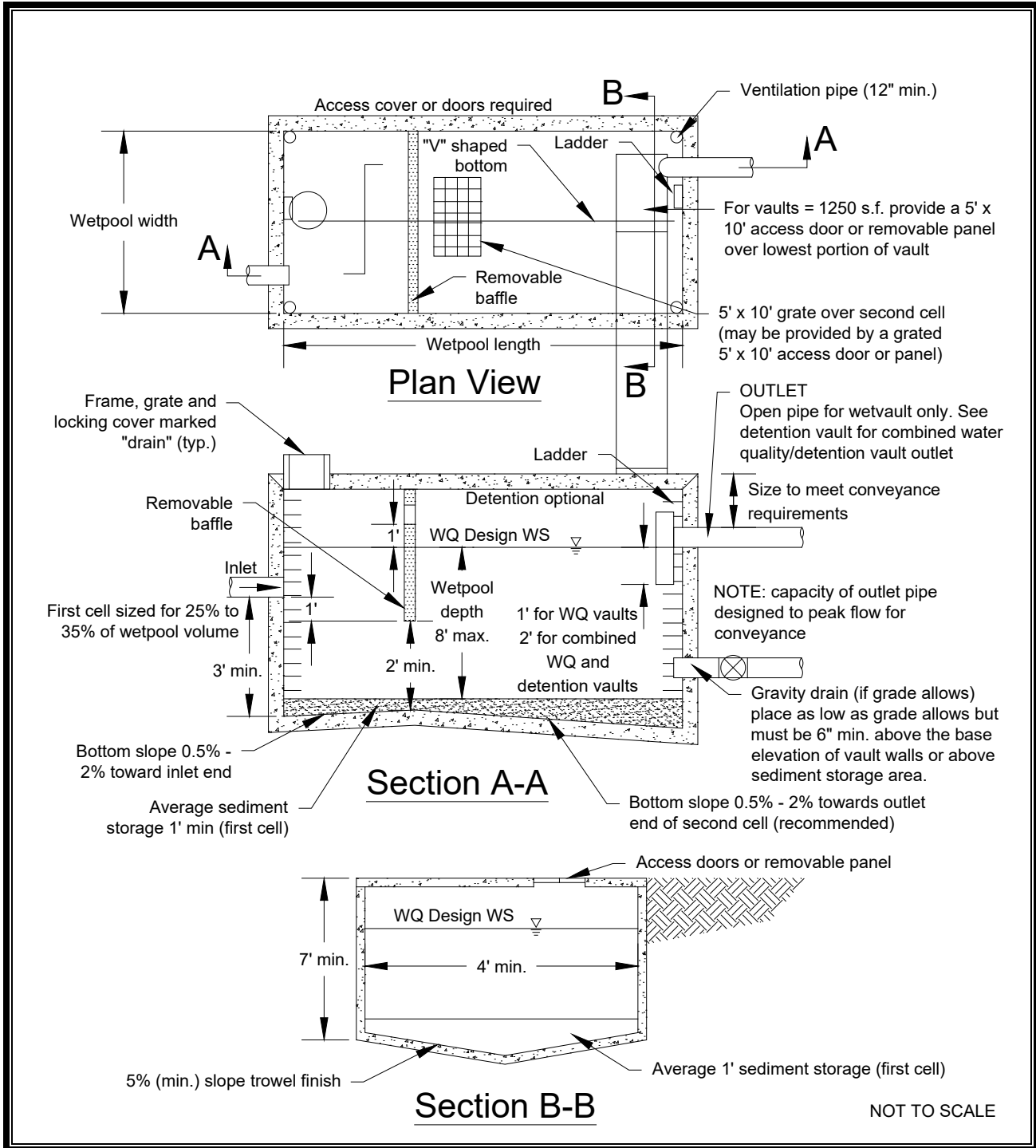


Figure V - 6.5 Wet Vault

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.

6.1.3.3 Submittals and Approval

The use of a wet vault for runoff treatment is restricted to those circumstances where other alternatives are not feasible or 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.

6.1.3.4 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.

6.1.3.5 Hydrologic and Hydraulic Design Considerations

6.1.3.5.1 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. 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 sizing procedure for a wet vault is identical to the sizing procedure for a wet pond. Refer to BMP WP.02: Wet ponds.

6.1.3.6 Design Criteria

Typical design details and concepts for the wet vault are shown in Figure V - 6.5.

6.1.3.6.1 Geometry

6.1.3.6.1a Wet Pool Geometry

The geometry of the wet pool within the wet vault is the same as specified for wet ponds, except for the following two modifications:

- The sediment storage depth 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:

<u>Vault Width</u>	<u>Sediment Depth (from bottom of side wall)</u>
15'	10"
20'	9"
40'	6"
60'	4"

- 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.

6.1.3.6.1b Vault Structure

- The vault shall be separated into two cells by a wall or a removable baffle. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells. 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 two cells of a wet vault should 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.

- 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). 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.

6.1.3.6.1c Inlet and Outlet

- 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.

- 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.
- Thurston County may require a bypass/shutoff valve to enable the vault to be taken off-line for maintenance.

Where feasible, the floor of the second cell should slope toward the outlet for ease of cleaning.

6.1.3.6.2 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.

6.1.3.6.3 Modifications for Combining with a Baffle Oil/Water Separator

If the project site requires an Oil Control BMP 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:

1. 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.
2. 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.
3. The vault shall have a minimum length-to-width ratio of 5:1.
4. The vault shall have a design water depth-to-width ratio of between 1:3 to 1:2.
5. The vault shall be watertight and shall be coated to protect from corrosion.

6. 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.
7. 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 V - 5.2.

Intent: This design minimizes the entrainment and/or emulsification of previously captured oil during very high flow events.

6.1.3.7 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.

6.1.3.8 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) except for the following additional requirement for wet vaults:

- A minimum of 50 square feet of grate should 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 should 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 wet pool in order to minimize stagnant conditions which can result in oxygen depletion, especially in warm weather.

6.1.3.9 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. The following combined facilities are addressed:

- Detention Ponds / Wet Ponds (Basic and Large)
- Detention Vaults / Wet Vaults
- Detention Ponds / Stormwater Treatment Wetlands

There are two sizes of the combined wet pond, a basic and a large, but only a basic size for the combined wet vault and combined stormwater wetland. The facility sizes (basic and large) are related to the pollutant removal goals.

6.1.4.1 Applicability

Combined detention and water quality facilities are very efficient for sites that have both Runoff Treatment and Flow Control requirements. The wet pool BMP may often be placed beneath the detention BMP without increasing the combined facility's surface area.

6.1.4.2 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.

6.1.4.3 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 core 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.

6.1.4.4 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.

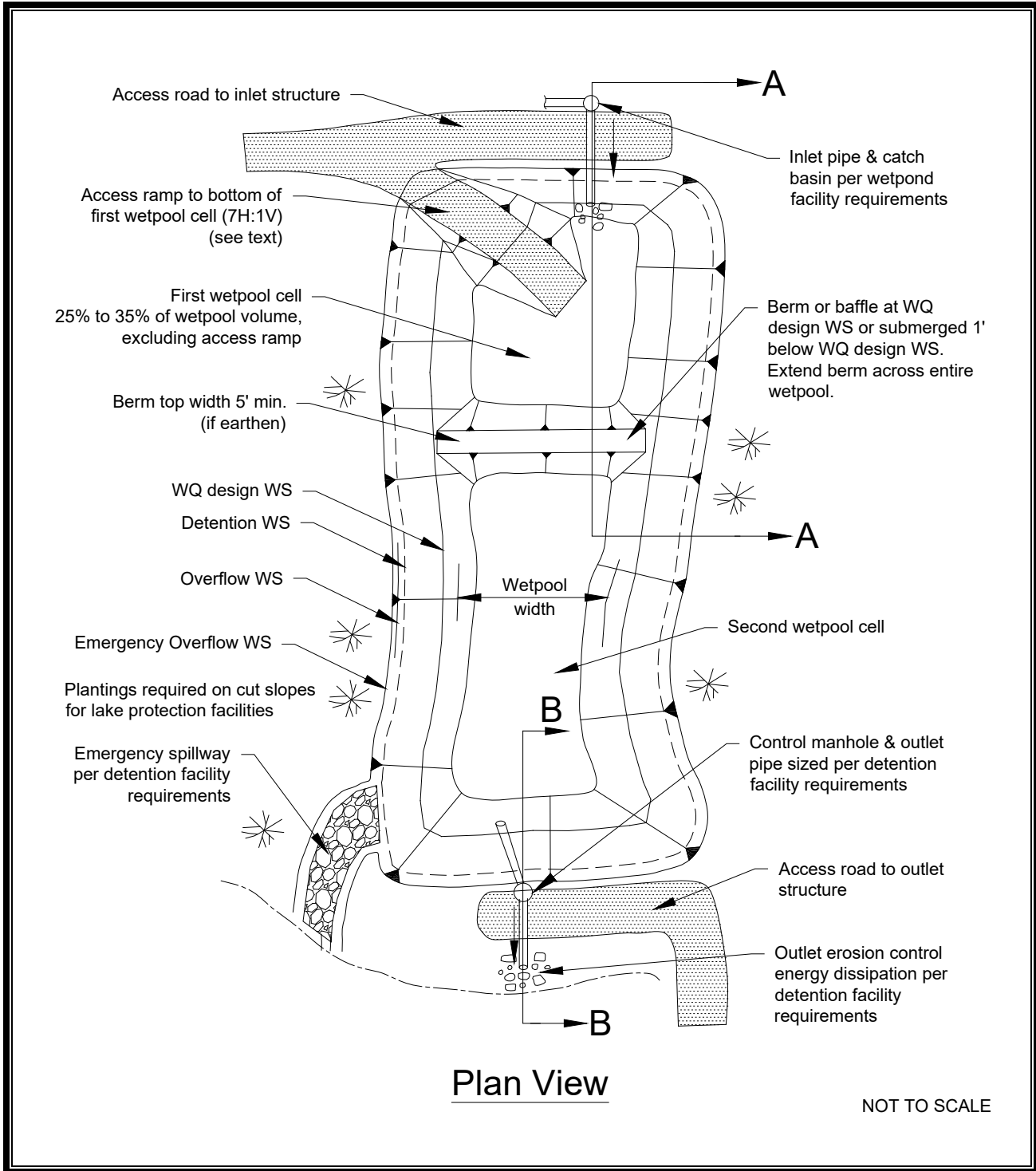


Figure V - 6.6 Combined Detention and Wetpond

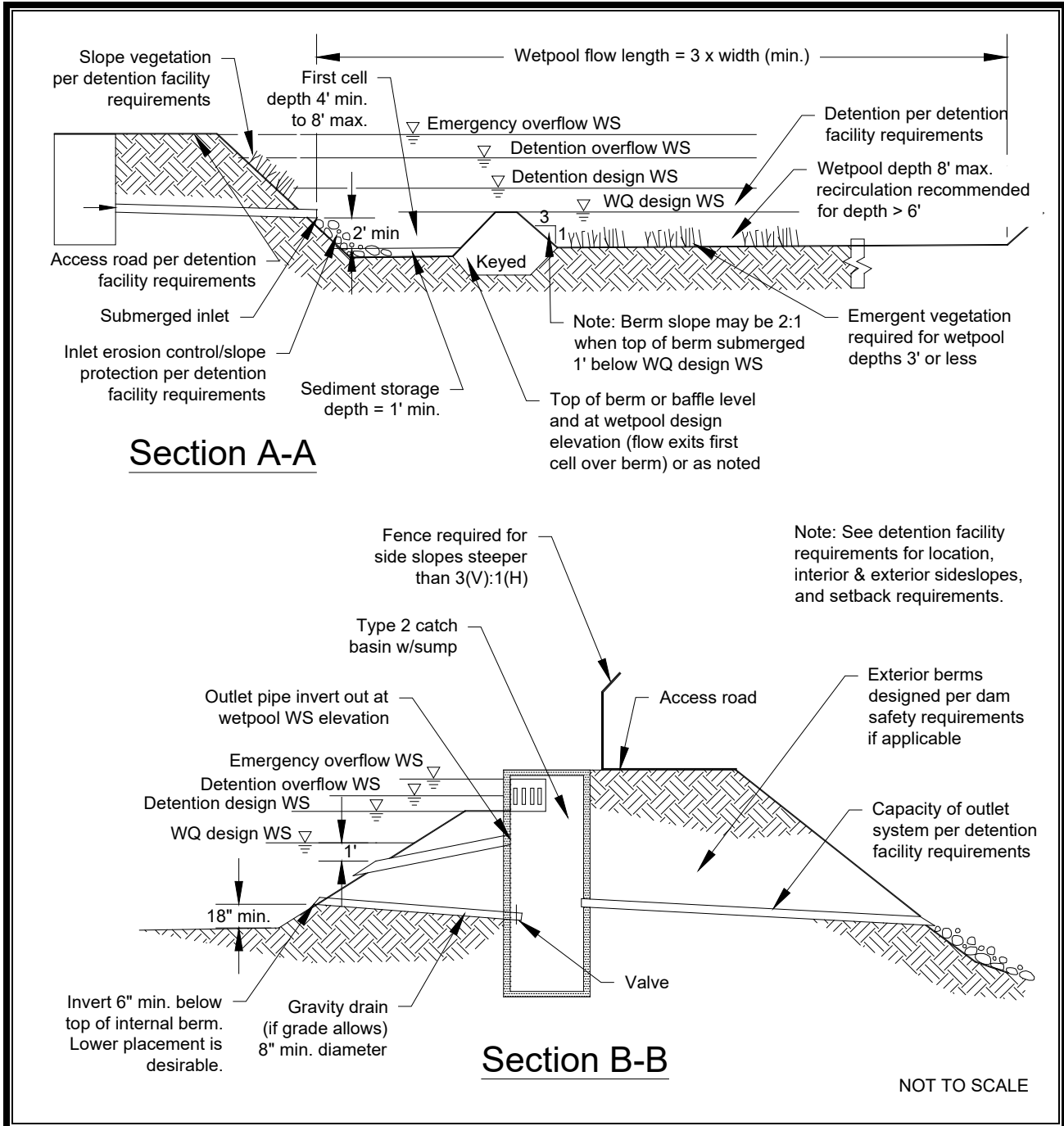


Figure V - 6.7 Combined Detention and Wetpond (continued)

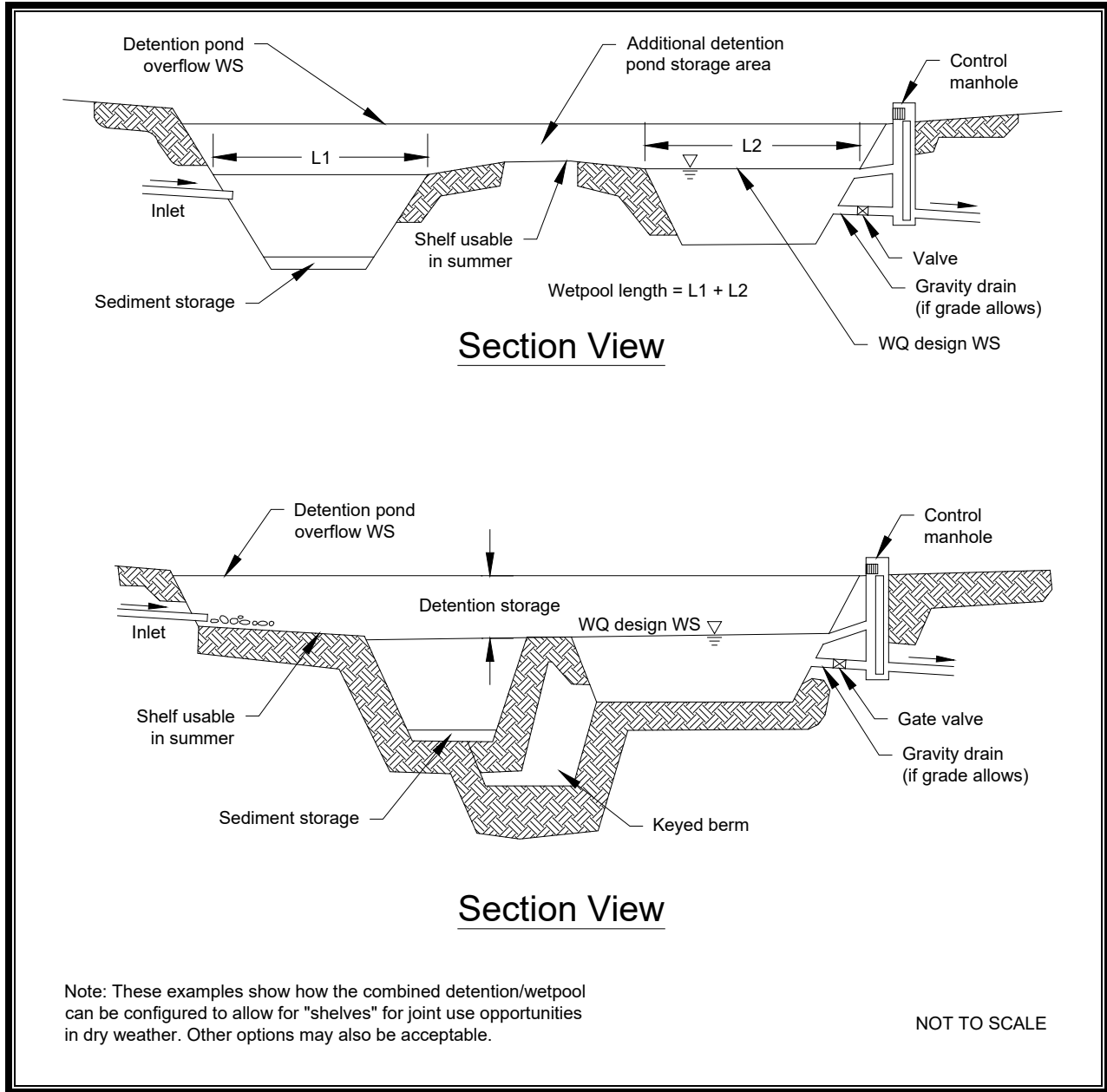


Figure V - 6.8 Alternative Configurations of Detention and Wetpool Areas

6.1.4.5 Combined Detention Pond and Wet Pond (Basic and Large)

6.1.4.5.1 Design Criteria

Typical design details and concepts for a combined detention and wet pond are shown in Figure V - 6.6, Figure V - 6.7, and Figure V - 6.8. The detention portion of the facility shall meet the design criteria and sizing procedures set forth in BMP D.01: Detention Ponds.

6.1.4.5.2 Sizing Procedure

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 water quality design storm volume estimated by an approved continuous runoff model. Follow the standard procedure specified in Volume III and guidance documents for use of an approved continuous runoff model to size the detention portion of the pond.

6.1.4.5.3 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 V - 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.

6.1.4.5.3a Berms, Baffles, and Slopes

Same as for wet ponds (see BMP WP.02).

6.1.4.5.3b 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.

6.1.4.5.4 Planting Requirements

Same as for wetponds.

6.1.4.5.5 Access and Setbacks

Same as for wetponds.

6.1.4.6 Combined Detention and Wetvault

6.1.4.6.1 Sizing Procedure

The sizing procedure for combined detention and wet vaults is identical to those outlined for wet vaults and for detention facilities. Refer to the guidance in BMP WP.03: Wet Vaults to size the wet pool volume for a combined facility. Refer to the guidance in BMP D.03: Detention Vaults to size the detention portion of the vault.

6.1.4.6.2 Geometry

The design criteria for BMP D.03: Detention Vaults and BMP WP.03: Wet Vaults must both be met, except for the following medications or clarifications:

- 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.

Intent: The greater depth of the baffle in relation to the water quality design water surface compensates for the greater water level fluctuations experienced in the combined vault. The greater depth is deemed prudent to better ensure that separated oils remain within the vault, even during storm events.

- A combined detention and wet vault may not be combined with BMP OW.01: API (Baffle Type) Separator Bay to function as an Oil Control BMP, as is allowed for wet vaults in BMP WP.03: Wet Vaults. This is because the added pool fluctuation in the combined detention and wet vault does not allow for the quiescent conditions needed for oil separation.

6.1.4.7 Combined Detention and Stormwater Treatment Wetland

6.1.4.7.1 Sizing Procedure

The sizing procedure for combined detention and stormwater treatment wetlands is identical to those outlined for stormwater treatment wetlands and for detention facilities. Follow the procedure outlined in BMP WP.01 to determine the stormwater wetland size. Follow the standard procedure for BMP D.01 to size the detention portion of the combined detention and wetland facility.

6.1.4.7.2 Geometry

The design criteria for detention ponds and stormwater treatment wetlands must both be met, except for the following modifications or clarifications:

- **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 treatment 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.

Intent: This criterion is designed to dampen the most extreme water level fluctuations expected in combined facilities to better ensure that fluctuation-tolerant wetland plants will be able to survive in the facility. It is not intended to protect native wetland plant communities and is not to be applied to natural wetlands.

- **The Wetland Geometry criteria for BMP WP.01: Stormwater Treatment Wetlands are modified as follows:**
 - 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.

Intent: Since emergent plants are limited to shallower water depths, the deeper water created before sediments accumulate is considered detrimental to robust emergent growth. Therefore, sediment storage is confined to the first cell which functions as a presettling cell.

6.1.4.7.3 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.

6.1.4.7.4 Planting Requirements

The Planting Requirements for stormwater treatment wetlands are modified to use the following plants which are better adapted to water level fluctuations:

<i>Scirpus acutus</i> (hardstem bulrush)	2 – 6' depth
<i>Scirpus microcarpus</i> (small-fruited bulrush)	1 – 2.5' depth
<i>Sparganium emersum</i> (burreed)	1 – 2' depth
<i>Sparganium eurycarpum</i> (burrreed)	1 – 2' depth
<i>Veronica</i> sp. (marsh speedwell)	0 – 1' depth

In addition, the shrub *Spirea douglasii* (Douglas spirea) may be used in combined facilities.

6.1.4.7.5 Access and Setbacks

Same as for stormwater wetlands.

6.1.5 WP.05 Presettling Basins and 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.

6.1.5.1 Applicability

Removal of suspended solids pretreatment helps prevent clogging or excessive sedimentation in the main water quality facility. Pretreatment must be provided in the following applications:

- For sand filters and infiltration BMPs to protect them from excessive siltation and debris.
- Where the basic, phosphorus, or enhanced Runoff Treatment BMP 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. Any Basic Treatment BMPs, or detention ponds, vaults, or tanks designed to meet Core Requirement #7: Flow Control, can also be used for pre-treatment. If an oil/water separator is necessary for oil control, it could also function as the pre-settling basin as long as the influent suspended solids concentrations are not high. However, frequent inspections are necessary to determine when accumulated solids exceed the 6-inch depth at which clean-out is recommended.

Ecology has also approved some emerging technologies for pretreatment through the TAPE process. See Chapter 9 for details.

This remainder of this section discusses Presettling Basins as a BMP.

6.1.5.2 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.

6.1.5.3 Design Criteria

1. A presettling basin shall be designed with a wet pool. The treatment volume shall be at least 30 percent of the total volume of runoff from the 6-month, 24-hour storm event. See Volume III for guidance on how to calculate this volume.
2. 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.

3. The presettling basin shall meet the following requirements:
 - a. The length-to-width ratio shall be at least 3:1. Berms or baffles may be used to lengthen the flow path.
 - b. The minimum depth shall be 4 feet; the maximum depth shall be 6 feet.
4. 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.

6.1.5.4 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.

6.1.5.5 Site Design Elements

6.1.5.5.1 Setbacks

Presettling basins shall be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by Thurston County.

Presettling basins shall be 100 feet from any septic tank/drainfield.

Presettling basins shall be a minimum of 50 feet from any steep (greater than 15 percent) slope.

6.1.5.6 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/>>.

All media filtration BMPs shall be maintained in accordance with the manufacturer's recommendations and schedules. Owners shall provide the Thurston County Water Resources Unit with maintenance logs annually at the end of each calendar year.

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.

A sand filter basin is constructed so that its surface is at grade and open to the elements, similar to an infiltration basin. However, instead of infiltrating into native soils, stormwater filters through a constructed sand bed with an underdrain system. See Figures V - 7.1 through 7.5.

A typical sand filtration system consists of a pretreatment system, flow spreader(s), sand bed, and underdrain piping. The sand filter bed includes a geotextile fabric between the sand bed and the bottom underdrain system.

Provide an impermeable liner under the facility if the filtered runoff requires additional treatment to remove soluble groundwater pollutants; or where additional groundwater protection is mandated.

7.1.1.1 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.

7.1.1.1.1 Basic Sand Filter

7.1.1.1.2 Use a basic sand filter basin to capture and treat the Water Quality Design Storm Volume; which is 91% of the total runoff volume as predicted by an approved continuous runoff model. Only 9% of the total runoff volume would bypass or overflow from the basic sand filter. **Large Sand Filter**

A large sand filter basin is virtually identical to a basic sand filter basin except that it is sized to provide a higher level of Runoff Treatment. While basic sand filter basin meets the basic treatment performance goal, a large sand filter basin meets the enhanced treatment and phosphorus treatment performance goals.

7.1.1.2 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.

Sand filters require adequate operation and maintenance capacity, including accessibility for operations and maintenance.

7.1.1.3 Sand filters require sufficient pretreatment of oil, debris and solids in the tributary runoff. Submittals and Approval

Submit design calculations, drawings and details as part of submittal requirements of Volume I.

7.1.1.4 Pretreatment

Pretreat runoff directed to the basic sand filter BMP to remove debris and other solids. For sites that require oil control, the pretreatment should be an appropriate oil control BMP as described in Chapter 1.

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).

7.1.1.5 Hydrologic and Hydraulic Design Considerations

If the drainage area maintains a base flow between storm events, , bypass the base flow around the filter to keep the sand from remaining saturated for extended periods.

Assume a design filtration rate of 1 inch per hour. Though the sand specified below will initially infiltrate at a much higher rate, that rate will slow as the filter accumulates sediment. When the filtration rate falls to 1 inch per hour, removal of sediment is necessary to maintain rates above the rate assumed for sizing purposes.

Sand filters may be located either on-line or off-line, subject to the following:

On-line Basic Sand Filter Design

- Do NOT place the basic sand filter BMP upstream of a detention facility. This restriction is to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants.
- Size on-line sand filters BMPs placed downstream of a detention BMP using an approved continuous runoff model to filter the Water Quality Design Flow Rate as described in Volume III.

- Include an overflow in the design. The overflow height should be at the maximum hydraulic head of the pond above the sand bed. On-line sand filter BMPs shall have overflows (primary, secondary, and emergency) in accordance with the design criteria for BMP D.01: Detention Ponds.

Off-line Basic Sand Filter Design

- Off-line 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 Design Flow Rate, as predicted by an approved continuous runoff model, to the sand filter BMP.
- Size the basic sand filter BMP to filter all of the runoff sent to it (no overflows from the BMP should occur). The continuous runoff model allows bypassed flows and flow filtered through the sand filter BMP to be directed to a downstream detention BMP.
- Off-line sand filters placed downstream of a detention BMP must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention BMP to the basic sand filter BMP. The basic sand filter BMP must be sized to filter all the runoff sent to it (no overflows from the basic sand filter BMP should occur).
- For off-line sand filter BMPs downstream of detention BMP, design the underdrain structure to pass the 2-year peak inflow rate, as determined using 15-minute time steps in an approved continuous runoff model.

7.1.1.5.1 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 continuous runoff model.

Currently approved continuous runoff models do not automatically calculate a flow rate that corresponds to 95% of the runoff volume of the period modeled. Therefore, to size a large sand filter basin, the designer must use an iterative process and verify that 95% of the runoff file volume passes through the large sand filter element within the 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.

7.1.1.5.1.a 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 $V \propto K$. 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 V - 7.1 shows values of V for different water depths d ($d=2h$).

Table V - 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).

7.1.1.5.1.b Modeling Method

When using continuous modeling to size a sand filter, apply the assumptions listed in Table V - 7.2. Several available modeling programs include built-in modules to size sand filters.

Table V - 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

7.1.1.5.2 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).

- If the sand filter is curved or an irregular shape, provide a flow spreader for a minimum of 20 percent of the filter perimeter.
- If the length-to-width ration of the filter is 2:1 or greater, locate a flow spreader on the longer side of the filter and for a minimum length of 20 percent of the facility perimeter.

- Provide erosion protection along the first foot of the sand bed adjacent to the flow spreader. Methods for this include geotextile weighted with sand bags at 15-foot intervals and quarry spalls.

7.1.1.5.3 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.

The design flows for the overflow and underdrains must be increased from the sizes used for basic sand filter basins for large sand filter basins.

Basic sand filter basin uses the 91% runoff volume as the Water Quality Design Volume, a 2-year return interval peak flow from an approved continuous model. The corresponding overflow and underdrain design flow is the 2-year storm.

Thus, the overflow and underdrain design flow can be calculated for large sand filter basin by increasing the 2-year return interval peak flow by the ratio of 95% runoff volume (the Water Quality Design Volume for large sand filter basin) and the 91% runoff volume (the Water Quality Design Volume for basic sand filter basin). In equation form: Design Flow Rate for Large Sand Filter Overflow = (95% Runoff Volume)/(91% Runoff Volume) * 2-year return interval peak flow.

7.1.1.5.4 Underdrain Piping

The following are design criteria for the underdrain piping:

- A central collector pipe with lateral feeder pipes, in an 8-inch gravel backfill or drain rock bed.
- A central collector pipe with a geotextile drain strip in an 8-inch gravel backfill or drain rock bed.
- Size underdrain piping for the 2-year return frequency flow indicated by an approved continuous runoff model (whether upstream or downstream of a detention BMP). Provide at least 1 foot of hydraulic head above the invert of the upstream end of the collector pipe. (King County Department of Natural Resources, 1998)
- Use underdrain pipe with a minimum of internal diameter of 6 inches, with two rows of three-eighth-inch holes spaced 6 inches apart longitudinally (maximum), and rows 120 degrees apart (laid with holes downward). Maintain a maximum perpendicular distance between two feeder pipes, or the edge of the filter and a feeder pipe, of 10 feet. All piping is to be schedule 40 PVC or piping with a greater wall thickness.
- Main collector underdrain pipe shall be at a slope of 1 percent minimum.

- Use 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. Drain rock should be 0.75 to 1.5 inch drain rock or gravel backfill, washed free of clay and organic material.
- See 7.1.1.5.3 Overflow for underdrain design criteria for large sand filter basin.

7.1.1.5.5 Sand

Sand medium specifications: The sand medium 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 V - 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 filter BMPs.)

Table V - 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

Source: King County Department of Natural Resources, 1988.

7.1.1.5.6 Impermeable Liners for Sand Bed Bottom

Impermeable liners are generally required for soluble pollutants such as metals and toxic organics and where the underflow could cause problems with structures. 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 V - 7.4.

- 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.
- 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 V - 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.
- 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.

7.1.1.6 Design Criteria

Figure V - 7.1, Figure V - 7.2, Figure V - 7.3, Figure V - 7.4, and Figure V - 7.5 provide details of a sand filter basin.

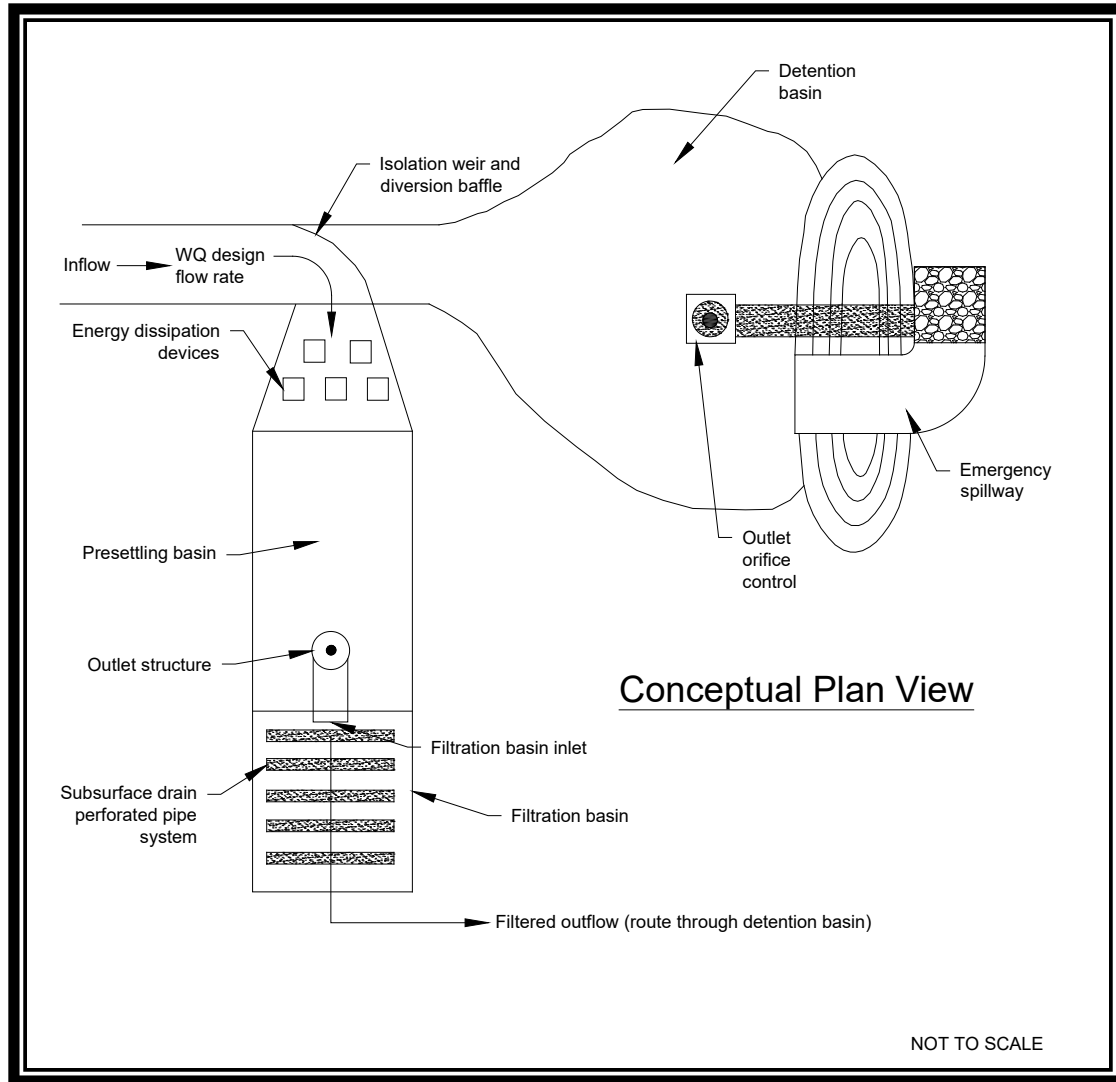


Figure V - 7.1 Sand Filtration Basin Preceded by Presettling Basin (Variation of a Basic Sand Filter)

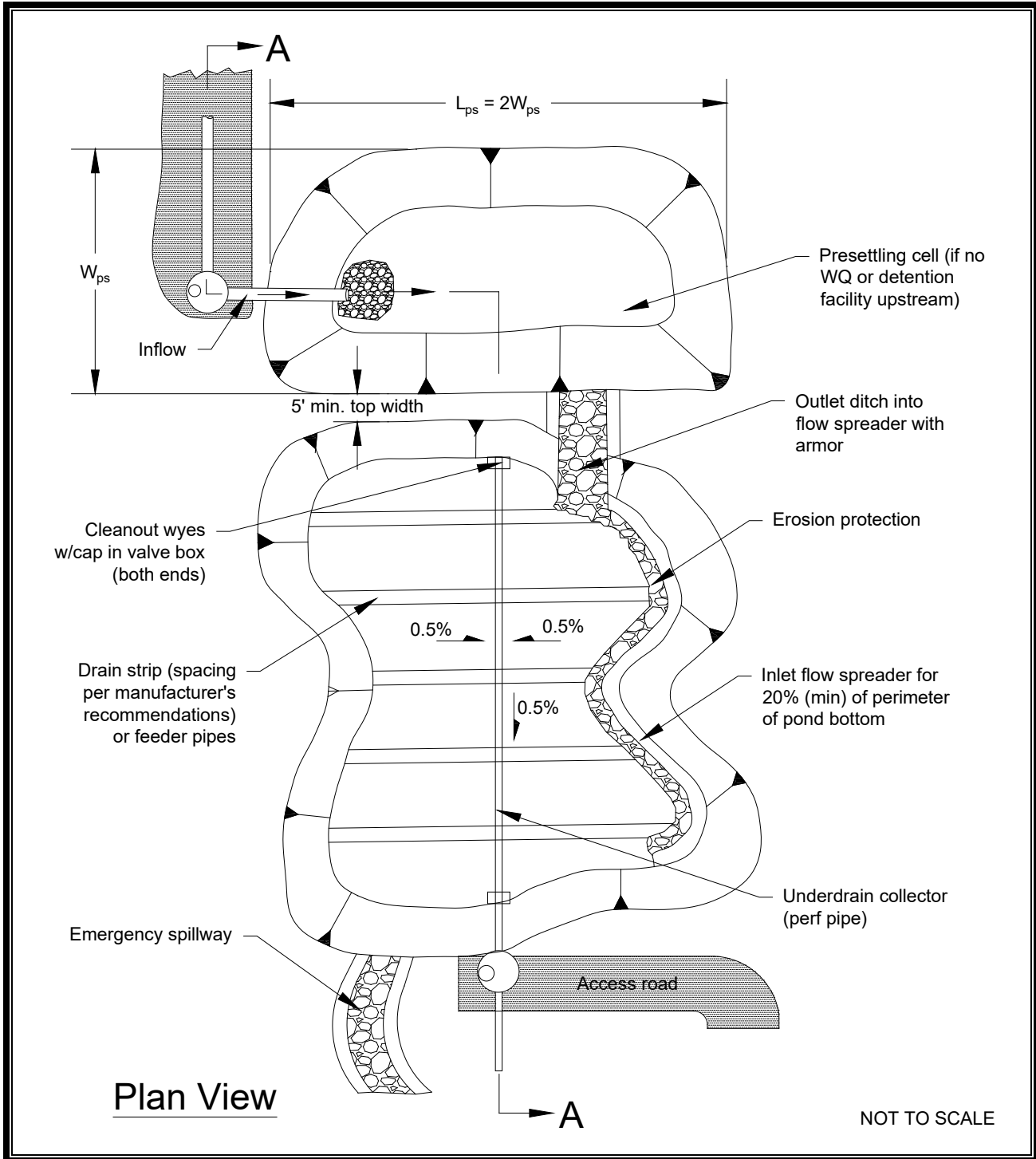


Figure V - 7.2 Sand Filter with Pretreatment Cell

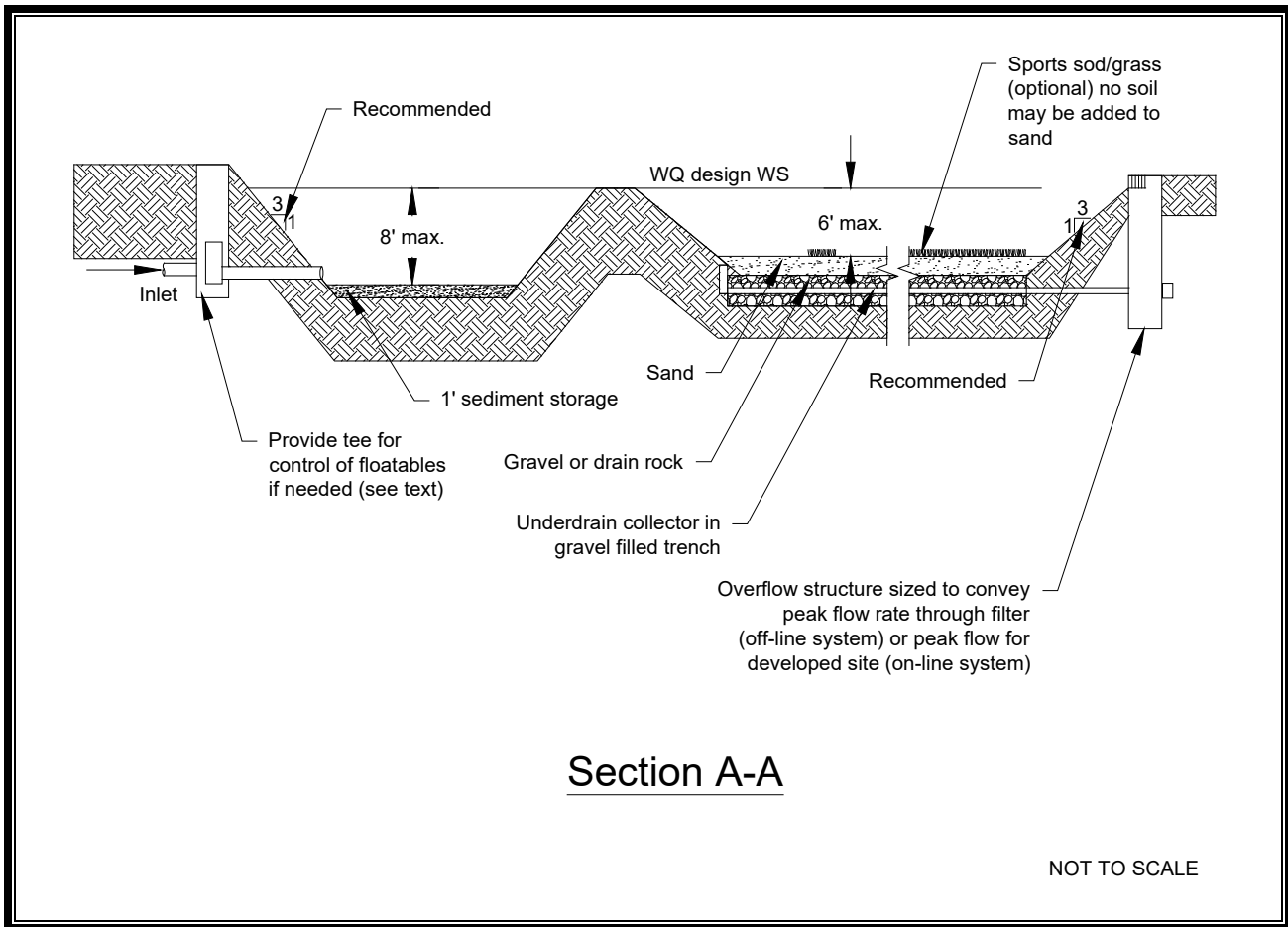


Figure V - 7.3 Sand Filter with Pretreatment Cell – Section

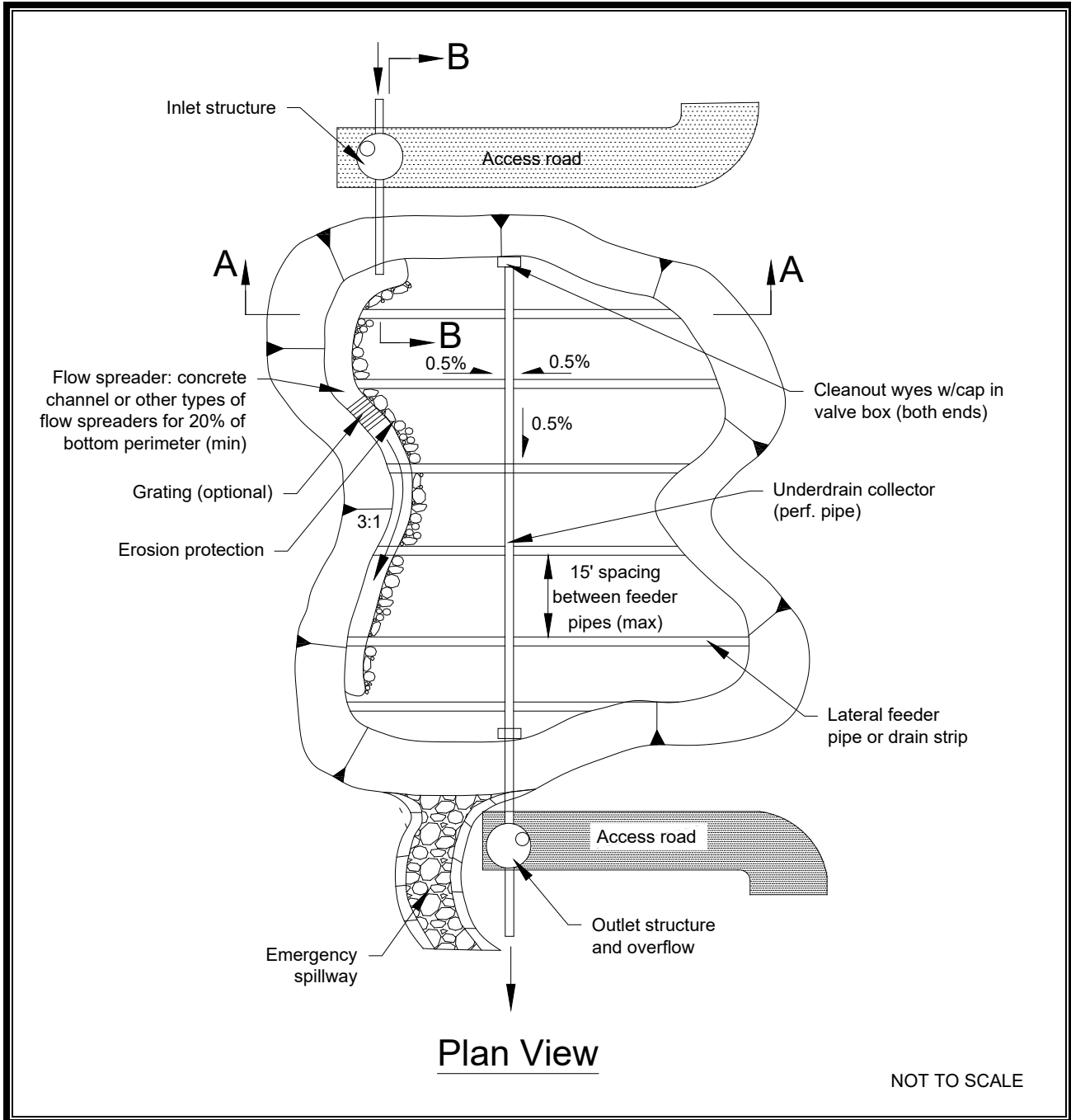


Figure V - 7.4 Sand Filter with Level Spreader

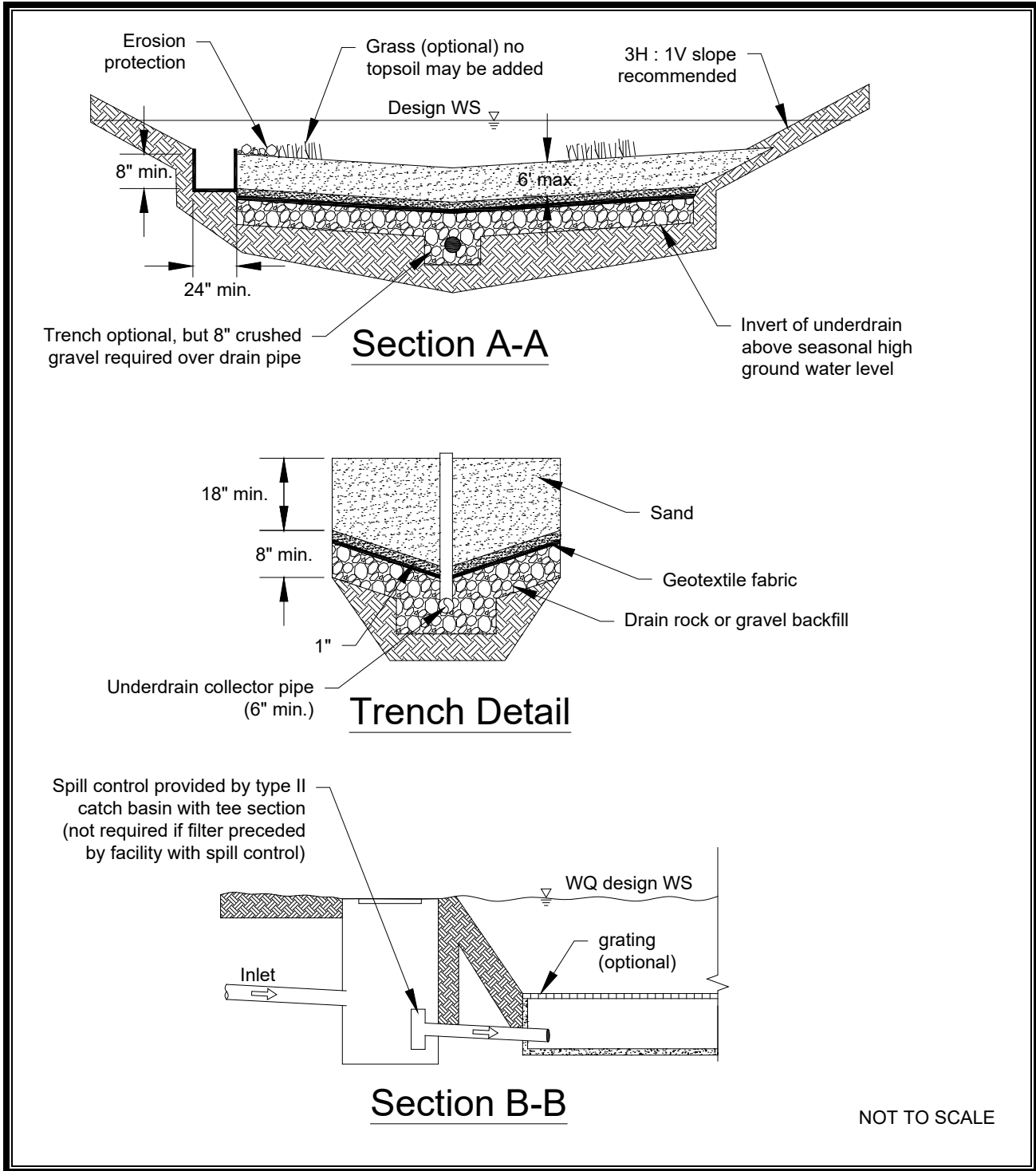


Figure V - 7.5 Sand Filter with Level Spreader – Sections and Details

7.1.1.7 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.

Side slopes for earthen/grass embankments must not exceed 3:1 to facilitate mowing.

7.1.1.8 Construction and Maintenance

7.1.1.8.1 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.

7.1.1.8.2 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.

7.1.1.8.3 Cleanouts and Underdrain Piping

A valve box must be provided for access to the cleanouts.

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.

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 is similar to a sand filter basin, except that the sand layer and underdrains are installed below grade in a vault. A sand filter vault consists of presettling and sand filtration cells.

7.1.2.1 Applicability

A sand filter vault is appropriate where space limitations preclude aboveground facilities or in areas subject to freezing.

7.1.2.2 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.

7.1.2.3 Submittals and Approval

Submit design calculations, drawings and details as part of submittal requirements of Volume I.

7.1.2.4 Pretreatment

Design shall include a forebay, pre-settling basin or other treatment BMP prior to the sand filter for coarse sediment removal.

7.1.2.5 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 on-line for small drainages.

7.1.2.5.1 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 Core Requirement #7), or to surface water.

7.1.2.5.2 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.

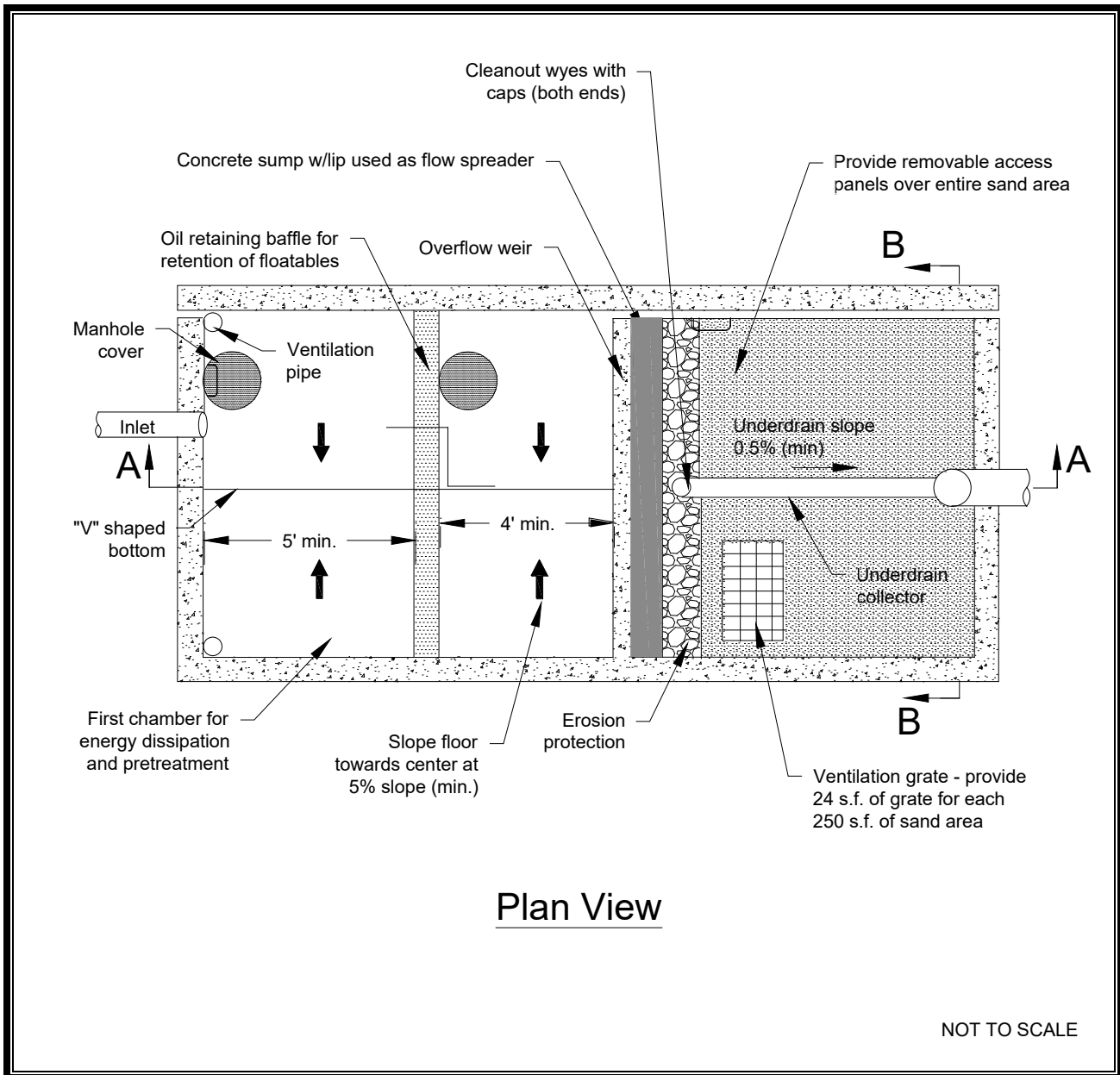


Figure V - 7.6 Sand Filter Vault

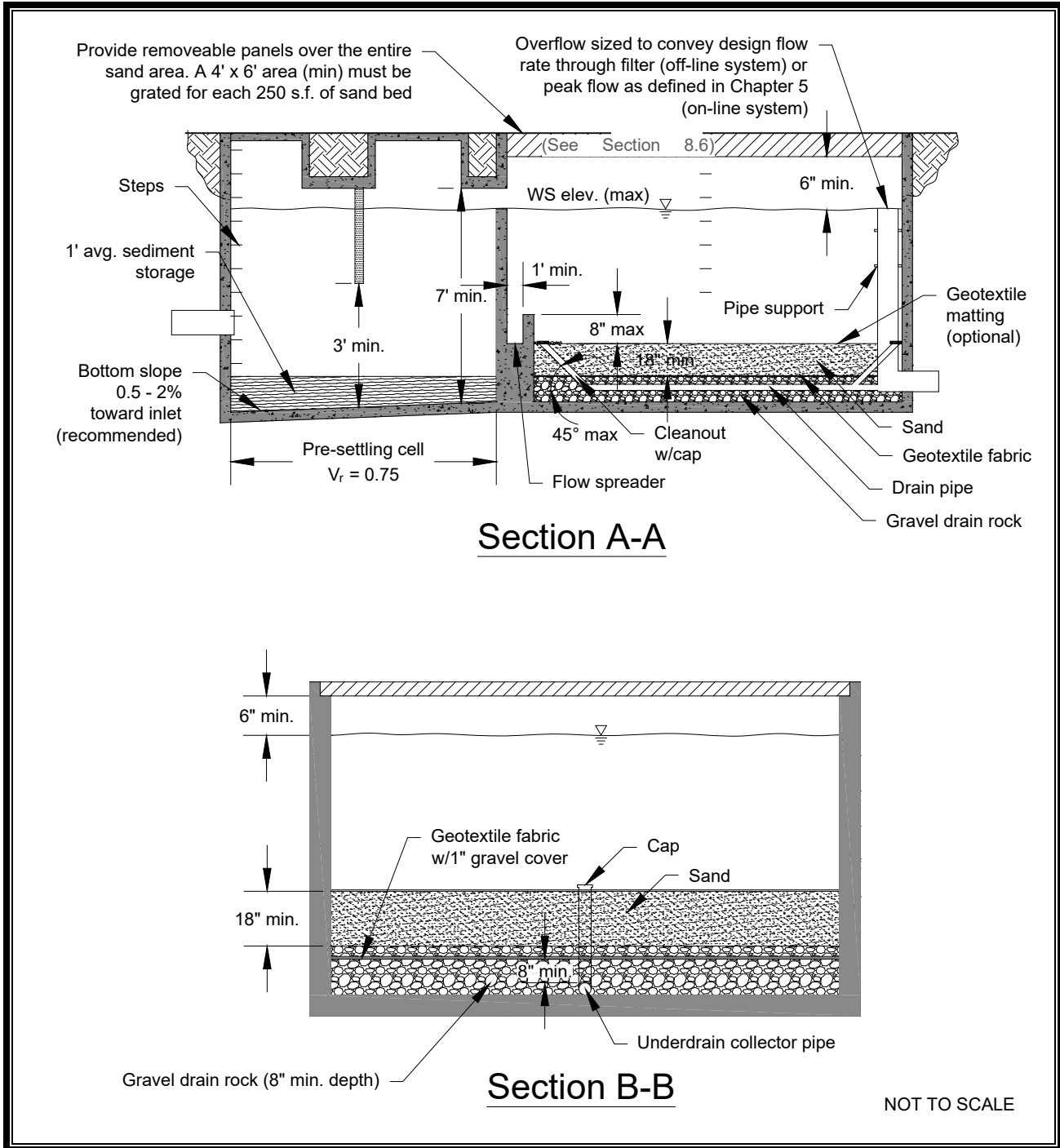


Figure V - 7.7 Sand Filter Vault: Sections

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.

7.1.2.6 Design Criteria

The filter bed shall consist of a sand top layer, and a geotextile fabric second layer with an underdrain system.

7.1.2.6.1 Geometry

7.1.2.6.1.a 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.

7.1.2.6.1.b 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.

7.1.2.6.2 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.

7.1.2.7 Structural Design Considerations

Sand filter vaults shall conform to the structural suitability and materials criteria specified for wet vaults.

7.1.2.8 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).

7.1.2.9 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 V - 7.8) 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.

7.1.3.1 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.

7.1.3.2 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.

7.1.3.3 Submittals and Approval

Submit design calculations, drawings and details as part of submittal requirements of Volume I.

7.1.3.4 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.

7.1.3.5 Hydrologic and Hydraulic Design Considerations

Maximum sand bed ponding depth is 1 foot.

Drain pipe must be sloped a minimum of 0.5 percent.

7.1.3.6 Design Criteria

Figure V - 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.

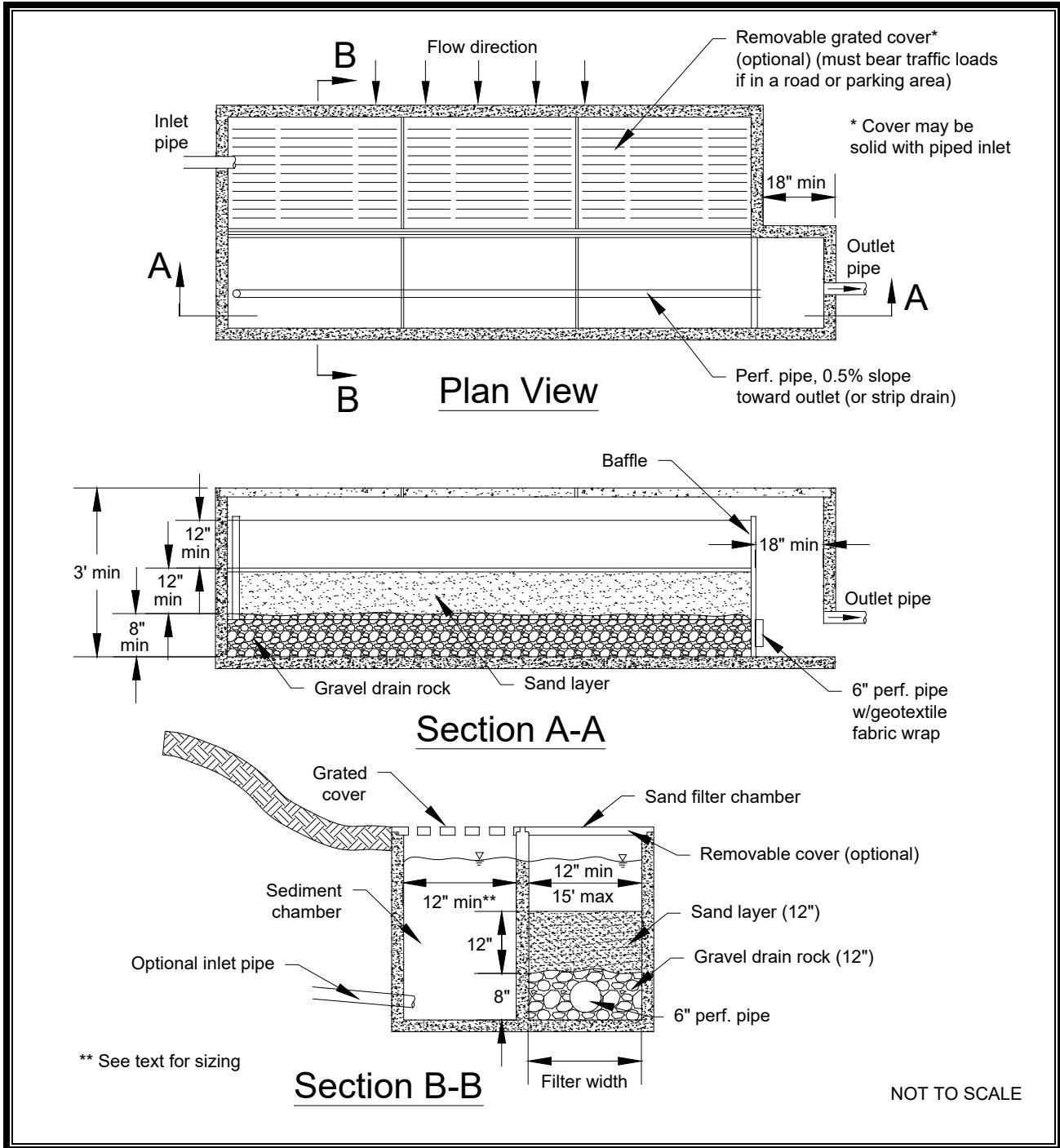


Figure V - 7.8 Linear Sand Filter

7.1.3.6.1 Geometry**7.1.3.6.1.a 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.

7.1.3.6.1.b 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.

7.1.3.6.2 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.

7.1.3.7 Structural Design Considerations

Linear sand filters must conform to the structural suitability materials criteria specified for wet vaults.

7.1.3.8 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).

7.1.3.9 Construction and Maintenance

Linear sand filters must be vented as for sand filter vaults.

7.1.4 MF.04 Media Filter Drain

The media filter drain (MFD) is a linear flow-through stormwater runoff treatment device. The MFD can be sited along highway side slopes (conventional design) and medians (dual media filter drain), borrow ditches, or other linear depressions. Cut-slope applications may also be considered.

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 Figure V - 7.9, Figure V - 7.10, and V - Figure V - 7.11. Note: The drawings are only templates and should be modified to fit each application per the sizing information below.

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.

7.1.4.1 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.

7.1.4.1.1 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 in highway settings are highway side slopes or other long, linear grades with lateral side slopes less than 4H:V1 and longitudinal slopes not steeper than 5%.

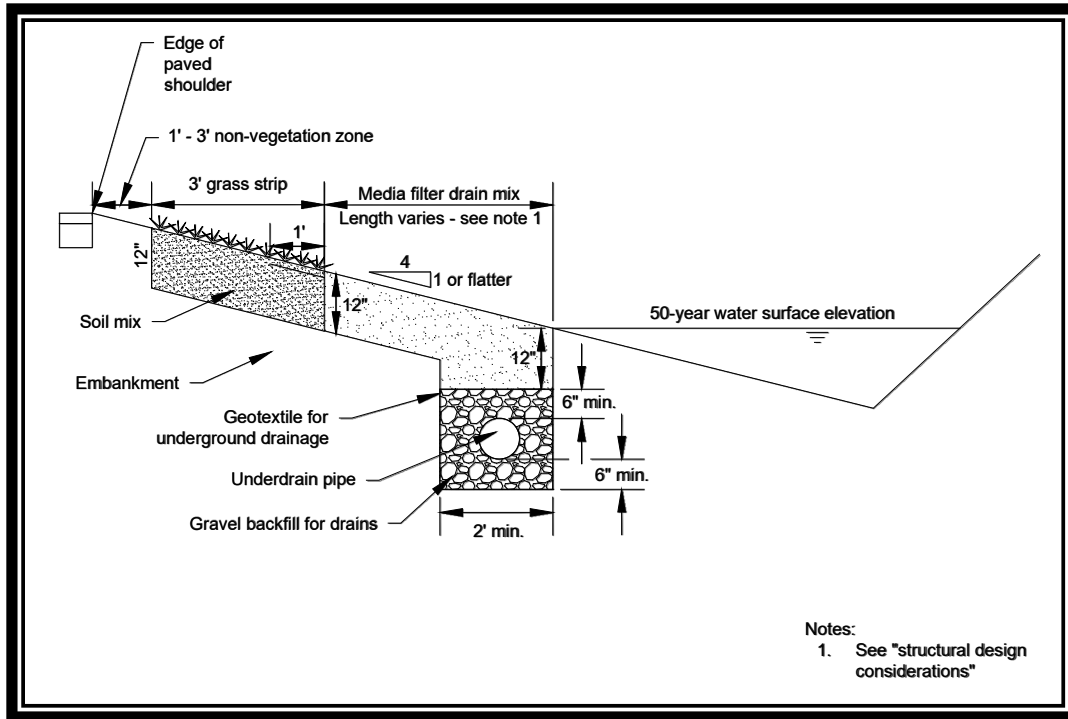


Figure V - 7.9 Media Filter Drain: Side Slope Application with Underdrain

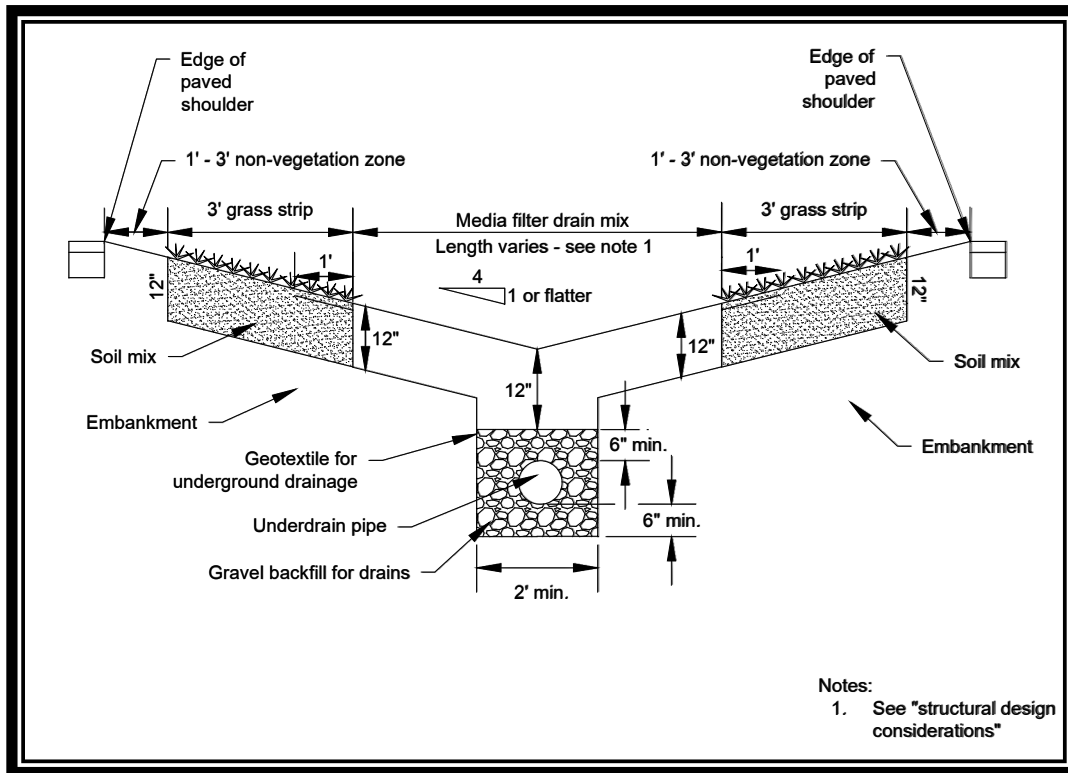
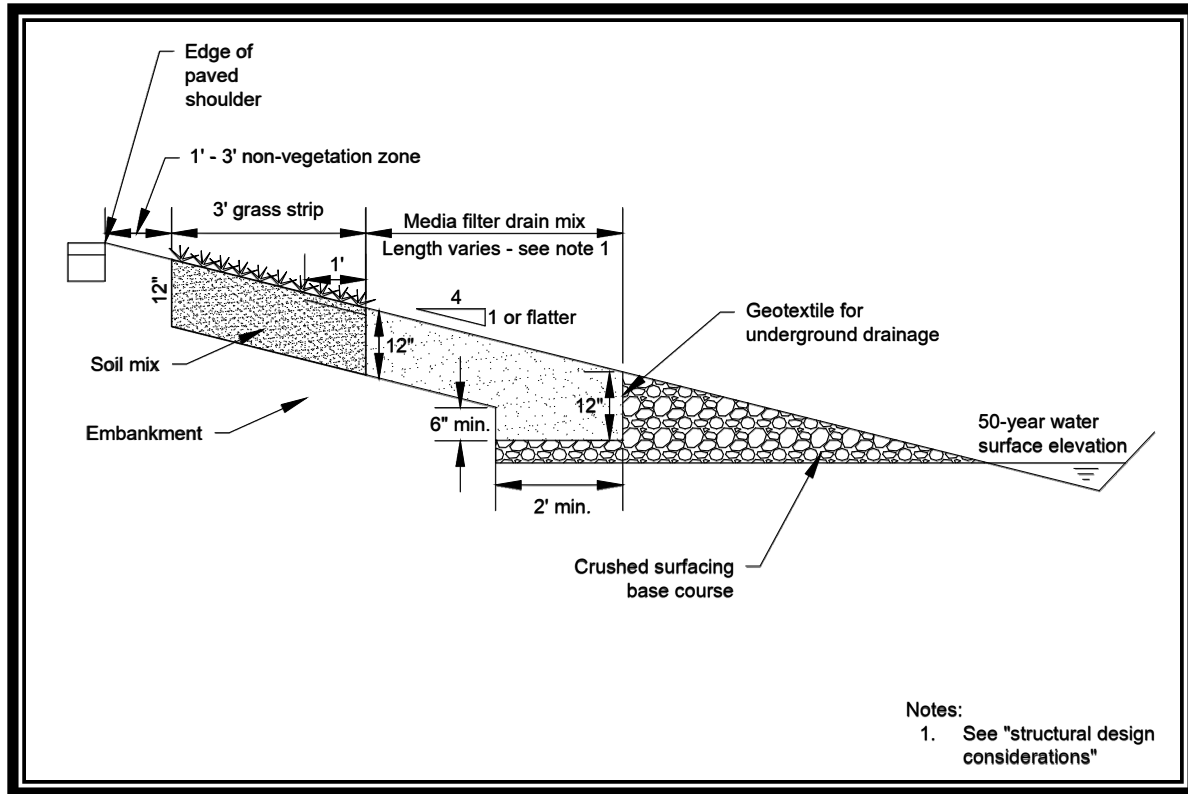


Figure V - 7.10 Dual Media Filter Drain: Median Application with Underdrain



V - Figure V - 7.11 Media Filter Drain: Side Slope Application without Underdrain

7.1.4.1.2 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 in a highway setting 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.

7.1.4.2 Limitations

7.1.4.2.1 Narrow Roadway Shoulders

In area where there is a narrow roadway shoulder that does not allow enough room for a vehicle to fully stop or park, consider placing the media filter drain farther down the embankment slope. This will reduce the amount of rutting in the media filter drain and decrease overall maintenance repairs.

7.1.4.2.2 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.

7.1.4.2.3 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.

7.1.4.2.4 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.

7.1.4.2.5 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.

7.1.4.3 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.

7.1.4.4 Pretreatment

No pretreatment is required. Sheet flow runoff from the roadway surface can be routed directly to the MFD.

7.1.4.5 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.

7.1.4.5.1 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.

7.1.4.5.2 Design Flow Rate

For western Washington, $Q_{Roadway}$ is the flow rate at or below which 91 percent of the runoff volume for the developed TDA will be treated, based on a 15-minute time step, and can be determined using an approved continuous runoff model.

7.1.4.5.3 Sizing MFD Mix Bed

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

For runoff treatment, sizing the MFD mix bed is based on the requirement that the Water Quality Design 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:

$$W_{EE} \geq \frac{Q_{Roadway} * C * SF}{LTIR_{EM} * L_{EE}}$$

Western Washington 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 V - 7.5 was developed by WSDOT to simplify the design steps and should be used to establish an appropriate width.

Table V - 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 V - 7.8).

7.1.4.6 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.

7.1.4.6.1 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.

7.1.4.6.2 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 zone located directly adjacent to the roadway 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 and a deposition area for coarse sediments.

7.1.4.6.3 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.

7.1.4.6.4 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.

7.1.4.6.5 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).

7.1.4.6.5.a 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 V - Figure V - 7.11) 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.

7.1.4.6.5.b Underdrain Pipe

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.

The trench's perforated underdrain pipe can provide a protective measure to ensure free flow through the MFD mix and is sized similar to storm drains. For media filter drain underdrain sizing, an additional step is required to determine the flow rate that can reach the underdrain pipe. This is done by comparing the contributing basin flow rate to the infiltration flow rate through the MFD mix and then using the smaller of the two to size the underdrain. The analysis described below considers the flow rate per foot of MFD, which allows the flexibility of incrementally increasing the underdrain diameter

where long lengths of underdrain are required. When underdrain pipe connects to a stormwater drain system, place the invert of the underdrain pipe above the 25-year water surface elevation in the storm drain to prevent backflow into the underdrain system.

The following describes the procedure for sizing underdrains installed in combination with media filter drains.

1. Calculate the flow rate per foot from the contributing basin to the MFD. The design storm event used to determine the flow rate should be relevant to the purpose of the underdrain. For example, if the underdrain will be used to convey treated runoff to a detention BMP, size the underdrain for the 50-year storm event.

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

where:

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

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

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

$$Q \frac{MFD}{ft} = \frac{f \times W \times 1ft}{ft} \times \frac{1ft}{12in} \times \frac{1hr}{3600 sec}$$

where:

$$Q \frac{MFD}{ft} = \text{flow rate of runoff through the media filter drain mix layer (cfs/ft)}$$

W = width of underdrain trench (ft); the minimum width is 2 ft

f = infiltration rate through the media filter drain mix (in/hr) = 10 in/hr

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

$$Q \frac{UD}{ft} = \text{smaller} \left\{ Q \frac{roadway}{ft} \text{ or } Q \frac{MFD}{ft} \right\}$$

where:

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

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

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

where:

Q_{UD} = estimated flow rate to the underdrain (cfs)

W = width of the underdrain trench (ft); the minimum width is 2 ft

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

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

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

where:

D = underdrain pipe diameter (inches)

n = Manning's coefficient

s = slope of pipe (ft/ft)

7.1.4.6.6 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 Water Quality 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.

7.1.4.6.7 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.

If the design is configured to allow the media filter drain laterally into a ditch, the crushed surfacing base course below the media filter drain should conform to Section 9-03.9(3).

7.1.4.6.7.a MFD Mix

The MFD mix is a mixture of crushed rock, 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 V - 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 V - 7.6 Media Filter Drain Mix

Amendment	Quantity
Mineral aggregate: Aggregate for Media Filter Drain Mix Aggregate for media filter drain mix shall be manufactured from ledge rock, talus, or gravel in accordance with Section 3-01 of the <i>Standard Specifications for Road, Bridge, and Municipal Construction</i> (2002), which meets the following test requirements for quality. The use of recycled material is not permitted.	3 cubic yards

Amendment	Quantity																
<p>Los Angeles Wear, 500 Revolutions 35% max. Degradation Factor 30 min.</p> <p>Aggregate for the MFD mix shall conform to the following requirements for grading and quality:</p> <table> <tr> <th>Sieve Size</th><th>Percent Passing (by weight)</th></tr> <tr> <td>1/ 2" square</td><td>100</td></tr> <tr> <td>3/8" square</td><td>90-100</td></tr> <tr> <td>U.S. No. 4</td><td>30-56</td></tr> <tr> <td>U.S. No. 10</td><td>0-10</td></tr> <tr> <td>U.S. No. 200</td><td>0-1.5</td></tr> <tr> <td>% fracture, by weight, min.</td><td>75</td></tr> <tr> <td>Static stripping test</td><td>Pass</td></tr> </table> <p>The fracture requirement shall be at least two fractured faces and will apply to material retained on the U.S. No. 10.</p> <p>The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.</p> <p>Aggregate for the MFD 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.</p>	Sieve Size	Percent Passing (by weight)	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	
Sieve Size	Percent Passing (by weight)																
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																
<p>Perlite:</p> <p>Horticultural grade, free of any toxic materials 0-30% passing US No. 18 Sieve 0-10% passing U.S. No. 30 Sieve</p>	1 cubic yard per 3 cubic yards of mineral aggregate.																
<p>Dolomite: $\text{CaMg}(\text{CO}_3)_2$ (calcium magnesium carbonate) Agricultural grade, free of any toxic materials 100% passing US No. 8 Sieve 0% passing U.S. No. 16 Sieve</p>	10 pounds per cubic yard of perlite																
<p>Gypsum: Noncalcined, agricultural gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (hydrated calcium sulfate) Agricultural grade, free of any toxic materials 100% passing US No. 8 Sieve 0% passing US No. 16 Sieve</p>	1.5 pounds per cubic yard of perlite.																

7.1.4.6.7.b 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.

7.1.4.6.7.c 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. Composted material used in the grass strip shall meet the specifications for compost used in Bioretention Soil Mix (BSM) (see BMP LID.08). The soil mix should ensure grass growth for the design life of the MFD.

7.1.4.7 Site Design Elements

7.1.4.7.1 Landscaping (Planting Considerations)

Landscaping is the same as for biofiltration swales (see BMP BF.01) unless otherwise specified and approved by Thurston County.

7.1.4.7.2 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.

7.1.4.8 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 separator BMPs remove oil and other water-insoluble hydrocarbons, and settleable solids from stormwater runoff . 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 Rate. Linear sand filters and manufactured treatment devices approved as an Oil Control BMP, may also be used for oil removal. Oil control devices and facilities should be placed upstream of other Runoff Treatment BMPs and as close to the source of oil generation as possible.

When designed properly, oil and water separator BMPs shall meet the oil control performance goal described in Chapter 1.

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 |

8.1.1 OW.01 API (Baffle Type) Separator

This type of separator uses internal baffles to separate the oil from the water. (API stands for American Petroleum Institute.)

8.1.1.1 Applicability

API separators are designed for use on sites larger than 2 acres.

8.1.1.2 Limitations

Ecology's 2019 *Stormwater Management Manual for Western Washington* (Ecology 2019) 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.

Without intense maintenance, oil and water separator BMPs may not be sufficiently effective in achieving oil and TPH removal down to the required levels.

8.1.1.3 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.

8.1.1.4 Pretreatment

A pretreatment BMP should be considered if the level of TSS in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the oil and water separator BMP.

8.1.1.5 Hydrologic and Hydraulic Design Considerations

8.1.1.5.1 Design Storm

The separator shall be located 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 by Figure V - 5.2. If it is necessary to locate the separator on-line, try to minimize the size of the area needing oil control, and use the Water Quality Design Flow Rate multiplied by the ratio indicated in Figure V - 5.1.

8.1.1.5.2 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:

- Determine the oil rise rate, V_t , in feet per minute, 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)

For Stormwater Inflow from Drainages More than 2 acres

- Determine V_t based on above criteria
- Determine Q :

Q = the 15-minute Water Quality design flow rate in ft³/min multiplied by the ratio indicated in Figure V - 5.1b for the site location (k). Note that WWHM gives the water quality design flow rate in ft³/sec. Multiply this flow rate by 60 to obtain the flow rate in ft³/min.

- Calculate horizontal velocity of the bulk fluid, V_h (in ft/min), and depth (d), ft.

$$V_h = 15V_t$$

$$d = (Q/2Vh)^{1/2}, \text{ with}$$

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).

- Calculate the minimum residence time (t_m), 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)

$$l(s) = FQ t_m / wd = F(V_h/V_t)d$$

Step 5. For other dimensions, including the length of the forebay, the length of the afterbay, and the overall length, L ; refer to Figure V - 8.1.

- Calculate $V = l(s)wd = FQ t_m$, and $A_h = wl(s)$

V = minimum hydraulic design volume, in cubic feet.

A_h = minimum horizontal area of the separator, in square feet.

8.1.1.6 Design Criteria

Figure V - 8.1 provides a plan and section view of the API Separator.

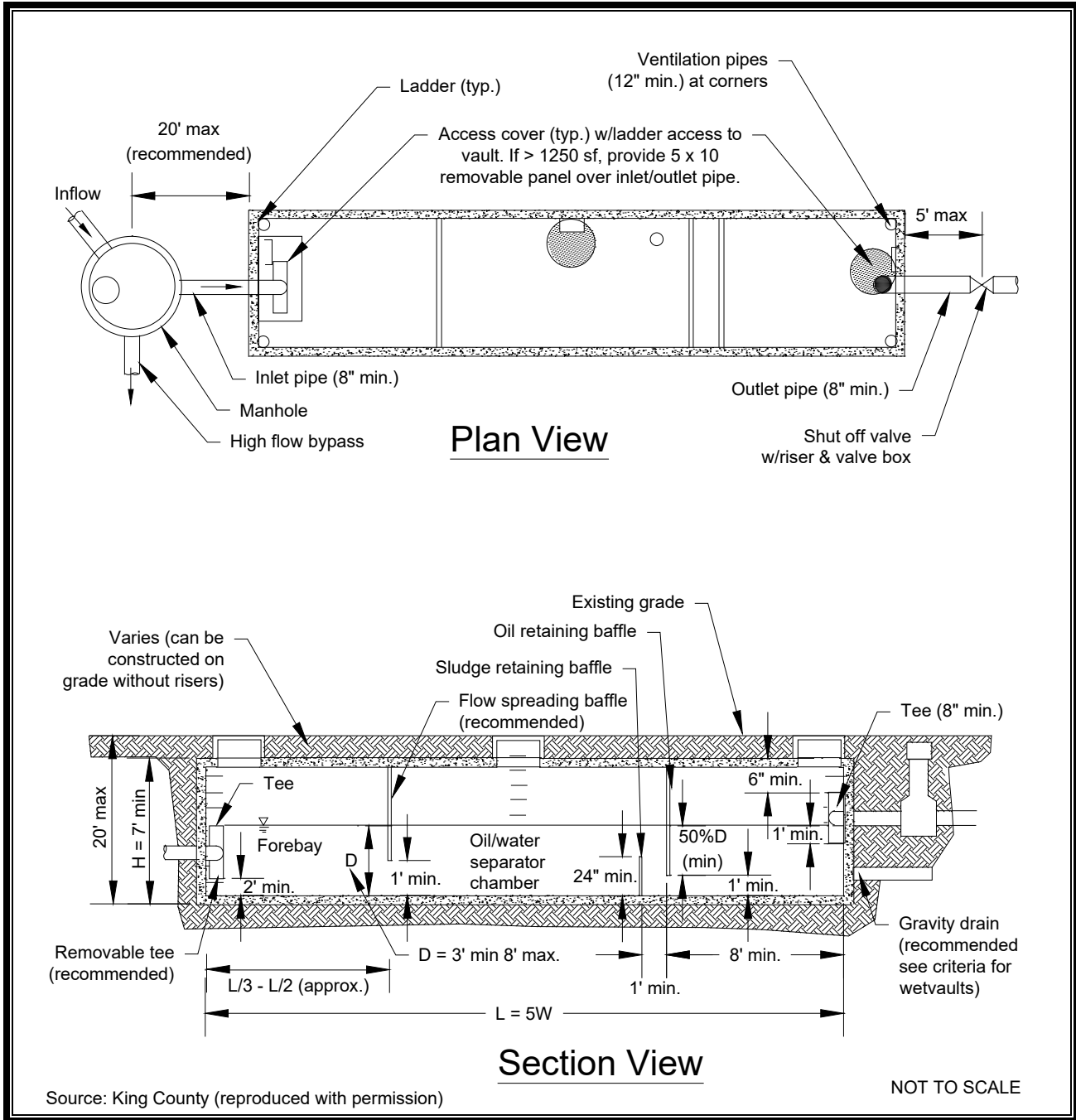


Figure V - 8.1 API (Baffle Type) Separator

8.1.1.6.1 Geometry

8.1.1.6.1.a Criteria for Separator Bays

To collect floatables and settleable solids, design the surface area of the forebay at $\geq 20 \text{ ft}^2$ 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.

Use absorbents and/or skimmers in the afterbay as needed.

8.1.1.6.1.b 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.

8.1.1.6.2 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.

8.1.1.7 Structural Design Considerations

Conform to the structural and materials criteria specified for wet vaults.

8.1.1.8 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).

8.1.1.9 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

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 V - 8.2).

8.1.2.1 Applicability and Limitations

Applicable for all sites requiring oil control.

Without intense maintenance, oil and water separator BMPs may not be sufficiently effective in achieving oil and TPH removal down to the required levels.

8.1.2.2 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.

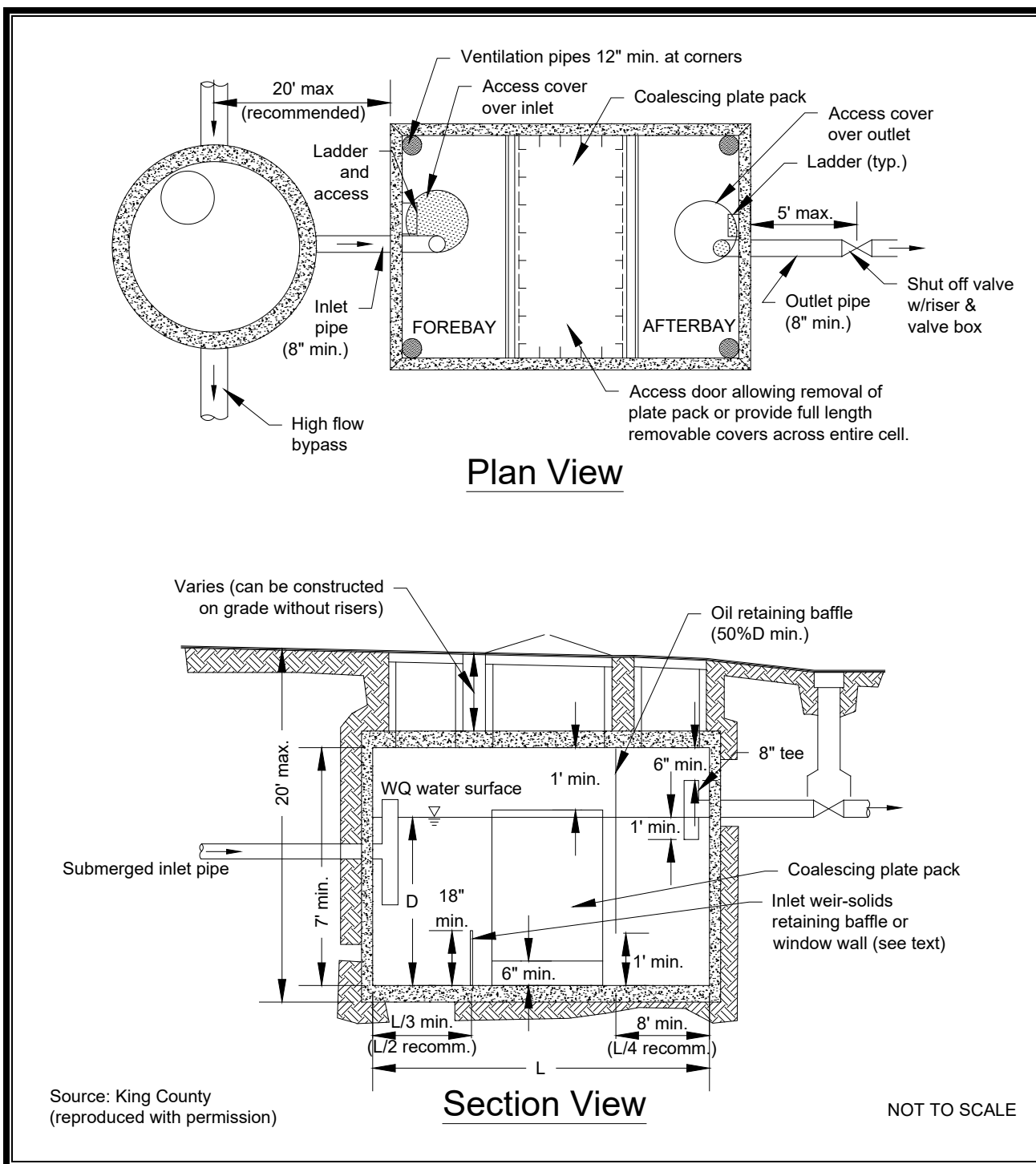
8.1.2.3 Pretreatment

Add pretreatment for total suspended solids that could clog the coalescing plate separator or otherwise impair the long-term effectiveness of the separator.

8.1.2.4 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 V - 5.2 of this volume. If it is necessary to locate the separator on-line, try to minimize the size of the area needing oil control, and use the Water Quality Design Flow Rate multiplied by the ratio indicated in Figure V - 5.1.



8.1.2.4.1 Sizing

Calculate the projected (horizontal) surface area of plates needed using the following equation:

$$A_p = Q/V_t = Q/[(0.00386)*((S_w - S_o)/(\mu_w))]$$

$$A_p = A_a(\cosine b)$$

Where:

Q = k (the ratio appropriate for the project location) indicated by Figure V - 5.1b x the 15- minute off-line water quality design flow rate, ft³/min

V_t = Rise rate of oil droplet = 0.033 ft/min (based on oil droplet of 60 microns), or empirical determination, or Stokes Law based.

A_p = projected surface area of the plate in ft²; 0.00386 is unit conversion constant

S_w = specific gravity of water at the design temperature

S_o = specific gravity of oil at the design temperature

A_a = actual plate area in ft² (one side only)

b = angle of plates with the horizontal in degrees (usually varies from 45-60 degrees).

μ_w = absolute viscosity of water (poise)

The above equation is based on an oil droplet diameter of 60 microns.

8.1.2.5 Design Criteria

8.1.2.5.1 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.

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

Traditional BMPs such as wet ponds and biofiltration swales may not be appropriate in many situations due to size and space restraints or their inability to remove target pollutants. Because of this, the stormwater treatment industry emerged to develop new manufactured treatment devices.

Manufactured treatment devices are emerging technologies that are new to the stormwater treatment marketplace. These devices include both permanent and construction site treatment technologies. Many of these devices have not undergone complete performance testing, so their performance claims cannot be verified..

Ecology has established a program, the Technology Assessment Protocol – Ecology (TAPE), to evaluate the capabilities of manufactured treatment devices. Manufactured treatment devices that have been evaluated by TAPE are approved at some level of use designated under specified conditions. Their use is restricted in accordance with their evaluation as explained in V-10.3 Approval Process for Manufactured Treatment Devices of Ecology's 2019 Stormwater Management Manual for Western Washington. The recommendations for use of individual manufactured treatment devices may change as Ecology collects more data on their performance. Updated recommendations on their use are posted to Ecology's TAPE website at the follow address:

<https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies>

All emerging technology BMPs shall be maintained in accordance with the manufacturer's recommendations and schedules. Owners shall provide the Thurston County Water Resources Division with maintenance logs annually at the end of each calendar year.

9.2 Ecology Role in Evaluating Emerging Technologies

To aid local governments in selecting manufacture treatment devices, Ecology developed the Technology Assessment Protocol – Ecology (TAPE) and Chemical Technology Assessment Protocol – Ecology (CTAPE) protocols. These protocols provide manufacturers with guidance on stormwater monitoring so they may verify their performance claims.

As part of this process Ecology:

- Posts information on manufactured treatment devices at the TAPE website: <https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies>
- Created a Board of External Reviewer (BER) to provide expert review services in the review of Quality Assurance Project Plans (QAPPs) and Technical Evaluation Reports (TERs).
- Created a Stakeholder Advisory Group (SAG) of local stakeholders to advise Ecology on the program protocols and develop new guidance.
- Participates in all activities which include reviewing manufacturer performance data and providing recommendations on use level designations.
- Grants use level designations based on performance and other pertinent data submitted by the manufacturers and vendors.
- Provides oversight and analysis of all submittals to ensure consistency with this manual.

For full details on the TAPE process for evaluating a manufactured treatment device, refer to *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies* (Ecology, 2011).

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 Redevelopments

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:

D.01 Detention Ponds

D.02 Detention Tanks

D.04 Detention Vaults

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.

A-1. 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, suture 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:

$$Q = C A \sqrt{2gh} \quad (\text{equation 4})$$

where: Q = flow (cfs)
 C = coefficient of discharge (0.62 for plate orifice)
 A = area of orifice (ft²)
 h = hydraulic head (ft)
 g = acceleration of gravity (32.2 ft/sec²)

Figure V - A.1 illustrates this simplified application of the orifice equation.

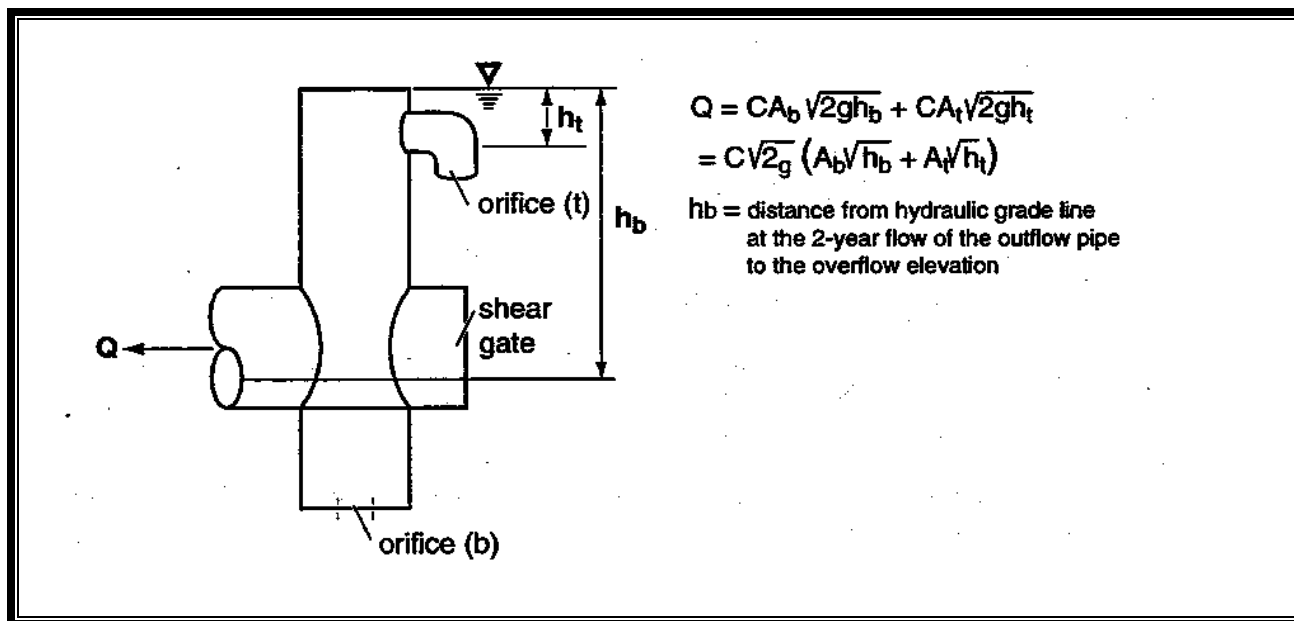


Figure V - A.1 Simple Orifice

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \quad (\text{equation 5})$$

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 V – A.2 may be analyzed using standard weir equations for the fully contracted condition.

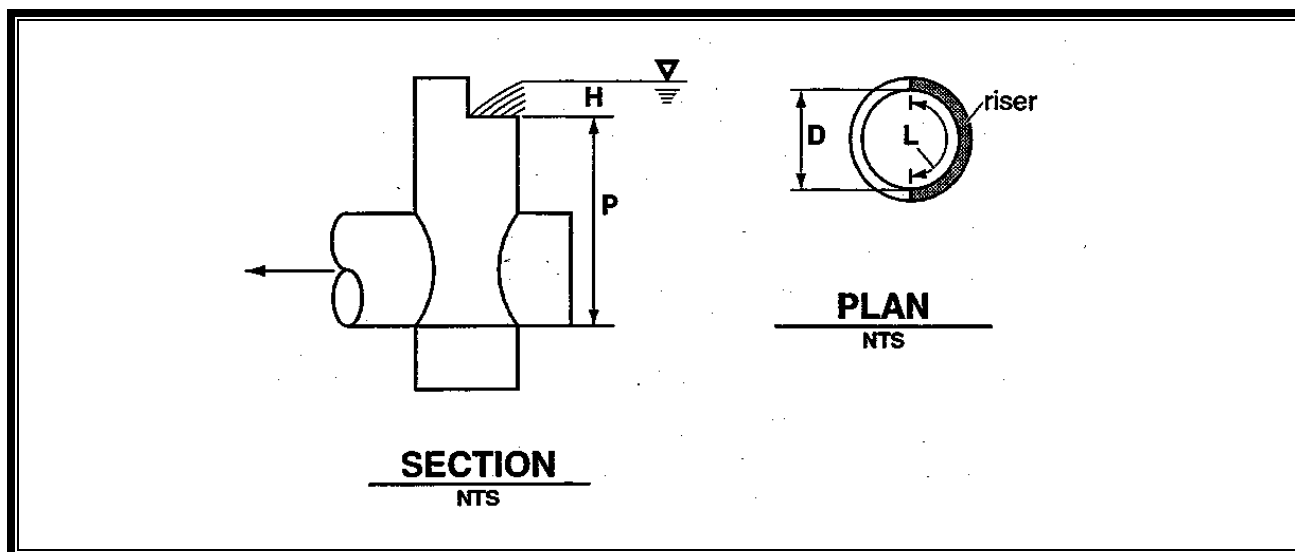


Figure V - A.2 Rectangular, Sharp-Crested Weir

$$Q = C (L - 0.2H) H^{3/2} \quad (\text{equation 6})$$

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 V – A.3 may be analyzed using standard equations for the fully contracted condition.

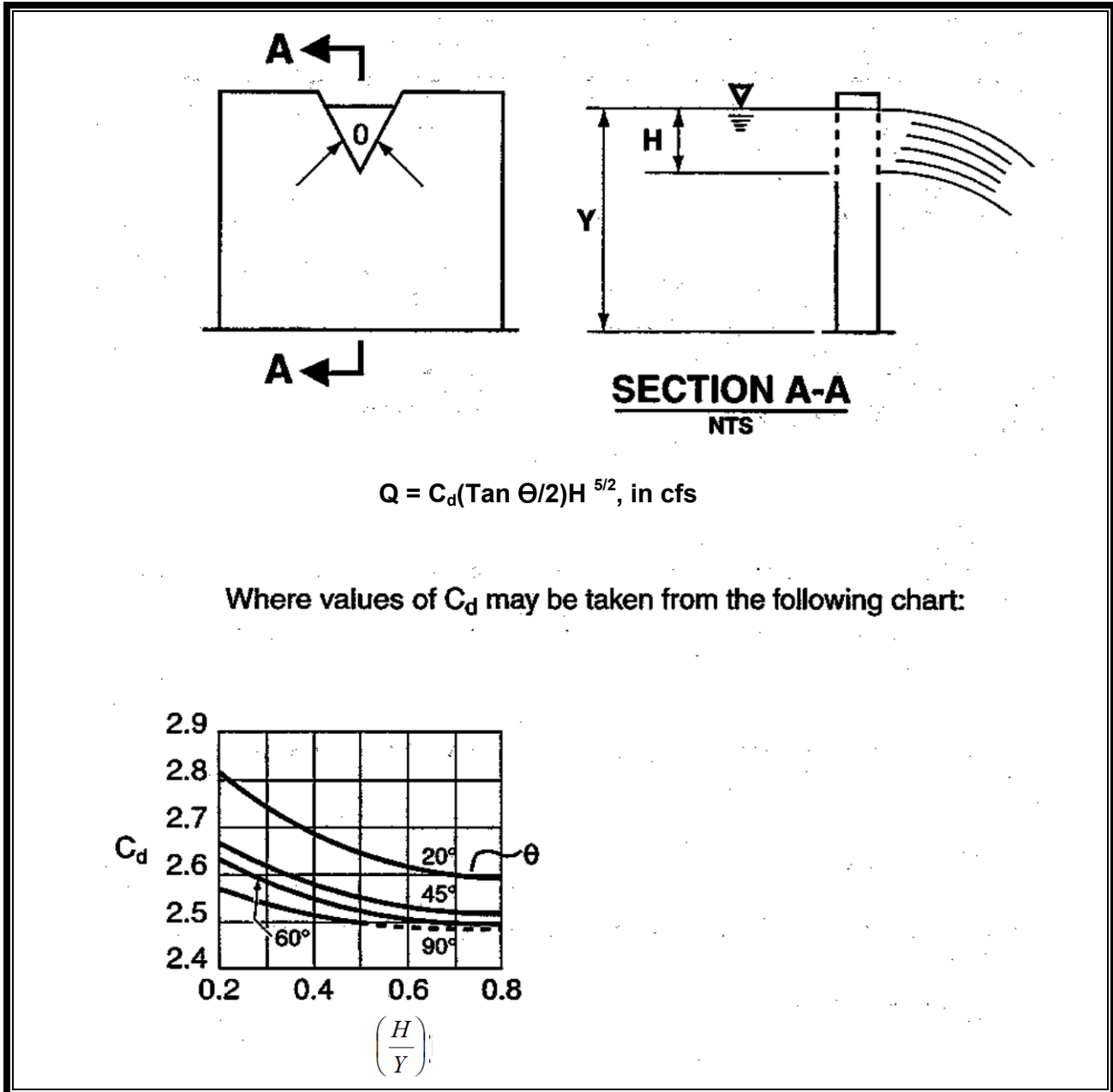


Figure V - A.3 V-Notch, Sharp-Crested Weir

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 V – A.4). The weir may be symmetrical or non-symmetrical.

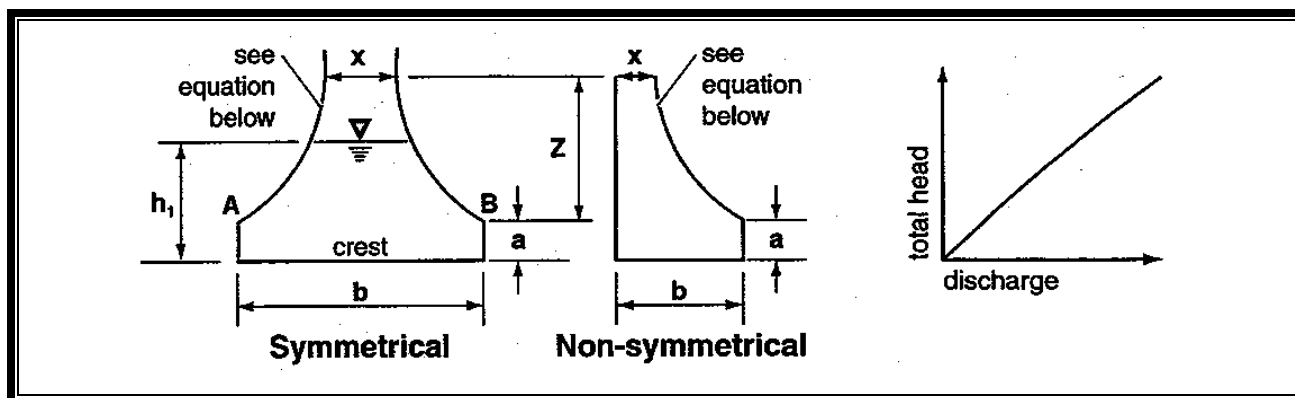


Figure V - A.4 Sutro Weir

For this type of weir, the curved portion is defined by the following equation (calculated in radians):

$$\frac{x}{b} = 1 - \frac{2}{\pi} \tan^{-1} \sqrt{\frac{Z}{a}} \quad (\text{equation 7})$$

where a, b, x and Z are as shown in Figure V - A.4. The head-discharge relationship is:

$$Q = C_d b \sqrt{2ga} \left(h_1 - \frac{a}{3} \right) \quad (\text{equation 8})$$

Values of C_d for both symmetrical and non-symmetrical sutro weirs are summarized in Table V - A.1.

Note: When $b > 1.50$ or $a > 0.30$, use $C_d=0.6$.

Table V - A.1 Values for 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

A-2. Broad-Crested Weir

The equation for flow through a broad-crested weir that is used as a spillway section would be:

$$Q_{100} = C (2g)^{1/2} \left[\frac{2}{3} LH^{3/2} + \frac{8}{15} (\tan \theta) H^{5/2} \right]$$

(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/sec²)
- 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:

$$Q_{100} = 3.21[LH^{3/2} + 2.4 H^{5/2}]$$

(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):

$$L = [Q_{100}/(3.21H^{3/2})] - 2.4 H \text{ or } 6 \text{ feet minimum (equation 3)}$$

Riser Overflow

The nomograph in Figure V – 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 V – A.6 through V – A.8.

A-3. 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 V – A.6 or on a baffle as shown in Figure V – 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 V – 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.

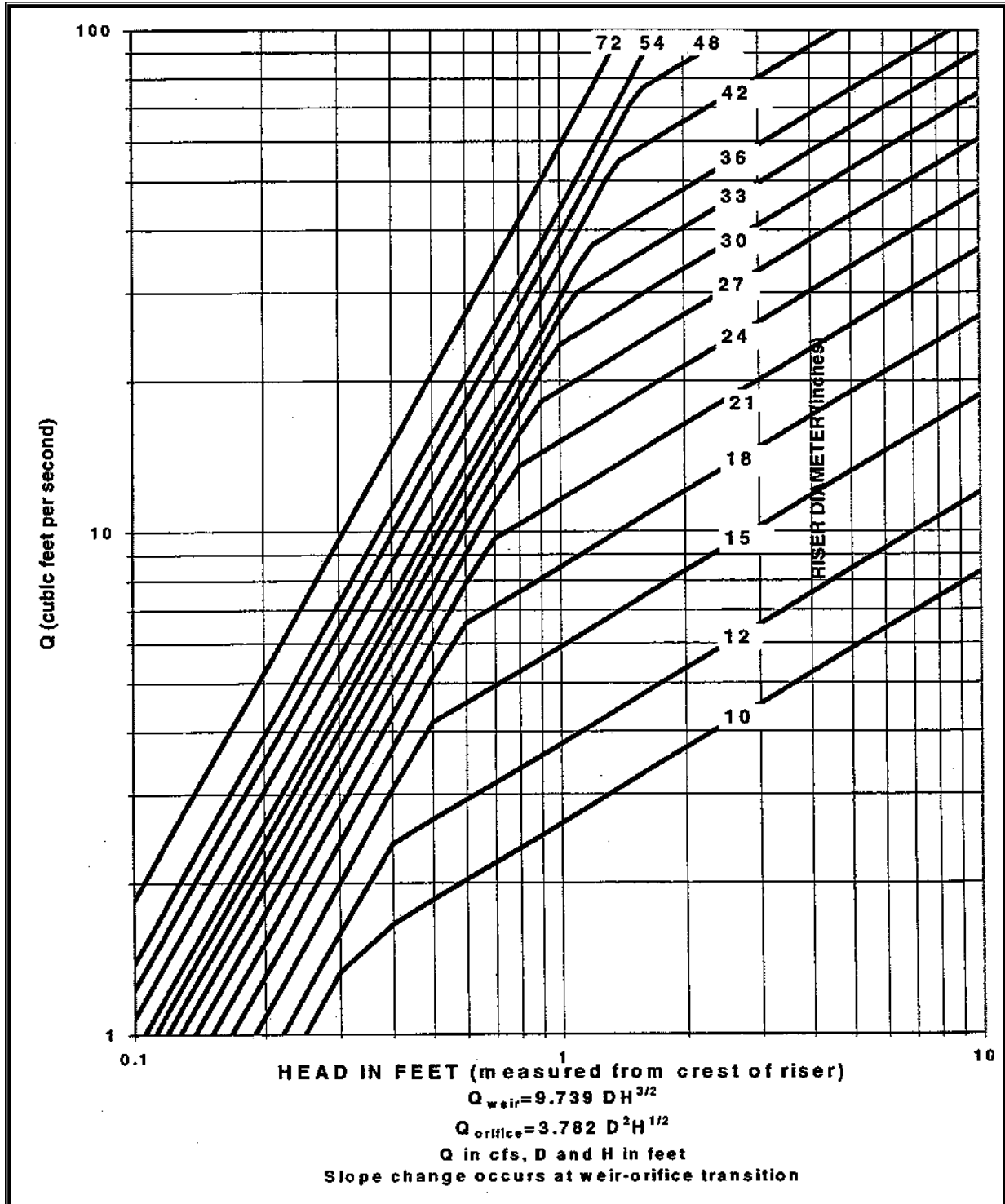


Figure V - A.5 Riser Inflow Curves

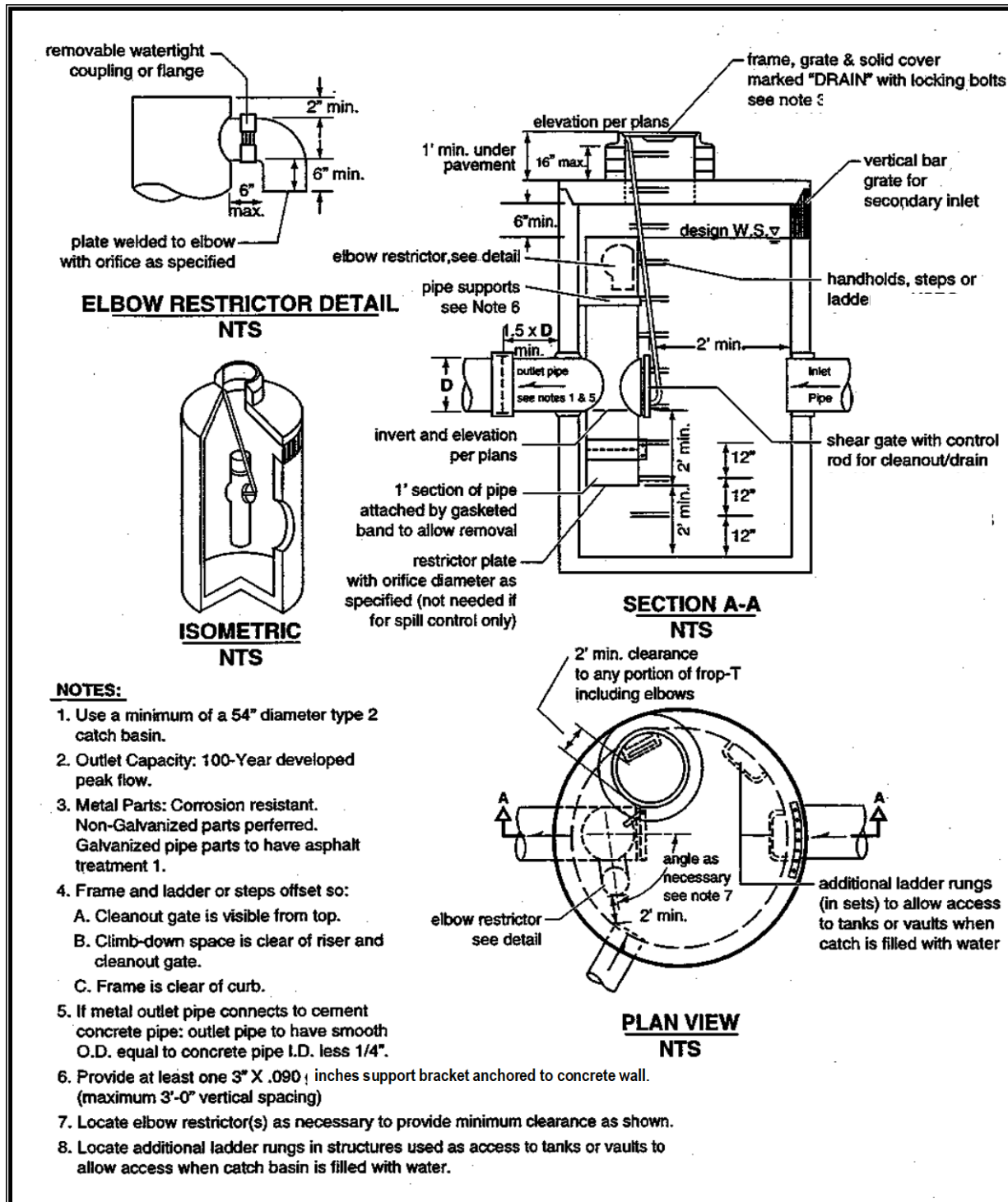


Figure V - A.6 Flow Restrictor (TEE)

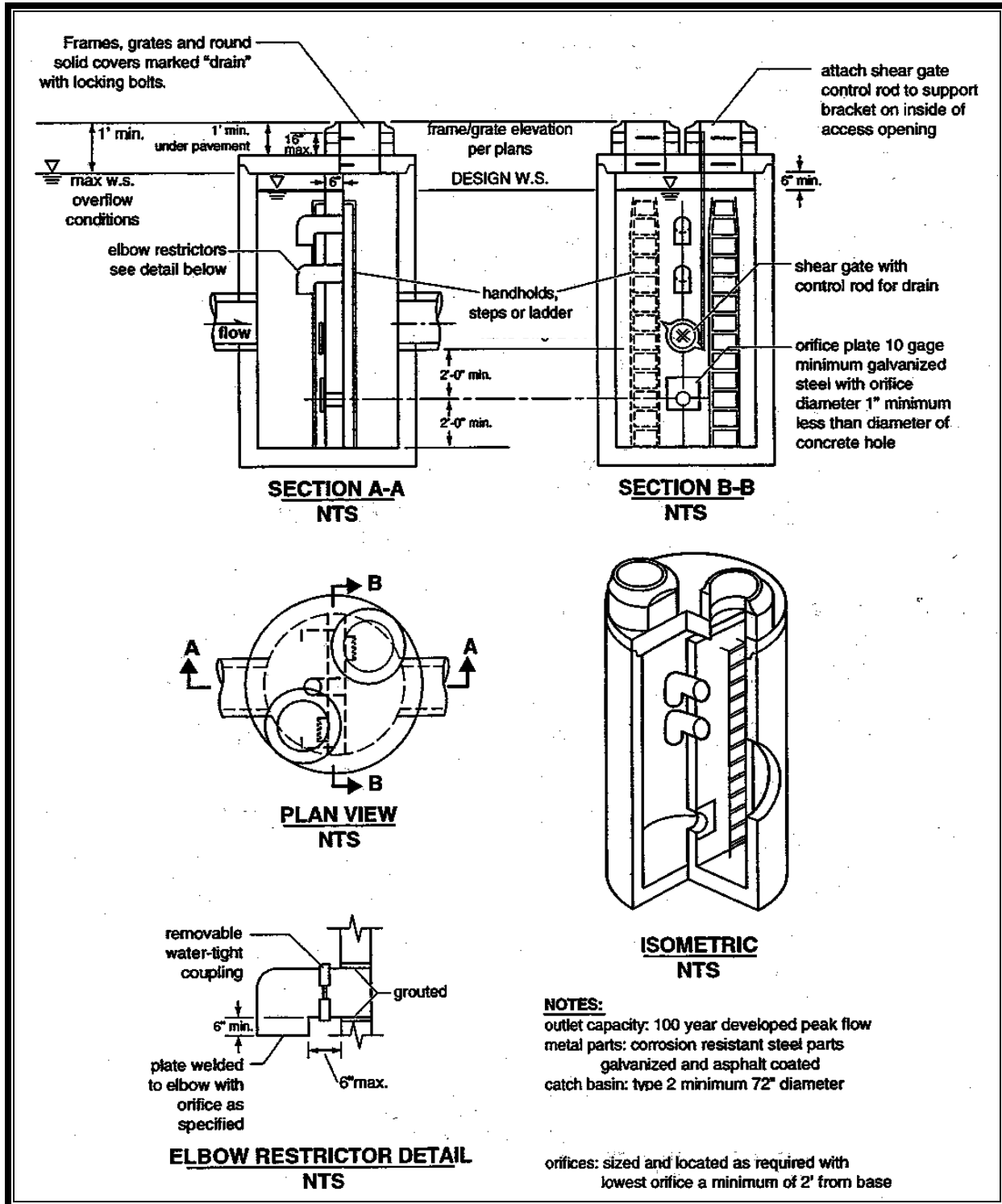


Figure V - A.7 Flow Restrictor (Baffle)

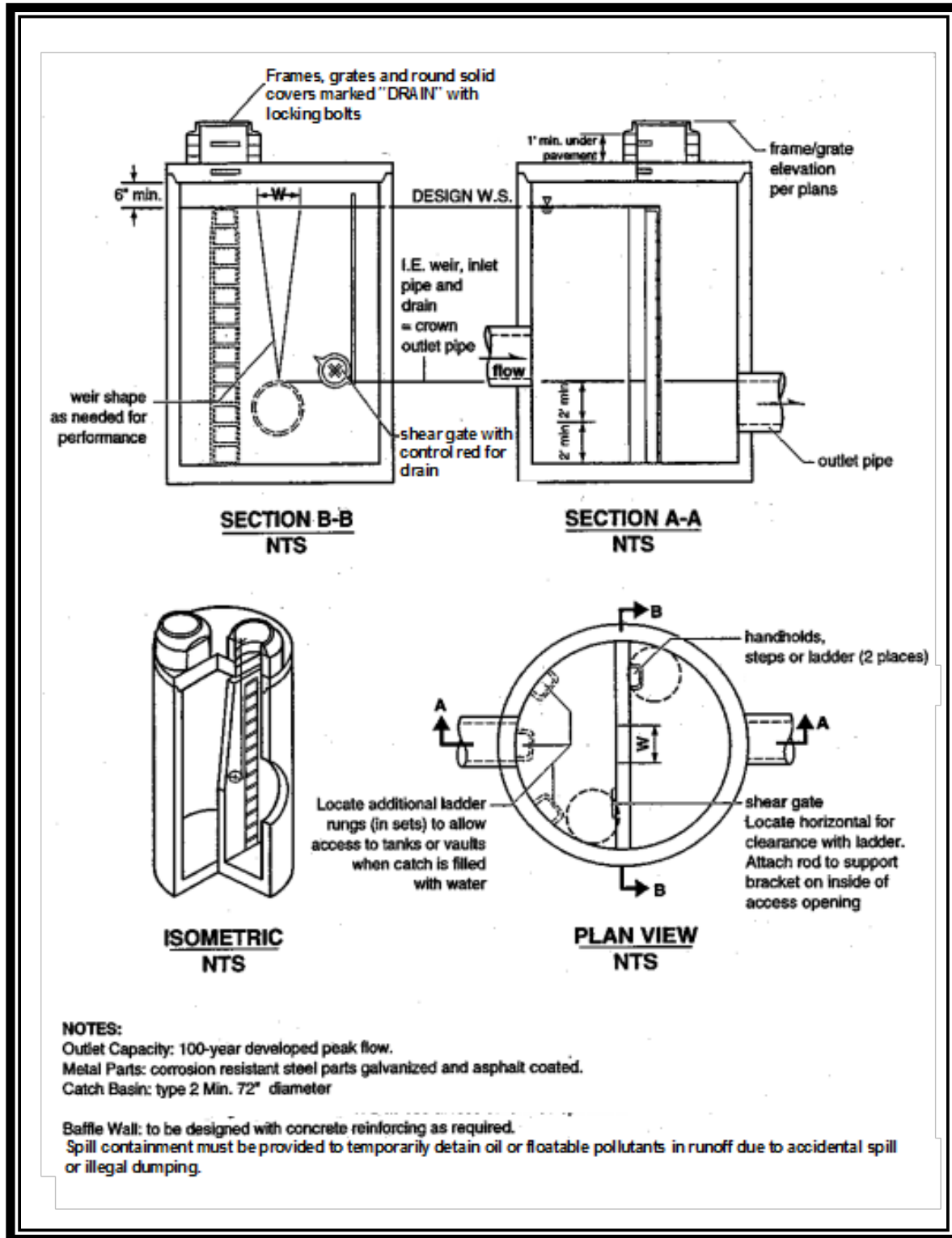


Figure V - A.8 Flow Restrictor (Weir)

A-4. Riser and Weir Restrictor

Properly designed weirs may be used as flow restrictors (see Figure V – 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 V – A.5 can be used to calculate the head in feet above a riser of given diameter and flow.

A-5. 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).

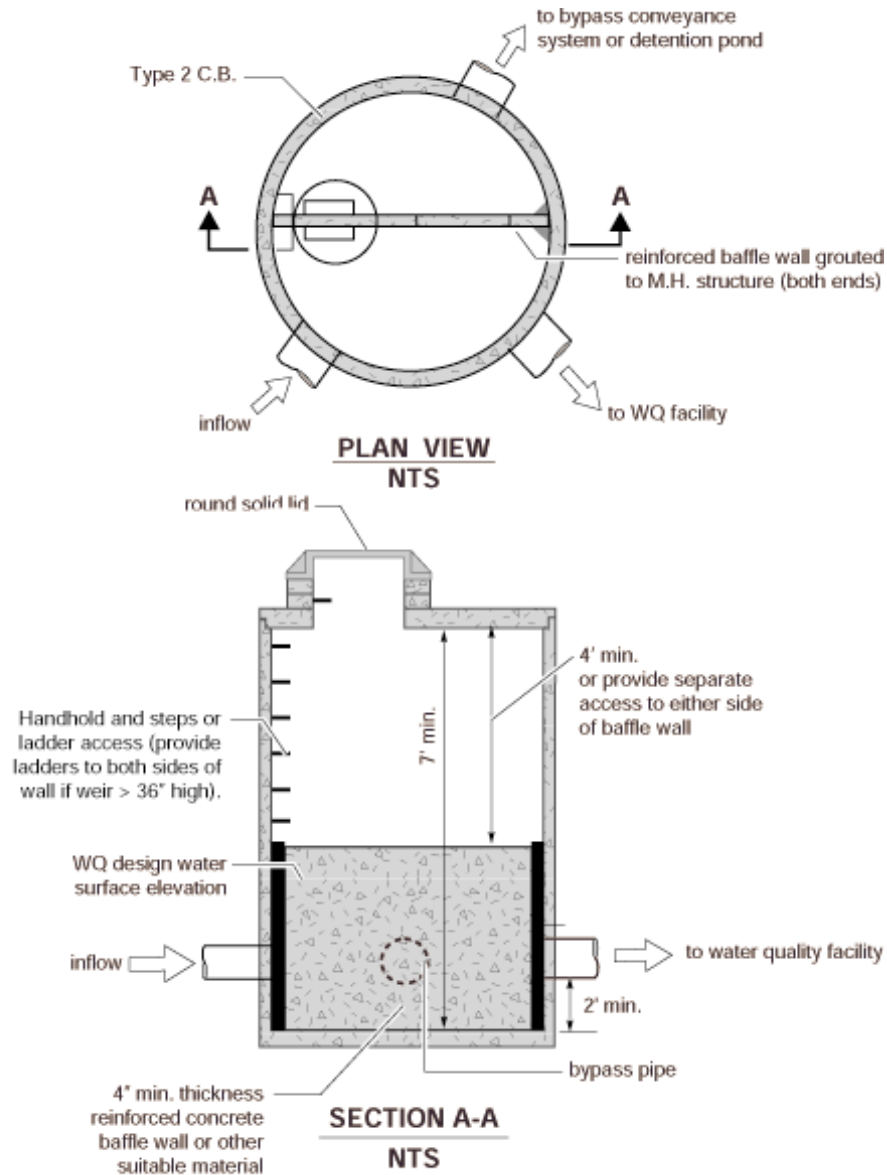
Note: WWHM allows any bypasses and the runoff filtered through the sand to be directed to the downstream detention facility.

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 V - A.9 through V – 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 V - A.3 and V – 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 minimum headwater/diameter ratio of 2.0 on the outlet pipe.

Figure V - A.9 Flow Splitter Option A

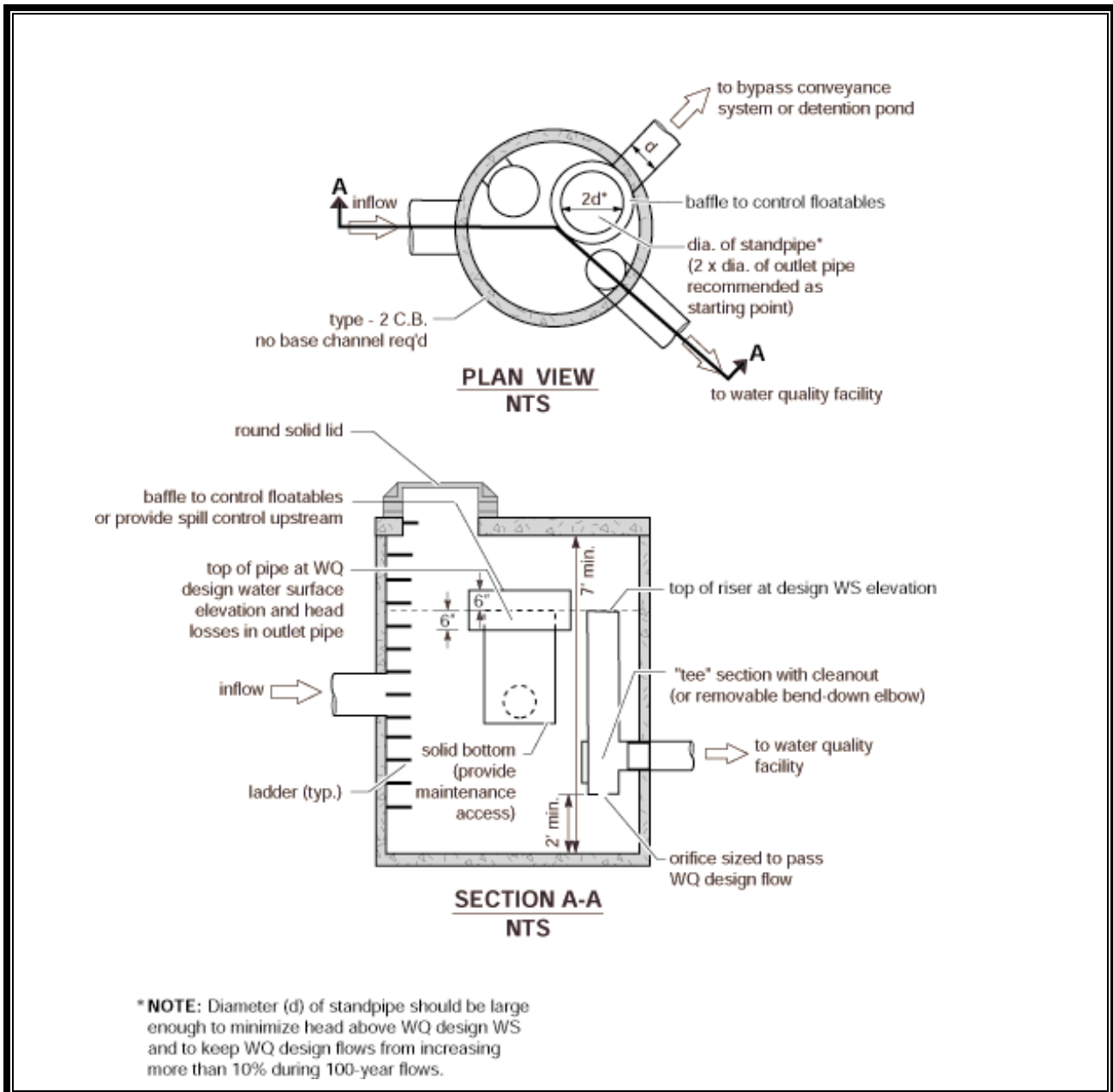


Figure V - A.10 Flow Splitter Option B

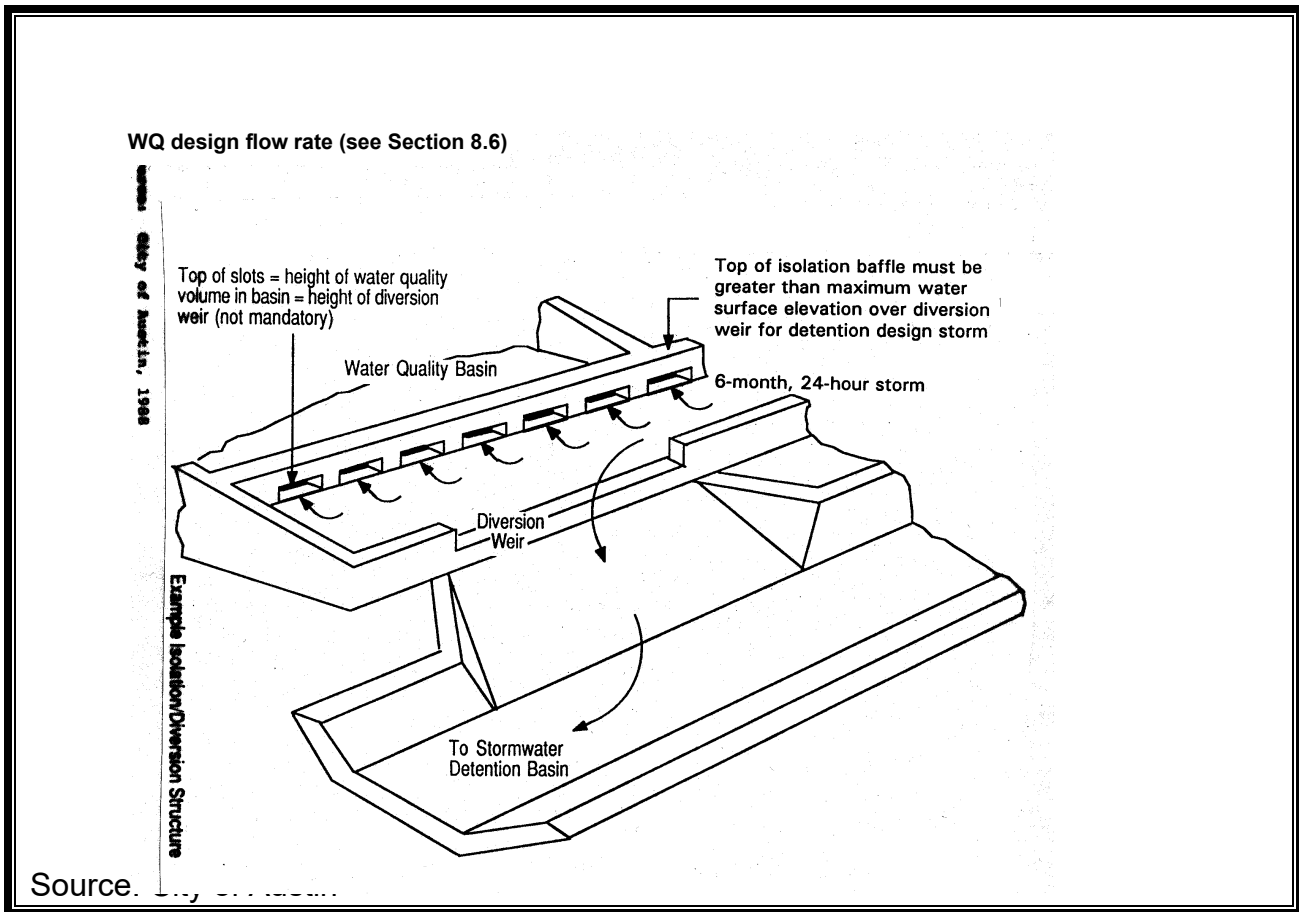


Figure V - A.11 Example Isolation/Diversion Structure

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.

A-6. 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.

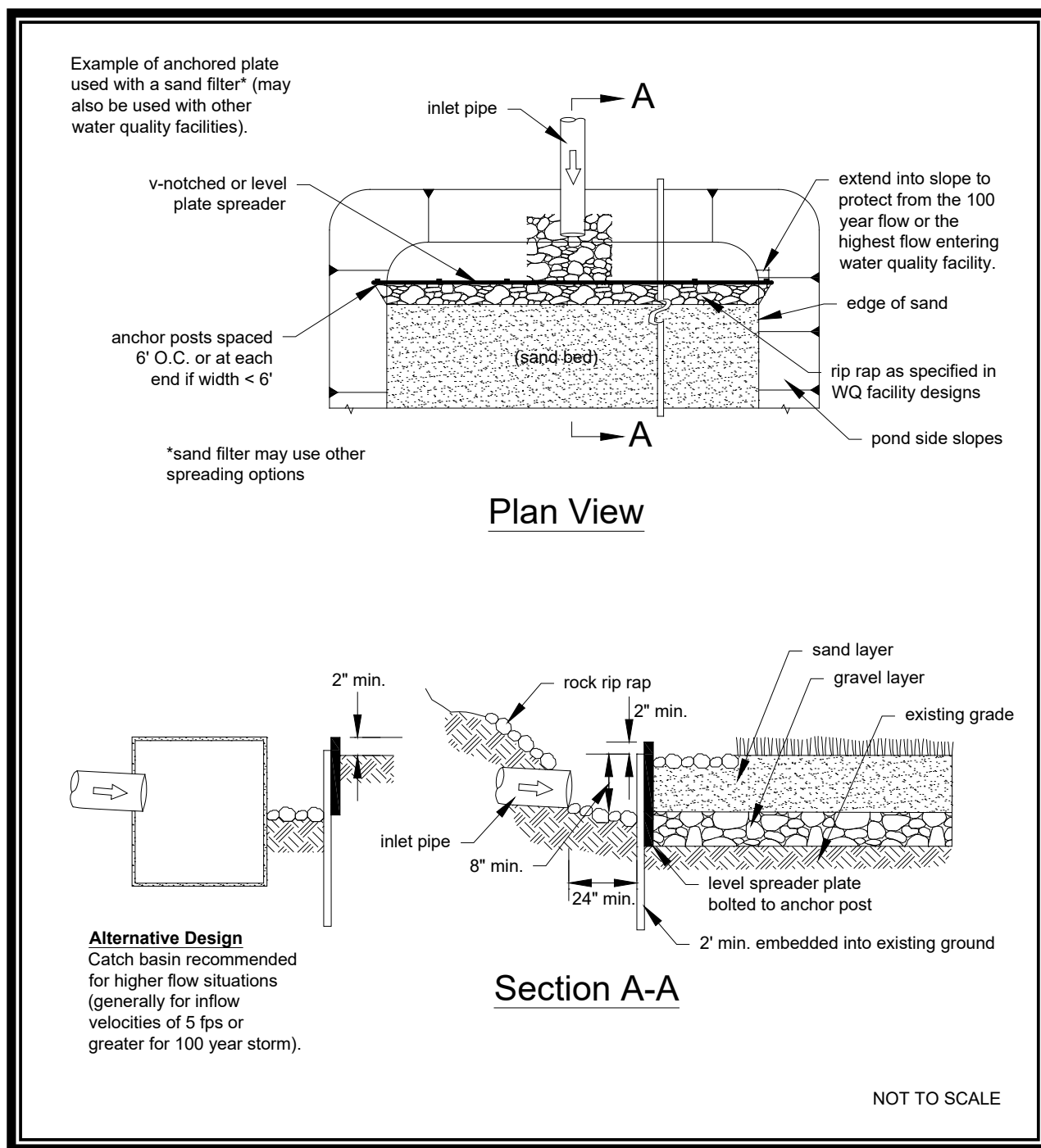


Figure V - A.12 Flow Spreader Option A: Anchored Plate

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.

A-7. Option B – Concrete Sump Box (Figure V - 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.

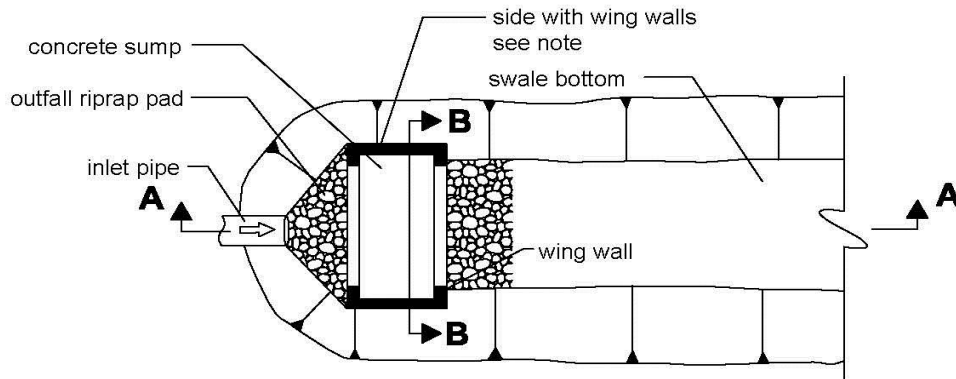
Concrete for a sump box can be either cast-in-place or precast, but the bottom of the sump shall be reinforced with wire mesh for cast-in-place sumps.

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.

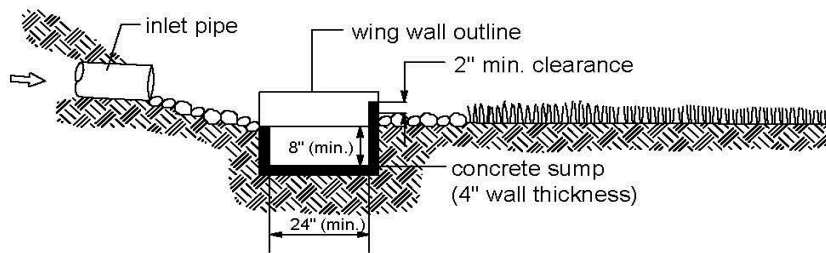
A-8. Option C – Notched Curb Spreader (Figure V - A.14)

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.

Example of a concrete sump flow spreader used with a biofiltration swale (may be used with other VQ facilities).

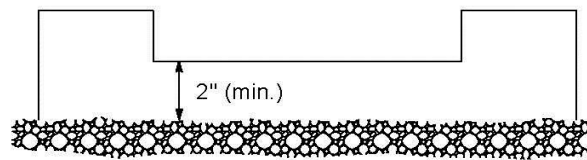


PLAN VIEW
NTS



SECTION A-A
NTS

Note: Extend sides into slope. Height of side wall and wing walls must be sufficient to handle the 100-year flow or the highest flow entering the facility.



SECTION B-B
NTS

Figure V - A.13 Flow Spreader Option B: Concrete Sump Box

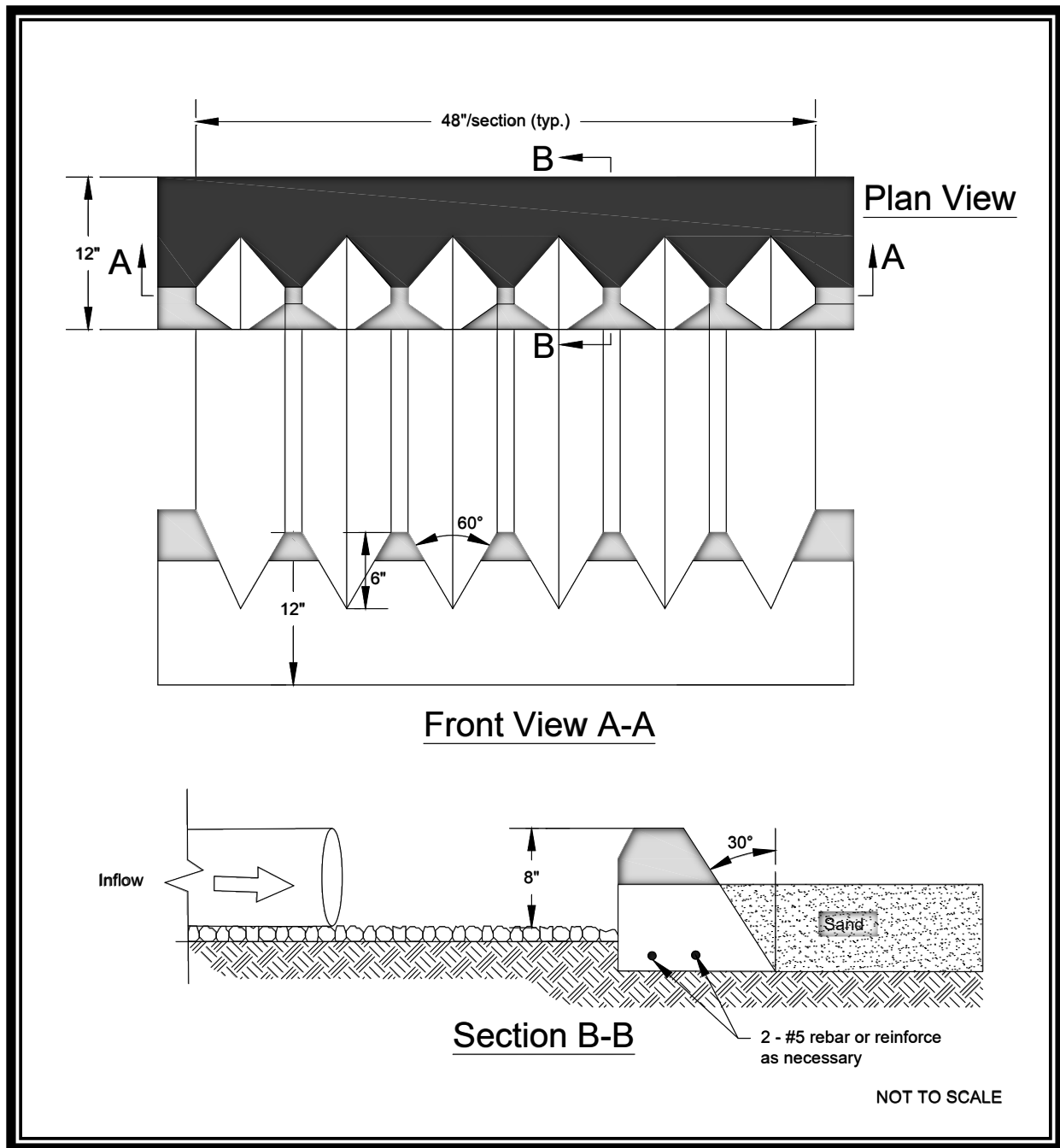


Figure V - A.14 Flow Spreader Option C: Notched Curb Spreader

A-9. 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.

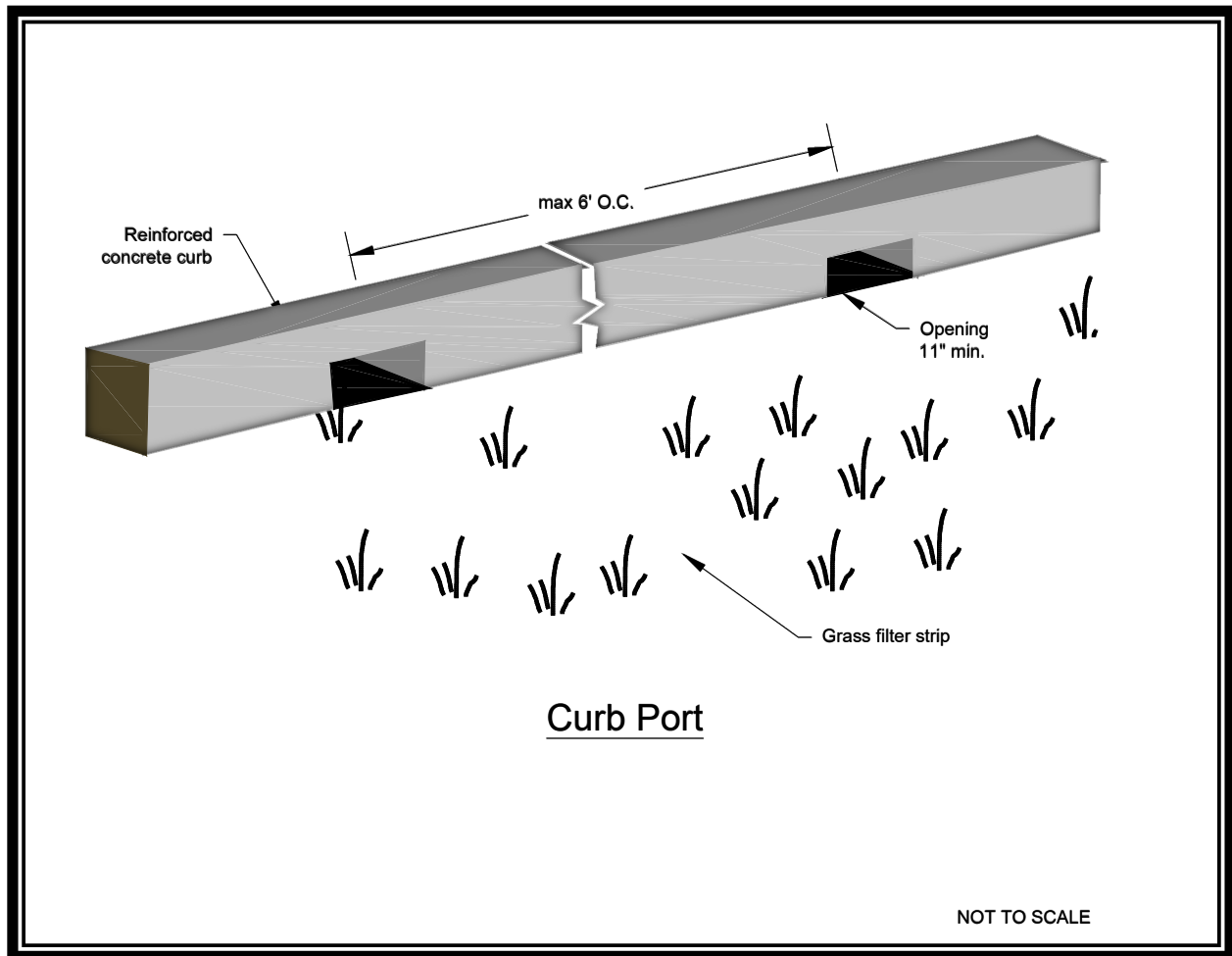


Figure V - A.15 Flow Spreader Option D: Through-Curb Port

A-10. 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.

Treatment liners amend the soil with materials that treat stormwater before it reaches more freely draining soils. They have slow rates of infiltration, generally less than 2.4 inches per hour (1.7×10^{-3} cm/s), but not as slow as low permeability liners. Treatment liners may be in-place native soils or imported soils.

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:

LID.04 Downspout Infiltration Systems

BF.01 Basic Biofiltration Swale

WP.01 Stormwater Treatment Wetlands

WP.02 Wet Ponds

WP.04 Combined Detention and Wet Pool Facilities

WP.05 Presettling Basins and Pretreatment

MF.01 Sand Filter Basin

MF.03 Linear Sand Filter

Liners Design Criteria

Table V - 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 V - 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 V - 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

Treatment Liners

This section presents the design criteria for treatment liners.

A two-foot thick layer of soil with a minimum organic content of 5% AND a minimum cation exchange capacity (CEC) of 5 milliequivalents/100 grams can be used as a treatment layer beneath a water quality or detention facility.

To demonstrate that in-place soils meet the above criteria, one sample per 1,000 square feet of facility area shall be tested. Each sample shall be a composite of subsamples taken throughout the depth of the treatment layer (usually two to six feet below the expected facility invert).

Typically, side wall seepage is not a concern if the seepage flows through the same stratum as the bottom of the treatment BMP. However, if the treatment soil is an engineered soil or has very low permeability, the potential to bypass the treatment soil through the side walls may be significant. In those cases, the treatment BMP side walls

may be lined with at least 18 inches of treatment soil, as described above, to prevent untreated seepage. This lesser soil thickness is based on unsaturated flow as a result of alternating wet-dry periods.

Organic content shall be measured on a dry weight basis using ASTM D2974.

Cation exchange capacity (CEC) shall be tested using EPA laboratory method 9081.

Certification by a soils testing laboratory that imported soil meets the organic content and CEC criteria above shall be provided to Thurston County for acceptance.

Animal manures used in treatment soil layers must be sterilized because of potential for bacterial contamination of the groundwater.

If a treatment liner will be below the seasonal high water level, the pollutant removal performance of the liner must be evaluated by a geotechnical or groundwater specialist and found to be as protective as if the liner were above the level of the groundwater.

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 V - B.2 below:

Table V - 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.

B-1. 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 V - B.3 and V - B.4 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 V - B.5 shall be used to specify survivability properties for the liner protection application. Table V - B.4, 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 V - B.3 and V - B.4 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 V - B.3 Geotextile Properties for Underground Drainage

Geotextile Property Requirements¹			
		Low Survivability	Moderate Survivability
Geotextile Property	Test Method	Woven/Nonwoven	Woven/Nonwoven
Grab Tensile Strength, min. in machine and x-machine direction.	ASTM D4632	180 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	160 lbs/100 lbs min.	220 lbs/140 lbs min.
Puncture Resistance	ASTM D6241	370 lb/220 lbs min.	495 lbs/310 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 V - B.4 Geotextile for Underground Drainage Filtration Properties

Geotextile Property Requirements ¹				
Geotextile Property	Test Method	Class A	Class B	Class C
AOS ²	ASTM D4751	0.43 mm max (#40 sieve)	0.25 mm max (#60 sieve)	0.18 mm max. (#80 sieve)
Water Permittivity	ASTM D4491	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 V - 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 V – B.3 and V – B.4: Section 9-33.2 “Geotextile Properties,” 2016 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.

BMP Maintenance Tables

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.
- (A) 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 are for reference only. The tables to be used as checklists can be downloaded from <https://www.thurstoncountywa.gov/sw/Pages/dm-current-2016.aspx>. Maintenance personnel may use the checklists and check off items inspected and problems noted during each inspection. Actions taken and corrective action recommended should also be noted.

Safety Warning:

Per OSHA regulations and for your safety, you should never stick your head or any part of your body into a manhole, catch basin, vault, or other type of confined space.

NO PART OF YOUR BODY SHOULD BREAK THE PLANE OF THE OPEN HOLE.

#1 – Maintenance Standards for Detention Ponds (BMP D.01):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash and Debris	Any trash and debris, including yard wastes such as grass clipping and tree branches, which exceed five cubic feet per 1,000 square feet. If less than threshold, all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
General	Poisonous Vegetation and Noxious Weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined in the Thurston County Noxious Weeds List . (Apply requirements of adopted integrated pest management policies for the use of herbicides.)	No danger of poisonous vegetation where maintenance personnel or the public might normally be. Noxious and nuisance vegetation removed according to applicable regulations. <i>(Coordinate with Thurston County.) Complete eradication of noxious weeds may not be possible. Compliance with state or local eradication policies required.</i>
General	Contaminants and Pollution	Any evidence of contaminants such as oil, gasoline, concrete slurries, or paint.	No contaminants or pollutants present. <i>(Coordinate source control, removal, and/or cleanup with Thurston County Water Resources 360-754-4681 and/or Dept. of Ecology Spill Response 800-424-8802.)</i>
General	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 removed and dam or berm repaired. <i>(Coordinate with Thurston County; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.)</i>
General	Beaver Dams	Beaver dam results in an adverse change in the functioning of the facility.	Facility is returned to design function. <i>(Contact WDFW Region 6 to identify the appropriate Nuisance Wildlife Control Operator.)</i>
General	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. <i>Apply insecticides in compliance with adopted integrated pest management policies.</i>
General	Tree Growth and Dense Vegetation	Trees growing on pond bottom or side slopes. Tree growth and dense vegetation impedes inspection, maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements).	Trees removed from facility bottom, side slopes, and maintenance access areas. Species removed that are not part of the planting plan.
General	Hazard Trees	If dead, diseased, or dying trees are identified (Use a certified Arborist to determine health of tree or removal requirements).	Hazard trees removed.
General	Performance	Check crest gauge against design expectations (see Maintenance and Source Control Manual).	Reading recorded. County notified if not meeting design performance.
Crest Gauge	Crest Gauge Missing/ Broken	Crest gauge is not functioning properly, has been vandalized, or is missing.	Repair/replace.

#1 – Maintenance Standards for Detention Ponds (BMP D.01):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Side Slopes of Pond	Erosion	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
Side Slopes of Pond	Erosion	Any erosion observed on a compacted berm embankment.	Slopes stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. <i>If erosion is occurring on compacted berms, a professional engineer should be consulted to resolve source of erosion.</i>
Storage Area	Sediment	Accumulated sediment that exceeds 10 percent of the designed pond depth unless otherwise specified or affects facility inlets or outlets.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion. <i>(If sediment contamination is a potential problem, sediment should be tested regularly to determine leaching potential prior to disposal.)</i>
Storage Area	Liner (If Applicable)	Liner is visible and has more than three one-fourth inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Storage Area	Vegetation	Grass cutting unnecessary unless maintaining scotch broom, blackberries, or other nuisance vegetation, or dictated by aesthetics.	Vegetation mowed or nuisance vegetation removed.
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation.	Dike is built back to the design elevation. <i>If settlement is significant, a professional engineer should be consulted to determine the cause of the settlement.</i>
Pond Berms Over 4 ft in height (Dikes)	Tree Growth	Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees on berms removed. <i>If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A professional engineer should be consulted for proper berm/spillway restoration.</i>
Pond Berms (Dikes)	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue.	Piping eliminated. Erosion potential eliminated. <i>Recommend a geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.</i>
Emergency Overflow/ Spillway	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping.	Trees on emergency spillway removed. <i>If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A professional engineer should be consulted for proper berm/spillway restoration.</i>

#1 – Maintenance Standards for Detention Ponds (BMP D.01):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Emergency Overflow/ Spillway	Rock Missing	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of outflow path of spillway.	Rocks and pad depth restored to design standards. (Riprap on inside slopes need not be replaced.)
Emergency Overflow/ Spillway	Erosion	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. <i>If erosion is occurring on compacted berms a professional engineer should be consulted to resolve source of erosion.</i>

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#2 – Maintenance Standards for Infiltration Basins (BMP IN.01) and Trenches (BMP IN.02):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash and Debris	Any trash and debris, including yard wastes such as grass clippings and tree branches, which exceed five cubic feet per 1,000 square feet. If less than threshold, all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
General	Poisonous Vegetation and Noxious Weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined in the Thurston County Noxious Weeds List . (Apply requirements of adopted integrated pest management policies for the use of herbicides.)	No danger of poisonous vegetation where maintenance personnel or the public might normally be. <i>(Coordinate with Thurston County Public Works) Complete eradication of noxious weeds may not be possible. Compliance with state or local eradication policies required.</i>
General	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants, or other pollutants.	No contaminants or pollutants present. <i>(Coordinate removal/cleanup with Thurston County Water Resources 360-754-4681 and/or Dept. of Ecology Spill Response 800-424-8802.)</i>
General	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 removed and dam or berm repaired. <i>(Coordinate with Thurston County; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.)</i>
General	Beaver Dams	Beaver dam results in an adverse change in the functioning of the facility.	Facility returned to design function. <i>(Contact WDFW Region 6 to identify the appropriate Nuisance Wildlife Control Operator)</i>
General	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. <i>Apply insecticides in compliance with adopted integrated pest management policies.</i>
General	Performance	Check crest gauge against design expectations (see Maintenance and Source Control Manual).	Crest gauge results reflect design performance expectations. Reading recorded. County notified if not meeting design performance.
Crest Gauge	Crest Gauge Missing/ Broken	Crest gauge is not functioning properly, has been vandalized, or is missing.	Crest gauge present and functioning. Repair/replace crest gauge if missing or broken.
Storage Area	Water Not Infiltrating	Water ponding in infiltration basin after rainfall ceases and appropriate time allowed for infiltration. Treatment basins should infiltrate Water Quality Design Storm Volume within 48 hours, and empty within 24 hours after cessation of most rain events. (A percolation test pit or test of facility indicates facility is only working at 90 percent of its designed capabilities. If 2 inches or more sediment is present, remove).	Facility infiltrates as designed. Sediment is removed and/or facility is cleaned so that infiltration system works according to design.

#2 – Maintenance Standards for Infiltration Basins (BMP IN.01) and Trenches (BMP IN.02):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Filter Bags (if applicable)	Filled with Sediment and Debris	Sediment and debris fill bag more than one-half full.	Filter bag less than one-half full. Filter bag is replaced or system is redesigned.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rainstorms.	Water flows through filter. Replace gravel in rock filter if needed.
Trenches	Observation Well (Use Surface of Trench if Well is Not Present)	Water ponds at surface during storm events. Less than 90 percent of design infiltration rate.	Remove and replace/clean rock and geomembrane.
Ponds	Vegetation	When grass becomes excessively tall. When nuisance weeds and other vegetation starts to take over.	Vegetation mowed or nuisance vegetation removed so that flow is not impeded. Grass or groundcover mowed to a height of 3 to 4 inches. Removed clippings.
Ponds	Vegetation	Bare spots.	No bare spots. Revegetate and stabilize immediately.
Side Slopes of Pond	Erosion	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. <i>If erosion is occurring on compacted slope, a professional engineer should be consulted to resolve source of erosion.</i>
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works.	Dike is built back to the design elevation. <i>If settlement is significant, a professional engineer should be consulted to determine the cause of the settlement.</i>
Pond Berms (Dikes)	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue.	No water flow through pond berm. Piping eliminated. Erosion potential eliminated. <i>Recommend a geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.</i>
General	Hazard Trees	If dead, diseased, or dying trees are identified.	Hazard trees removed. <i>(Use a certified Arborist to determine health of tree or removal requirements).</i>
General	Tree Growth and Dense Vegetation	Trees growing on pond bottom or side slopes. Tree growth and dense vegetation which impedes inspection, maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements).	Trees removed from facility bottom, side slopes, and maintenance access areas. Species removed that are not part of recorded planting plan. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood).

#2 – Maintenance Standards for Infiltration Basins (BMP IN.01) and Trenches (BMP IN.02):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Pond Berms (Dikes)	Tree Growth	Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees on berms removed. <i>If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A professional engineer should be consulted for proper berm/spillway restoration.</i>
Emergency Overflow/ Spillway	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping.	Trees on emergency spillways removed. <i>If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A professional engineer should be consulted for proper berm/spillway restoration.</i>
Emergency Overflow/ Spillway	Rock Missing	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of out flow path of spillway.	Rocks and pad depth restored to design standards. (Riprap on inside slopes need not be replaced.)
Emergency Overflow/ Spillway	Erosion	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. <i>If erosion is occurring on compacted berms a professional engineer should be consulted to resolve source of erosion.</i>
Presettling Ponds and Vaults	Facility or sump filled with Sediment and/or Debris	6 inches or designed sediment trap depth of sediment.	No sediment present in presettling pond or vault. Sediment is removed.
Drain Rock	Water Ponding	If water enters the facility from the surface, inspect to see if water is ponding at the surface during storm events. If buried drain rock, observe drawdown through observation port or cleanout.	No water ponding on surface during storm events. <i>Clear piping through facility when ponding occurs. Replace rock material/sand reservoirs as necessary. Tilling of subgrade below reservoir may be necessary (for trenches) prior to backfill.</i>

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#3 – Maintenance Standards for Closed Detention Systems (BMP D.02: Detention Tanks, BMP D.03: Detention Vaults):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Storage Area	Plugged Air Vents	One-half of the cross-section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning. Remove blockage or replace air vent if damaged.
Storage Area	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.	All sediment and debris removed from storage area.
Storage Area	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability.)	All joint between tank/pipe sections are sealed.
Storage Area	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10 percent of its design shape. (Review required by engineer to determine structural stability.)	Tank/pipe repaired or replaced to design.
Storage Area	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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.
Storage Area	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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 one-fourth inch wide at the joint of the inlet/outlet pipe. No water or soil entering vault through joints or walls.
Crest Gauge	Crest Gauge Missing/Broken	Crest gauge is not functioning properly, has been vandalized, or is missing.	Crest gauge present and functioning. <i>Repair/replace crest gauge if missing or broken.</i>
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole access cover/ lid is in place and secure.
Manhole	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.
Manhole	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
Manhole	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.

If you are unsure whether a problem exists, please contact Thurston County 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.

#4 – Maintenance Standards for Control Structure/Flow Restrictor:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash and Debris (Includes Sediment)	Material exceeds 25 percent of sump depth or 1 foot below orifice plate.	No trash and debris blocking or potentially blocking control structure orifice.
General	Structural Damage	Structure is not securely attached to manhole wall.	Structure securely attached to wall and outlet pipe.
General	Structural Damage	Structure is not in upright position (allow up to 10 percent from plumb).	Structure in correct position.
General	Structural Damage	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.
General	Structural Damage	Any holes—other than designed holes—in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
Cleanout Gate	Damaged or Missing	Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
Cleanout Gate	Damaged or Missing	Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
Cleanout Gate	Damaged or Missing	Gate is rusted over 50 percent of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
Orifice Plate	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole access cover/ lid is in place and secure.
Manhole	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.
Manhole	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
Manhole	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

Control structures are usually considered a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

#5 – Maintenance Standards for Catch Basins:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	"Dump no pollutants" (or similar) stencil or stamp not visible	Stencil or stamp should be visible and easily read.	Warning signs (e.g., "Dump No Waste-Drains to Stream" or "Only rain down the drain"/ "Puget Sound starts here") painted or embossed on or adjacent to all storm drain inlets.
General	Trash and Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inlet capacity by more than 10 percent.	No trash or debris located immediately in front of catch basin or on grate opening.
General	Trash and Debris	Trash or debris (in the basin) that exceeds 1/3 of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
General	Trash and Debris	Trash or debris in any inlet or outlet pipe blocking more than one-third of its height.	Inlet and outlet pipes free of trash or debris.
General	Trash and Debris	Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
General	Sediment	Sediment (in the basin) that exceeds 1/3 of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe.	No sediment in the catch basin.
General	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than one-fourth inch.	No holes and cracks in the top slab allowing material to run into the basin.
General	Structure Damage to Frame and/or Top Slab	Frame not sitting flush on top slab, i.e., separation of more than three-fourth 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.
General	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.
General	Fractures or Cracks in Basin Walls/ Bottom	Grout fillet has separated or cracked wider than one-half-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.	Pipe is regouted and secure at basin wall.
General	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
General	Vegetation	Vegetation growing across and blocking more than 10 percent of the basin opening.	No vegetation blocking opening to basin.

#5 – Maintenance Standards for Catch Basins:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	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.
General	Contamination and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants.	No contaminants or pollutants present. <i>(Coordinate removal/cleanup with Thurston County Water Resources 360-754-4681 and/or Dept. of Ecology Spill Response 800- 424-8802.)</i>
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is in place and secured.
Catch Basin Cover	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.	Mechanism opens with proper tools.
Catch Basin Cover	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is to keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Grates	Grate Opening Unsafe	Grate with opening wider than seven-eighths of an inch.	Grate opening meets design standards.
Grates	Trash and Debris	Trash and debris that is blocking more than 20 percent of grate surface inletting capacity.	Grate free of trash and debris.
Grates	Damaged or Missing	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance .

#6 – Maintenance Standards for Debris Barriers (e.g., Trash Racks):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash and Debris	Trash or debris that is plugging more than 20 percent of the openings in the barrier.	Barrier cleared to receive design flow capacity.
General	Damaged/Missing Bars	Bars are bent out of shape more than 3 inches.	Bars in place with no bends more than three-fourth inch.
General	Damaged/Missing Bars	Bars are missing or entire barrier missing.	Bars in place according to design.
General	Damaged/Missing Bars	Bars are loose and rust is causing 50 percent deterioration to any part of barrier.	Barrier replaced or repaired to design standards.
General	Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe.	Barrier firmly attached to pipe.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance .

#7 – Maintenance Standards for Energy Dissipaters:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
External:			
Rock Pad	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil.	Rock pad replaced to design standards.
Rock Pad	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad replaced to design standards.
Dispersion Trench	Pipe Plugged with Sediment	Accumulated sediment that exceeds 20 percent of the design depth.	Pipe cleaned/flushed so that it matches design.
Dispersion Trench	Not Discharging Water Properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a "sheet flow" of water along trench). Intent is to prevent erosion damage.	Water discharges from feature by sheet flow. Trench redesigned or rebuilt to standards.
Dispersion Trench	Perforations Plugged	Over one-half of perforations in pipe are plugged with debris and sediment.	Perforations freely discharge flow. Perforated pipe cleaned or replaced.
Dispersion Trench	Water Flows Out Top of "Distributor" Catch Basin	Water flows out of distributor catch basin during any storm less than the design storm or is causing or appears likely to cause damage.	No flow discharges from distributor catch basin. Facility rebuilt or redesigned to standards.
Dispersion Trench	Receiving Area Over-Saturated	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Internal:			
Manhole/ Chamber	Worn or Damaged Post, Baffles, Side of Chamber	Structure dissipating flow deteriorates to one-half of original size or any concentrated worn spot exceeding 1 square foot which would make structure unsound.	Structure in no danger of failing. Structure replaced to design standards if needed.
Manhole/ Chamber	Trash and Debris	Trash or debris (in the basin) that exceeds 1/3 of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
Manhole/ Chamber	Trash and Debris	Trash or debris in any inlet or outlet pipe blocking more than one-third of its height.	Inlet and outlet pipes free of trash or debris.
Manhole/ Chamber	Trash and Debris	Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
Manhole/ Chamber	Sediment	Sediment (in the basin) that exceeds 1/3 of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe.	No sediment in the catch basin.

#7 – Maintenance Standards for Energy Dissipaters:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Manhole/ Chamber	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than one-fourth inch.	No holes and cracks in top slab allowing material to run into the basin.
Manhole/ Chamber	Structure Damage to Frame and/or Top Slab	Frame not sitting flush on top slab, i.e., separation of more than three-fourth 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.
Manhole/ Chamber	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.
Manhole/ Chamber	Fractures or Cracks in Basin Walls/ Bottom	Grout fillet has separated or cracked wider than one-half-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.	Pipe is regouted and secure at basin wall.
Manhole/ Chamber	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
Manhole/ Chamber	Contamination and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants.	No contaminants or pollutants present. <i>(Coordinate removal/cleanup with Thurston County Water Resources 360-754-4681 and/or Dept. of Ecology Spill Response 800- 424-8802.)</i>
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is closed.
Catch Basin Cover	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.	Mechanism opens with proper tools.
Catch Basin Cover	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is to keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#8 – Maintenance Standards for Basic (BMP BF.01) and Compost-Amended Biofiltration Swales (BMP BF.05):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches or inhibits vegetation growth in 10 percent or more of swale.	No sediment deposits in treatment area of the biofiltration swale. Remove sediment deposits on grass treatment area of the swale. 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.
General	Standing Water	When water stands in the swale between storms and does not drain freely.	Swale drains freely and no standing water in swale between storms. <i>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.</i>
General	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Spreader leveled and cleaned and flow spread evenly over entire swale width.
General	Constant Base Flow	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.	Base flow removed from swale by a low-flow pea-gravel drain the length of the swale, or by-passed around the swale.
General	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10 percent of the swale bottom.	Swale has no bare spots and grass is thick and healthy. <i>If grass growth is poor, determine and address the cause. 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.</i>
General	Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and other vegetation starts to take over.	Vegetation mowed or nuisance vegetation removed so that flow not impeded. <i>Grass mowed to a height of 3 to 4 inches. No grass clippings left in swale.</i>
General	Excessive Shading	Grass growth is poor because sunlight does not reach swale.	Over-hanging limbs trimmed back and brushy vegetation on adjacent slopes removed.
General	Inlet/Outlet	Inlet/outlet areas impacted by sediment, vegetation, and/or debris.	Inlet and outlet areas clear of sediment, vegetation, and debris.
General	Trash and Debris Accumulation	Trash and debris accumulated in the bioswale.	Leaves, litter, and oily materials removed as needed. Curb cuts and level spreaders cleaned as needed.

#8 – Maintenance Standards for Basic (BMP BF.01) and Compost-Amended Biofiltration Swales (BMP BF.05):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	No eroded or scoured areas in biofiltration swale. Cause of erosion or scour addressed. <i>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.</i>

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#9 – Maintenance Standards for Wet Biofiltration Biofiltration Swales (BMP BF.02) and Continuous Inflow Biofiltration Swales (BMP BF.03):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Sediment Accumulation	Sediment depth exceeds 2 inches in 10 percent of the swale treatment area.	No sediment deposits in treatment area.
General	Water Depth	Water not retained to a depth of about 4 inches during the wet season.	Water depth of four inches throughout swale for most of wet season. Build up or repair outlet berm so that water is retained in the wet swale.
General	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.	Wetland vegetation fully covers bottom of swale. Cause of lack of vigor of vegetation addressed. Replant as needed. <i>No cattails or nuisance vegetation present. 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.</i>
General	Inlet/Outlet	Inlet/outlet area impacted by sediment, vegetation, and/or debris.	Inlet and outlet areas clear of sediment, vegetation, and debris.
General	Trash and Debris Accumulation	Any trash and debris which exceed one cubic foot per 1,000 square feet. If less than threshold, all trash and debris will be removed as part of next scheduled maintenance.	No trash and debris present. Any trash and debris removed from wet swale.
General	Erosion/Scouring	Swale has eroded or scoured due to flow channelization, or higher flows.	No eroded or scoured areas in biofiltration swale. <i>Cause of erosion or scour addressed, Design flows checked to assure swale is large enough to handle flows. Excess flows are bypassed or swale enlarged. Eroded areas replanted with fibrous-rooted plants such as Juncus effusus (soft rush) in wet areas or snowberry (Symphoricarpos albus) in dryer areas.</i>

If you are unsure whether a problem exists, please contact Thurston County for technical assistance

#10 – Maintenance Standards for Filter Strips (BMP BF.04: Basic Filter Strip, BMP BF.05: Compost-Amended Vegetated Filter Strip (CAVFS):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	No sediment deposits in treatment areas. Slope re-leveled to be even and pass flows evenly through strip.
General	Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and other vegetation starts to take over.	Grass is healthy and nuisance vegetation controlled such that flow not impeded. Grass should be mowed to a height between 3-4 inches.
General	Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	No trash or debris present. Any trash and debris removed from filter.
General	Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	No eroded or scoured areas, cause of erosion or scour addressed. <i>For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel (basic filter strip) or a 50/50 mixture of crushed gravel and compost (CAVFS). 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.</i>
General	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Flows are spread evenly over entire filter width. Spreader is level and clean.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance .

#11 – Maintenance Standards for Wet Ponds (BMP WP.02):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Water level	First cell is empty, does not hold water.	Water retained in first cell for most of the year. <i>Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.</i>
	Trash and Debris	Accumulation that exceeds one cubic foot per 1,000 square feet of pond area.	No trash or debris on site. Any trash and debris removed from pond.
	Vegetation	When nuisance weeds and other vegetation take over. Cattail covers more than 25% of the pond.	Vegetation mowed or nuisance vegetation removed so that flow is not impeded.
	Tree Growth	Trees growing in pond bottom or side slopes. Tree growth and dense vegetation which impedes inspection, maintenance access, or interferes with maintenance activity (e.g., slope mowing, silt removal, vactoring, or equipment movements).	Trees removed from facility bottom, side slopes, and maintenance access areas.
	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Sediment Accumulation in Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6 inches, usually in the first cell.	Sediment removed from pond bottom. <i>(If sediment contamination is a potential problem, sediment should be tested regularly to determine leaching potential prior to disposal.)</i>
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. <i>If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.</i>
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom that exceeds 6 inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Settlement of Pond Dike/Berm	Any part of these components that has settled 4 inches or lower than the design elevation, or inspector determines dike/berm is unsound.	Dike/berm is repaired to specifications.
	Internal Berm	Berm dividing cells should be level.	Berm surface is leveled so that water flows evenly over entire length of berm.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#12 – Maintenance Standards for Wet Vaults (BMP WP.03):

Drainage System Feature	Problem	Conditions to Check For	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet/outlet (includes floatables and non-floatables).	No trash or debris present. Any trash and debris removed from vault.
General	Sediment Accumulation in Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment in vault. <i>(If sediment contamination is a potential problem, sediment should be tested regularly to determine leaching potential prior to disposal.)</i>
General	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
General	Access Cover Damaged/Not Working	Cover cannot be opened or removed, especially by one person.	Pipe repaired or replaced to proper working specifications.
General	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).
Vault Structure	Damage – Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	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.
Vault Structure	Damage – Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half-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 one-fourth inch at the joint of the inlet/outlet pipe.
Vault Structure	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection staff.	Baffles repaired or replaced to specifications.
Access Ladder	Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracks and/or misaligned. Confined space warning sign missing.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel. Replace sign warning of confined space entry requirements.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

A vault is a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

#13 – Maintenance Standards for Sand Filters (BMP MF.01: Sand Filter Basin, BMP MF.02: Sand Filter Vault, BMP MF.03: Linear Sand Filter):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Above ground (open sand filter)	Sediment and Silt Accumulation On Top Layer	Sediment and silt depth exceeds one-half inch over 10 percent of surface area of sand filter.	No sediment deposit on grass layer of sand filter that would impede permeability of the filter section. Silt scraped off during dry periods using steel rakes or other devices. Surface layer of the media striated.
Above ground (open sand filter)	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	No trash or debris present. Any trash and debris removed from sand filter bed.
Above ground (open sand filter)	Sediment/ Debris in Cleanouts	When the cleanouts become full or partially plugged with sediment and/or debris.	No sediment or debris present. Any sediment and debris removed from cleanouts and/or drainpipes.
Above ground (open sand filter)	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, flow through the overflow pipes occurs frequently, or hydraulic conductivity is less than 1 inch per hour.	Sand filter infiltrates as designed. Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging and influent suspended solids loads (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material). <i>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.</i>
Above ground (open sand filter)	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.
Above ground (open sand filter)	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. No leaks in the cleanouts or underdrains.
Above ground (open sand filter)	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.
Above ground (open sand filter)	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
Above ground (open sand filter)	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.
Above ground (open sand filter)	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 for technical assistance.

#14 – Maintenance Standards for Sand Filters (BMP MF.01: Sand Filter Basin, BMP MF.02: Sand Filter Vault, BMP MF.03: Linear Sand Filter):

Drainage System Feature	Problem	Conditions to Check For	Results Expected When Maintenance is Performed
Below Ground Vault	Sediment and Silt Accumulation on Top Layer	Sediment and silt depth exceeds one-half inch.	No sediment deposits on grass layer of sand filter that would impede permeability of the filter section. Silt scraped off during dry periods using steel rakes or other devices. Surface layer of the media striated.
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.
Below Ground Vault	Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	No trash or debris present. Any trash and debris removed from vault and inlet/outlet piping.
Below Ground Vault	Sediment in Drain Pipes/Cleanouts	When drain pipes, cleanouts become full with sediment and/or debris.	No sediment or debris present. Any sediment and debris removed from cleanouts and/or drainpipes.
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, and/or hydraulic conductivity is less than 1 inch per hour.	Sand filter infiltrates as designed. Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging and influent suspended solids loads (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material). <i>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.</i>
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. No leaks in the cleanouts or underdrains.
Below Ground Vault	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
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.
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).
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.

#14 – Maintenance Standards for Sand Filters (BMP MF.01: Sand Filter Basin, BMP MF.02: Sand Filter Vault, BMP MF.03: Linear Sand Filter):

Drainage System Feature	Problem	Conditions to Check For	Results Expected When Maintenance is Performed
Below Ground Vault	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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.
Below Ground Vault	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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 one-fourth inch at the joint of the inlet/outlet pipe.
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.
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 for technical assistance.

A below ground enclosed sand filter is a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

#15 – Maintenance Standards for Manufactured Media Filters:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Media filter vault	Sediment Accumulation on Top of Filter Cartridges	Sediment accumulation exceeds 0.25 inches on top of cartridges.	No sediment deposits on top of cartridges. Sediment on cartridges likely indicates that cartridges are plugged and require maintenance.
Media filter vault	Sediment Accumulation in Vault	Sediment accumulation in vault exceeds 6 inches. Look for other indicators of clogged cartridges or overflow.	No sediment accumulation in vault. <i>Sediment in vault should be removed. Cartridges should be checked and replaced or serviced as needed.</i>
Media filter vault	Trash and Floatable Debris Accumulation	Trash and floatable debris accumulation in vault.	No trash or other floatable debris in filter vault.
Media filter vault	Filter Cartridges Submerged	Filter vault does not drain within 24 hours following storm. Look for evidence of submergence due to backwater or excessive hydrocarbon loading.	Filter media checked and replaced if needed. <i>If cartridges are plugged with oil additional treatment or source control BMP may be needed.</i>
Forebay	Sediment Accumulation	Sediment accumulation exceeds 6 inches or one-third of the available sump.	Sediment accumulation less than 6 inches.
Forebay	Trash and Floatable Debris Accumulation	Trash and/or floatable debris accumulation.	No trash or other floatable debris accumulation in forebay. Trash and/or floatable debris should be removed during inspections. <i>Significant oil accumulation may indicate the need for additional treatment or source control.</i>
Drain Pipes/Cleanouts	Sediment in Drain Pipes/Cleanouts	Accumulated sediment that exceeds 20 percent of the diameter.	No sediment or debris in drainpipes or cleanouts. Sediment and debris removed.
Below ground vault	Access cover Damaged/ Not working	One maintenance person cannot remove lid after applying 80 pounds of lift, corrosion or deformation of cover.	Cover repaired to proper working specifications or replaced.
Below ground vault	Damaged Pipes	Any part of the pipes are crushed or damaged due to corrosion and/or settlement.	Pipe repaired or replaced.
Below ground vault	Vault Structure Has Cracks in Wall, Bottom, and Damage to Frame and/or Top Slab.	Cracks wider than one-half 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 repaired or replaced so that vaults meets design specifications and is structurally sound.
Below ground vault	Vault Structure has Cracks in Wall, Bottom, and Damage to Frame and/or Top Slab.	Cracks wider than 0.5 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 0.25 inch at the joint of inlet/outlet pipe.
Below ground vault	Baffles	Baffles corroding, cracking, warping, and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to design specifications.

#15 – Maintenance Standards for Manufactured Media Filters:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Below ground vault	Ladder Rungs Unsafe	Maintenance person judges that ladder is unsafe due to missing rungs, misalignment, rust, or cracks. Ladder must be fixed or secured immediately.	Ladder meets design standards and allows maintenance persons safe access.
Below Ground Cartridge Type	Media	Drawdown of water through the media takes longer than 1 hour, and/or overflow occurs frequently.	Media cartridges replaced.
Below Ground Cartridge Type	Short Circuiting	Flows do not properly enter filter cartridges.	Filter cartridges replaced.

Also check Department of Ecology website and refer to manufacturer guidelines for updates to O&M requirements.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

A vault is a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

#16 – Maintenance Standards for Baffle Oil/Water Separators (BMP OW.01) (American Petroleum Institute [API] Type):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Effluent Water Quality	Inspection of Discharge Water for Obvious Signs of Poor Water Quality	Floating oil in excess of 1 inch in first chamber, any oil in other chambers or effluent, or other contaminants of any type in any chamber.	No contaminants present other than a surface oil film. Effluent discharge from vault should be clear without thick visible sheen.
Structure	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth.	No sediment deposits on vault bottom that would impede flow through the vault and reduce separation efficiency.
General	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
General	Oil Accumulation	Oil accumulations that exceed 1 inch, at the surface of the water or 6 inches of sludge in the sump.	No visible oil depth on water. <i>Extract oil/sludge from vault by vactoring. Disposal in accordance with state and local rules and regulations.</i>
Structure	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
Structure	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
Structure	Vault Structure Damage Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Maintenance person judges that structure is unsound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
Structure	Vault Structure Damage Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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 one-fourth inch at the joint of the inlet/outlet pipe.
Structure	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
Structure	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 and meets specifications, and is safe to use as determined by inspection personnel.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

An oil/water separator vault is a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

#17 – Maintenance Standards for Coalescing Plate Oil/Water Separators (BMP OW.02):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Effluent Water Quality	Inspection of Discharge Water for Obvious Signs of Poor Water Quality	Floating oil in excess of 1 inch in first chamber, any oil in other chambers or effluent, or other contaminants of any type in any chamber.	No contaminants present other than surface oil film. Effluent discharge from vault should be clear with no thick visible sheen.
Structure	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth and/or visible signs of sediment on plates.	No sediment deposits on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.
General	Trash and 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.
General	Oil Accumulation	Oil accumulation that exceeds 1 inch at the water surface.	No visible oil depth on water and coalescing plates clear of oil. <i>Oil is extracted from vault using vactoring methods. Dispose of in accordance with state and local rules and regulations. Coalescing plates are cleaned by thoroughly rinsing and flushing. Direct wash-down effluent to the sanitary sewer system where permitted. Should be no visible oil depth on water.</i>
Structure	Damaged Coalescing Plates	Plate media broken, deformed, cracked and/or showing signs of failure.	A portion of the media pack or the entire plate pack is replaced depending on severity of failure.
Structure	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and or replaced.
Structure	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
Structure	Vault Structure Damage – Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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.
Structure	Vault Structure Damage – Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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 one-fourth inch at the joint of the inlet/outlet pipe.
Structure	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 and meets specifications, and is safe to use as determined by inspection personnel.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

An oil/water separator vault is a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

#18 – Maintenance Standards for Stormwater Treatment Wetlands (BMP WP.01):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash and Debris	Any trash and debris accumulations which exceed five cubic feet per 1,000 square feet. If there is less than the threshold, remove all trash and debris as part of the next scheduled maintenance.	Trash and debris cleared from site.
General	Poisonous Vegetation and Noxious Weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined in the Thurston County Noxious Weeds List . (Apply requirements of adopted integrated vegetation management (IVM) policies for the use of herbicides.)	No danger of poisonous vegetation where maintenance personnel or the public might have contact. (<i>Coordinate with Thurston County Noxious Weed Coordinator.</i>) Complete eradication of noxious weeds may not be possible, however compliance with state or local eradication policies are required.
General	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. <i>If chronic low levels of oil persist, plant emergent wetland plants such as Juncus effusus (soft rush) which can assist filtering small concentrations of oil.</i>
General	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material or damaged.	No clogging or blockage in the inlet and outlet piping.
General	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 removed and dam or berm repaired. (<i>Coordinate with Thurston County; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.</i>)
General	Beaver Dams	Beaver dam results in an adverse change in the functioning of the facility.	Facility is fully functioning. <i>Evaluate using beaver deceiver and lever devices. If beaver removal is necessary, contact WDFW Region 6 to coordinate with a Nuisance Wildlife Control Operator.</i>
General	Tree Growth and Hazard Trees	Tree growth that impedes maintenance access.	Trees removed from facility bottom, side slopes, and maintenance access areas. Species removed that are not part of the recorded planting plan.
General	Tree Growth and Hazard Trees	If dead, diseased, or dying trees are identified, use a certified Arborist to determine the health of tree and whether removal is required.	Hazard trees removed.
General	Liner	Liner is visible and has more than three one-fourth inch holes in it.	Liner is repaired or replaced. Liner is fully covered.
Forebay	Sediment Accumulation	Sediment accumulation in forebay exceeds the design depth of the sediment zone plus 6 inches.	Accumulated sediment is removed from forebay bottom to the design depth of the sediment zone.

#18 – Maintenance Standards for Stormwater Treatment Wetlands (BMP WP.01):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Side Slopes of Wetland	Erosion	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes stabilized using appropriate erosion control measure(s) such as rock reinforcement, planting of grass, or additional compaction.
Side Slopes of Wetland	Erosion	Any erosion observed on a compacted berm embankment.	<i>If erosion is occurring on compacted berms a professional engineer should be consulted to resolve source of erosion.</i>
Wetland Cell	Wetland Vegetation	20 percent or more of the constructed wetland area has dead or dying vegetation, as measured by stem counts relative to the design plant coverage.	Plants in wetland cell surviving and not interfering with wetland function. Dead or dying vegetation is replaced by like species, unless recommended otherwise by the Wetlands Consultant and approved by the county. <i>(Watering, physical support, mulching, and weed removal may be required on a regular basis especially during the first 3 years.)</i>
Wetland Cell	Wetland Vegetation	Percent vegetated cover of constructed wetland bottom area, excluding exotic and invasive species, is less than 50 percent after 2 years.	Exotic/invasive species removed. Additional plantings may be required.
Wetland Cell	Wetland Vegetation	Decaying vegetation produces foul odors.	Decaying vegetation is removed, preferably in late summer.
Wetland Cell	Wetland Vegetation	Wetland vegetation is blocking flow paths causing flow back-up and flooding.	Areas of blocking vegetation are cut back sufficient to allow design flows and prevent flooding.
Wetland Cell	Wetland Vegetation	Water quality monitoring indicates that wetland vegetation is contributing phosphorus and metals to downstream waters rather than sequestering them.	Water quality monitoring indicates improved water quality. To maximize removal of wetland pollutants, wetland vegetation must be periodically harvested, particularly with respect to phosphorus and metals removal. Harvesting should occur by mid-summer before plants begin to transfer phosphorus from the aboveground foliage to subsurface roots, or begin to lose metals that desorb during plant die off. Every 3 to 5 years the entire plant mass including roots should be harvested because the below ground biomass constitutes a significant reservoir (as much as half) of the nutrients and metals that are removed from stormwater by plants.
Wetland Cell	Sediment Accumulation	Sediment accumulation inhibits growth of wetland plants or reduces wetland volume (greater than 1 feet of sediment accumulation).	Wetland dredged to remove sediment accumulation.

#18 – Maintenance Standards for Stormwater Treatment Wetlands (BMP WP.01):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Wetland Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works.	Dike restored to the design elevation. <i>A professional engineer should be consulted to determine the source of the settlement.</i>
Wetland Berms (Dikes)	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue.	Piping eliminated. Erosion potential eliminated. <i>(Recommend a geotechnical engineer be called in to inspect and evaluate condition and recommend repairs.)</i>
Wetland Berms Over 4 ft in height (Dikes)	Tree Growth	Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees on berms removed. <i>If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A professional engineer should be consulted for proper berm/spillway restoration.</i>
Emergency Overflow/ Spillway	Obstruction	Tree growth or other blockage on emergency spillways may cause failure of the berm due to uncontrolled overtopping.	Obstruction on emergency spillway removed. <i>A professional engineer should be consulted for proper berm/spillway restoration.</i>
Emergency Overflow/ Spillway	Rock Missing	Only one layer of rock exists above native soil in an area five square feet or larger, or any exposure of native soil at the top of out flow path of spillway.	Rocks and pad depth are restored to design standards. (Riprap on inside slopes need not be replaced.)
Emergency Overflow/ Spillway	Erosion	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. <i>If erosion is occurring on compacted berms a professional engineer should be consulted to resolve source of erosion.</i>

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#19 – Maintenance Standards for Fencing/Shrubby Screen/Other Landscaping:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Missing or Broken Parts/Dead Shrubby	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.
General	Erosion	Erosion has resulted in an opening under a fence that allows entry by people or pets.	Soil under fence replaced so that no opening exceeds 4 inches in height.
General	Unruly Vegetation	Shrubby, including blackberries and scotch broom, is growing out of control or is infested with weeds. See also Thurston County Noxious weeds list.	Shrubby is trimmed and weeded. Use Thurston County Integrated Pest Control methods when applicable.
Fences	Damaged Parts	Posts out of plumb more than 6 inches.	Posts plumb to within 1.5 inches of plumb.
Fences	Damaged Parts	Top rails bent more than 6 inches.	Top rail free of bends greater than 1 inch.
Fences	Damaged Parts	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.
Fences	Damaged Parts	Missing or loose tension wire.	Tension wire in place and holding fabric.
Fences	Damaged Parts	Missing or loose barbed wire that is sagging more than 2.5 inches between posts.	Barbed wire in place with less than three-fourth inch sag between posts.
Fences	Damaged Parts	Extension arm missing, broken, or bent out of shape more than 1.5 inches.	Extension arm in place with no bends larger than three-fourth inch.
Fences	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.
Fences	Openings in Fabric	Openings in fabric are such that an 8-inch diameter ball could fit through.	No openings in fabric.

#20 – Maintenance Standards for Grounds (Landscaping):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Weeds (nonpoisonous)	Weeds growing in more than 20 percent of the landscaped area (trees and shrubs only). See also Thurston County Noxious weeds list.	Weeds present in less than five percent of the landscaped area.
General	Insect Hazard/Vegetation (poisonous)	Any presence of poison ivy or other poisonous vegetation or insect nests.	No poisonous vegetation or insect nests present in landscaped area.
General	Trash or Litter	See Detention Ponds (Checklist #1).	See Detention Ponds (Checklist #1).
General	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.
Trees and shrubs	Damage	Limbs or parts of trees or shrubs that are split or broken which affect more than 25 percent of the total foliage of the tree or shrub.	Trim trees/shrubs to restore shape. Replace trees/shrubs with severe damage.
Trees and shrubs	Damage	Trees or shrubs that have been blown down or knocked over.	Tree replanted, inspected for injury to stem or roots. Replace if severely damaged.
Trees and shrubs	Damage	Trees or shrubs which are not adequately supported or are leaning over, causing exposure of the roots.	Stakes and rubber-coated ties placed around young trees/shrubs for support.

#21 – Maintenance Standards for Gates:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
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.
General	Damaged or Missing Components	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.
General	Damaged or Missing Components	Gate is out of plumb more than 6 inches and more than 1 foot out of design alignment.	Gate is aligned and vertical.
General	Damaged or Missing Components	Missing stretcher bands, and ties.	Stretcher bar, bands, and ties in place.

#22 – Maintenance Standards for Conveyance Systems (Pipes and Ditches):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Pipes	Sediment & Debris	Accumulated sediment that exceeds 20 percent of the diameter of the pipe.	Pipe cleaned of all sediment and debris.
Pipes	Vegetation	Vegetation that reduces free movement of water through pipes.	Vegetation does not impeded free movement of water through pipes. <i>Prohibit use of sand and sealant application and protect from construction runoff.</i>
Pipes	Damaged (Rusted, Bent or Crushed)	Protective coating is damaged: rust is causing more than 50 percent deterioration to any part of pipe.	Pipe repaired or replaced.
Pipes	Damaged (Rusted, Bent or Crushed)	Any dent that significantly impedes flow (i.e. decreases the cross section area of pipe by more than 20 percent).	Pipe repaired or replaced.
Pipes	Damaged (Rusted, Bent or Crushed)	Pipe has major cracks or tears allowing groundwater leakage.	Pipe repaired or replaced.
Open Ditches	Trash & Debris	Dumping of yard wastes such as grass clippings and branches. Unsightly accumulation of non-degradable materials such as glass, plastic, metal, foam, and coated paper.	No trash or debris present. Trash and debris removed and disposed of as prescribed by the County.
Open Ditches	Sediment Buildup	Accumulated sediment that exceeds 20 percent of the design depth.	Ditch cleaned of all sediment and debris so that it matches design.
Open Ditches	Vegetation	Vegetation (e.g. weedy shrubs or saplings) that reduces free movements of water through ditches.	Water flows freely through ditches. Grassy vegetation should be left alone.
Open Ditches	Erosion Damage to Slopes	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	No erosion damage present. Slopes stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
Open Ditches	Erosion Damage to Slopes	Any erosion observed on a compacted berm embankment.	<i>If erosion is occurring on compacted berms a professional engineer should be consulted to resolve source of erosion.</i>
Open Ditches	Rock Lining Out of Place or Missing (If Applicable)	Native soil is exposed beneath the rock lining.	Rocks replaced to design standards.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#23 – Maintenance Standards for Media Filter Drain (BMP MF.04):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
No Vegetation Zone adjacent to pavement	Erosion, Scour, or Vehicular Damage	No vegetation zone uneven or clogged so that flows are not uniformly distributed.	Area leveled and cleaned so that flows are spread evenly.
No Vegetation Zone adjacent to pavement	Sediment Accumulation on Edge of Pavement	Flows no longer sheet flowing off of roadway. Sediment accumulation on pavement edge exceeds top of pavement elevation.	No sediment accumulation on pavement edge that impedes sheet flow. Sediment deposits removed such that flows can sheet flow off of roadway.
Vegetated Filter	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Sediment deposits removed, slope is re-leveled so that flows pass evenly through Ecology Embankment.
Vegetated Filter	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. See also Thurston County Noxious weeds list.	Grass mowed and nuisance vegetation controlled such that flow not impeded. <i>Grass should be mowed to a height that encourages dense even herbaceous growth.</i>
Vegetated Filter	Erosion, Scour, or Vehicular Damage	Eroded or scoured areas due to flow channelization, high flows or vehicular damage.	No eroded or scoured areas. <i>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.</i>
Media Bed	Erosion, Scour, or Vehicular Damage	Eroded or scoured areas due to flow channelization, high flows or vehicular damage.	No eroded or scoured areas. <i>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.</i>
Media Bed	Sediment Accumulation on Media Bed	Sediment depth inhibits free infiltration of water.	Sediment accumulation does not impeded infiltration. Sediment deposits removed and slope is re-leveled so that flows pass freely through Media Bed.
Underdrains	Sediment	Depth of sediment within perforated pipe exceeds one-half inch.	Depth of sediment within perforated pipe does not exceed one-half inch. Flush underdrains through access ports and collect flushed sediment.
General	Trash and Debris Accumulation	Any trash and debris accumulations which exceed one cubic foot per 1,000 square feet. If there is less than the threshold, remove all trash and debris as part of the next scheduled maintenance.	No trash or debris present. Remove trash and debris from media filter.

#23 – Maintenance Standards for Media Filter Drain (BMP MF.04):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Flows are Bypassing Ecology Embankment	Evidence of significant flows downslope (rills, sediment, vegetation damage, etc.) of media filter drain.	Facility functions as designed. Sediment deposits removed and slope is re-leveled so that flows pass evenly through media filter drain. If media filter drain is completely clogged, it may require a more extensive repair or replacement.
General	Media Filter Drain Mix Replacement	Water is seen on surface of the media filter drain mix from storms that are less than the 91st percentile 24-hour rain event (approx 1.25" in 24 hours). Maintenance also needed on a 10-year cycle and during a preservation project.	No water ponded on surface after design storm. <i>Excavate and replace all of the media filter drain mix contained within the media filter drain.</i>

See also the latest version of the WSDOT Highway Runoff Manual for additional maintenance information.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#24 – Maintenance Standards for Vortechs Stormwater Treatment System:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Sediment Accumulation	Sediment depth is within 6 inches of dry weather water surface elevation.	Accumulated sediment should be removed.
General	Trash and 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.
General	Oil Accumulation	Oil accumulation that exceeds 1 inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
Structure	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and or replaced.
Structure	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
Structure	Vault Structure Damage – Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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.
Structure	Vault Structure Damage – Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half 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 one-fourth inch at the joint of the inlet/outlet pipe.

Designers must also review the most current manufacturer guidelines for any updates or additions to the following O&M requirements.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

A vault is a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

#25 – Maintenance Standards for Stormceptor System:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Settling chamber	Excessive Sediment Accumulation	Capacities vary depending on model number ¹ .	Sediments removed.
Settling chamber	Trash and Floatable Debris Accumulation	Excessive trash and floatable debris accumulation.	Minimal trash or other floatable debris.
Settling chamber	Excessive Oil Accumulation	Oil exceeds 6 inches in depth or evidence of a spill.	Oil cleaned out.
Manhole Cover	Cover Damaged/ Not Working	One maintenance person cannot remove lid after applying 80 pounds of lift, corrosion or deformation of cover.	Cover repaired to proper working specifications or replaced.
Disk Insert	Disk Insert Inlet/ Outlet Obstructed	Inlet or outlet piping obstructed.	Disk insert inlet/outlet free from obstructions.
Structure	Structure has Cracks in wall, Bottom, and Damage to Frame and/or Top Slab	Cracks wider than one-half 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 repaired or replaced so that vaults meets design specifications and is structurally sound.
Structure	Structure has Cracks at the Joint of any Inlet/ Outlet Pipe	Cracks wider than one-half 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 one-fourth inch at the joint of inlet/outlet pipe.

Designers must also review the most current manufacturer guidelines for any updates or additions to the following O&M requirements.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance or the manufacturer's representative.

1. Model number and sediment depth capacities:

Sediment Depths Indicating Required Servicing	
Model	Sediment Depth
STC 450i	8"
STC 900	8"
STC 1200	10"
STC 1800	15"
STC 2400	12"
STC 3600	17"
STC 4800	15"
STC 6000	18"
STC 7200	15"
STC 11000	15"
STC 13000	18"
STC 16000	15"

#26 – Maintenance Standards for Filterra:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Inlet	Excessive Sediment or Trash Accumulation	Accumulated sediments or trash impair free flow of water into Filterra system.	Inlet free of obstructions and allows free distributed flow of water into Filterra system. Sediments and/or trash removed.
Mulch Cover	Trash and Floatable Debris Accumulation	Excessive trash and/or debris accumulation.	Minimal trash or other debris on mulch cover. Trash and debris removed and mulch cover raked level.
Mulch Cover	Ponding of Water on Mulch Cover	Ponding in unit could be indicative of clogging due to excessive fine sediment accumulation or spill of petroleum oils.	Stormwater drains freely and evenly through mulch cover. <i>Recommend contact manufacturer and replace mulch or soil if necessary.</i>
Vegetation	Plants not Growing or in Poor Condition	Soil/ mulch too wet, evidence of spill. Incorrect plant selection. Pest infestation. Vandalism to plants.	Plants healthy and pest free. <i>Contact manufacturer for advice.</i>
Vegetation	Excessive Plant Growth	Excessive plant growth inhibits facility function or becomes a hazard for pedestrian and vehicular circulation and safety.	Plants trimmed/pruned in accordance with manufacturer's recommendations to maintain appropriate plant density and aesthetics. Appropriate plants are present.
Structure	Structure has Cracks in Wall, Bottom, and Damage to Frame and/or Top Slab	Cracks wider than one-half inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the structure is not structurally sound.	Structure sealed and structurally sound.
Structure	Structure has Cracks at the Joint of any Inlet/ Outlet Pipe	Cracks wider than one-half inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Structure repaired so that no cracks exist wider than one-fourth inch at the joint of inlet/outlet pipe.

Designers must also review the most current manufacturer guidelines for any updates or additions to the following O&M requirements.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance or the manufacturer's representative.

#27 – Maintenance Standards for CDS Media Filtration System (MFS) ®:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Media filter vault	Sediment Accumulation on Top of Filter Cartridges	Sediment accumulation exceeds one-half inch on top of cartridges.	Minimal sediment deposits on top of cartridges. Excess sediment on cartridges likely indicates that cartridges are plugged and require maintenance.
Media filter vault	Sediment Accumulation in Vault	Sediment accumulation in vault exceeds 6 inches.	Sediment in vault removed.
Media filter vault	Trash and Floatable Debris Accumulation	Excessive trash and floatable debris accumulation in vault.	Minimal trash or other floatable debris in filter vault.
Media filter cartridges	Filter Cartridges Full	Filter cartridge media appears dark. Check should be performed on a dry day. Requires entry to vault ¹ .	Filter media checked and replaced if needed. If cartridges are plugged with oil, additional treatment or source control BMP may be needed.
Media filter cartridges	Filter Cartridges Full	Area around cartridges has standing water and cartridges are submerged 24 hours after a storm.	Filter media checked and replaced if needed. If cartridges are plugged with oil, additional treatment or source control BMP may be needed.
Media filter cartridges	Filter Cartridges Full	Water flowing over the head control box during light storm events and more than 1 inch of floatables has accumulated in the cartridge vent pipe.	Filter media checked and replaced if needed. If cartridges are plugged with oil, additional treatment or source control BMP may be needed.
Access Cover	Access Cover Damaged/ Not Working	One maintenance person cannot remove lid after applying 80 pounds of lift, corrosion or deformation of cover.	Cover repaired to proper working specifications or replaced.
Collector manifold	Damaged Piping	Any part of the pipes are crushed or damaged due to corrosion and/or settlement.	Pipe repaired or replaced.
Vault	Vault Structure has Cracks in Wall, Bottom, and Damage to Frame and/or Top Slab	Cracks wider than one-half 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 repaired or replaced so that vault meets design specifications and is structurally sound.
Vault	Structure has Cracks at the Joint of any Inlet/ Outlet Pipe	Cracks wider than one-half 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 at the joint of inlet/outlet pipe.
Baffles	Baffles	Baffles corroding, cracking, warping, and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to design specifications.
Access Ladder	Ladder Rungs Unsafe	Maintenance person judges that ladder is unsafe due to missing rungs, misalignment, rust, or cracks. Ladder must be fixed or secured immediately.	Ladder meets design standards and allows maintenance persons safe access.

Designers must also review the most current manufacturer guidelines for any updates or additions to the following O&M requirements.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance or the manufacturer's representative.

1. CDS MFS system vault is a confined space. Visual inspections should be performed aboveground. If entry is required it should be performed by qualified personnel.

Default maintenance is annual.

Configuration options include precast or cast in place concrete vaults or precast manhole structures.

#28 – Maintenance Standards for Aqua Shield Aqua-Swirl:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Sediment Storage area	Excessive Sediment Accumulation	Sediment accumulation within 36 inches of water surface.	Sediment removed.
Aqua Swirl Chamber	Trash and Floatable Debris Accumulation	Excessive trash and floatable debris accumulation swirl chamber.	Minimal trash or other floatable debris.
Manhole Cover	Cover Damaged/ Not Working	One maintenance person cannot remove lid after applying 80 pounds of lift, corrosion or deformation of cover.	Cover repaired to proper working specifications or replaced.
Structure	Vault Structure has Cracks in Wall, Bottom, and Damage to Frame and/or Top Slab	Cracks wider than one-half 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 repaired or replaced so that vault meets design specifications and is structurally sound.
Structure	Vault Structure has Cracks at the Joint of any Inlet/ Outlet Pipe	Cracks wider than one-half 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 one-fourth inch at the joint of inlet/outlet pipe.
Baffles	Baffles	Baffles corroding, cracking, warping, and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to design specifications.

Designers must also review the most current manufacturer guidelines for any updates or additions to the following O&M requirements.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance or the manufacturer's representative.

#29 – Maintenance Standards for Bioretention (BMP LID.08) (Cells, Swales, and Planter Boxes):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash	Trash and debris present.	No trash and debris present.
Concrete Sidewalls	Cracks or Failure in Concrete Planter Reservoir	Cracks wider than 0.5 inch or maintenance/inspection personnel determine that the planter is not structurally sound.	Concrete repaired or replaced.
Rockery Sidewalls	Instable Rockery	Rock walls are insecure.	Rockery sidewalls are stable (may require consultation with professional engineer, particularly for walls 4 feet or greater in height).
Earthen Side Slopes and Berms	Failure in Earthen Reservoir (Embankments, Dikes, Berms, and Side Slopes)	Erosion (gullies/rills) greater than 2 inches around inlets, outlet, and along side slopes.	Source of erosion eliminated and damaged area stabilized (regrade, rock, vegetation, erosion control blanket). For deep channels or cuts (over 3 inches in ponding depth), temporary erosion control measures are in place until permanent repairs can be made.
Earthen Side Slopes and Berms	Failure in Earthen Reservoir (Embankments, Dikes, Berms, and Side Slopes)	Erosion of sides causes slope to become a hazard.	The hazard is eliminated and slopes are stabilized.
Earthen Side Slopes and Berms	Failure in Earthen Reservoir Embankments, Dikes, Berms, and Side Slopes)	Settlement greater than 3 inches (relative to undisturbed sections of berm).	The design height is restored with additional mulch.
Earthen Side Slopes and Berms	Failure in Earthen Reservoir (Embankments, Dikes, Berms, and Side Slopes)	Downstream face of berm or embankment wet, seeps or leaks evident.	Holes are plugged and berm is compacted. May require consultation with professional engineer, particularly for larger berms.
Earthen Side Slopes and Berms	Failure in Earthen Reservoir (Embankments, Dikes, Berms, and Side Slopes)	Any evidence of rodent holes or water piping around holes if facility acts as dam or berm.	Rodents (see "Pests: Insects/Rodents") removed or destroyed and berm repaired/ compacted.
Ponding Area	Sediment or Debris Accumulation	Accumulation of sediment or debris to extent that infiltration rate is reduced (see "Ponded water") or surface storage capacity significantly impacted.	Sediment cleaned out to restore facility shape and depth. Damaged vegetation is replaced and mulched. Source of sediment identified and controlled (if feasible).
Ponding Area	Leaf Accumulation	Accumulated leaves in facility.	No leaves clogging outlet structure or impeding water flow.
Ponding Area	Facility Inlet via Surface Flow	Soil is exposed or signs of erosion are visible.	Erosion sources repaired and controlled.
Curb Cut Inlet	Sediment or Debris Accumulation	Sediment, vegetation, or debris partially or fully blocking inlet structure.	Curb cut is clear of debris. Source of the blockage is identified and action is taken to prevent future blockages.

#29 – Maintenance Standards for Bioretention (BMP LID.08) (Cells, Swales, and Planter Boxes):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Splash Block Inlet	Water Not Properly Directed to Facility	Water is not being directed properly to the facility and away from the inlet structure.	Blocks are reconfigured to direct water to facility and away from structure.
Splash Block Inlet	Erosion	Water disrupts soil media.	Splash block is reconfigure/repared.
Inlet/outlet pipe	Damaged Pipe	Pipe is damaged.	Pipe is repaired/replaced. No cracks more than 0.25 inched wide at the joint of inlet/outlet pipes exist.
Inlet/outlet pipe	Clogged Pipe	Pipe is clogged.	Pipe is clear of roots or debris. Source of the blockage is identified and action is taken to prevent future blockages.
Inlets/outlet and access pathways	Blocked Access	Maintain access for inspections.	Vegetation is cleared within 1 foot of inlets and outlets. Access pathways are maintained.
Ponding Area	Erosion	Water disrupts soil media.	No eroded or scoured areas in bioretention area. Cause of erosion or scour addressed. A cover of rock or cobbles or other erosion protection measure maintained (e.g., matting) to protect the ground where concentrated water enters or exits the facility (e.g., a pipe, curb cut or swale).
Trash Rack	Trash or Debris Accumulation	Trash or debris present on trash rack.	No trash or debris on trash rack. Clean and dispose trash.
Trash Rack	Damaged Trash Rack	Bar screen damaged or missing.	Barrier repaired or replaced to design standards.
Check Dams and Weirs	Sediment or Debris Accumulation	Sediment, vegetation, or debris accumulated at or blocking (or having the potential to block) check dam, weir, or orifice.	Blockage is cleared. Identify the source of the blockage and take actions to prevent future blockages.
Check Dams and Weirs	Erosion	Erosion and/or undercutting is present.	No eroded or undercut areas in bioretention area. Cause of erosion or undercutting addressed. Check dam or weir is repaired.
Check Dams and Weirs	Unlevel Top of Weir	Grade board or top of weir damaged or not level.	Weir restored to level position.
Flow Spreader	Sediment Accumulation	Sediment blocks 35 percent or more of ports/notches or, sediment fills 35 percent or more of sediment trap.	Sediment removed and disposed of.
Flow Spreader	Damaged or Unlevel Grade Board/Baffle	Grade board/baffle damaged or not level.	Board/baffle removed and reinstalled to level position.
Overflow/emergency spillway	Sediment or Debris Accumulation	Overflow spillway is partially or fully plugged with sediment or debris.	No sediment or debris in overflow.
Overflow/emergency spillway	Erosion	Native soil is exposed or other signs of erosion damage are present.	Erosion repaired and surface of spillway stabilized.

#29 – Maintenance Standards for Bioretention (BMP LID.08) (Cells, Swales, and Planter Boxes):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Overflow/emergency spillway	Missing Spillway Armament	Spillway armament is missing.	Armament replaced.
Underdrain	Blocked Underdrain	Plant roots, sediment or debris reducing capacity of underdrain. Prolonged surface ponding (see "Bioretention Soil").	Underdrains and orifice are free of sediment and debris.
Bioretention soil	Ponded Water	Excessive ponding water: Water overflows during storms smaller than the design event or ponded water remains in the facility 48 hours or longer after the end of a storm.	Cause of ponded water is identified and addressed: 1. Leaf or debris buildup is removed 2. Underdrain is clear 3. Other water inputs (e.g., groundwater, illicit connections) investigated 4. Contributing area verified If steps #1-4 do not solve the problem, imported bioretention soil is replaced and replanted.
Bioretention soil	Protection of Soil	Maintenance requiring entrance into the facility footprint.	Maintenance is performed without compacting bioretention soil media.
Vegetation	Bottom Swale and Upland Slope Vegetation	Less than 75 percent of swale bottom is covered with healthy/ surviving vegetation.	Plants are healthy and pest free. Cause of poor vegetation growth addressed. Bioretention area is replanted as necessary to obtain 75 percent survival rate or greater. Plant selection is appropriate for site growing conditions.
Trees and shrubs	Causing Problems for Operation of Facility	Large trees and shrubs interfere with operation of the facility or access for maintenance.	Trees and shrubs do not hinder facility performance or maintenance activities.. Species removed that are not part of the recorded planting plan.
Trees and shrubs	Dead Trees and Shrubs	Standing dead vegetation is present.	Trees and shrubs do not hinder facility performance or maintenance activities. Dead vegetation is removed and cause of dead vegetation is addressed. Specific plants with high mortality rate are replaced with more appropriate species.
Trees and shrubs adjacent to vehicle travel areas (or areas where visibility needs to be maintained)	Safety Issues	Vegetation causes some visibility (line of sight) or driver safety issues.	Appropriate height for sight clearance is maintained. Regular pruning maintains visual sight lines for safety or clearance along a walk or drive. Tree or shrub is removed or transplanted if presenting a continual safety hazard.
Emergent Vegetation	Conveyance Blocked	Vegetation compromises conveyance.	Sedges and rushes are clear of dead foliage.
Mulch	Lack of Mulch	Bare spots (without much cover) are present or mulch covers less than 2 inches.	Facility has a maximum 3-inch layer of an appropriate type of mulch and mulch is kept away from woody stems.
Vegetation	Accumulation of Clippings	Grass or other vegetation clippings accumulate to 2 inches or greater in depth.	Clippings removed.

#29 – Maintenance Standards for Bioretention (BMP LID.08) (Cells, Swales, and Planter Boxes):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Noxious Weeds	Presence of Noxious Weeds	Listed noxious vegetation is present. See Thurston County Noxious Weed List .	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where County personnel or the public might normally be. It is strongly encouraged that herbicides and pesticides not be used in order to protect water quality.
Vegetation	Weeds	Weeds are present (unless on edge and providing erosion control).	Weed material removed and disposed of. It is strongly encouraged that herbicides and pesticides not be used in order to protect water quality.
Excessive Vegetation	Adjacent Facilities Compromised	Low-lying vegetation growing beyond facility edge onto sidewalks, paths, or street edge poses pedestrian safety hazard or may clog adjacent permeable pavement surfaces due to associated leaf litter, mulch, and soil.	Vegetation does not impede function of adjacent facilities or pose as safety hazard. Groundcovers and shrubs trimmed at facility edge. Excessive leaf litter is removed.
Excessive Vegetation	Causes Facility to Not Function Properly	Excessive vegetation density inhibits stormwater flow beyond design ponding or becomes a hazard for pedestrian and vehicular circulation and safety.	Pruning and/or thinning vegetation maintains proper plant density and aesthetics. Plants that are weak, broken, or not true to form are removed or replaced in-kind. Appropriate plants are present.
Irrigation (if any)	NA	Irrigation system present.	Manufacturer's instructions for O&M are met.
Plant watering	Plant Establishment	Plant establishment period (1-3 years).	Plants are watered as necessary during periods of no rain to ensure plant establishment.
Summer Watering (after establishment)	Drought Period	Longer term period (3+ years).	Plants are watered as necessary during drought conditions and trees are watered up to five years after planting.
Spill Prevention and Response	Spill Prevention	Storage or use of potential contaminants in the vicinity of facility.	Spill prevention measures are implemented whenever handling or storing potential contaminants.
Spill Prevention and Response	Spill Response	Any evidence of contaminants such as oil, gasoline, concrete slurries, paint, etc.	Spills are cleaned up as soon as possible to prevent contamination of stormwater. No contaminants or pollutants present. <i>(Coordinate source control, removal, and/or cleanup with Thurston County Water Resources 360-754-4681 and/or Dept. of Ecology Spill Response 800-424-8802.)</i>
Safety	Safety (Slopes)	Erosion of sides causes slope to exceed 1:3 or otherwise becomes a hazard.	Actions taken to eliminate the hazard.
Safety	Safety (Hydraulic Structures)	Hydraulic structures (pipes, culverts, vaults, etc.) become a hazard to children playing in and around the facility.	Actions taken to eliminate the hazard (such as covering and securing any openings).

#29 – Maintenance Standards for Bioretention (BMP LID.08) (Cells, Swales, and Planter Boxes):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Aesthetics	Aesthetics	Damage/vandalism/debris accumulation.	Facility restored to original aesthetic conditions.
Aesthetics	Edging	Grass is starting to encroach on swale.	Edging repaired.
Pest Control	Pests: Insects/Rodents	Pest of concern is present and impacting facility function.	Pests removed or destroyed and facility returned to original functionality. Do not use pesticides or <i>Bacillus thuringiensis israelensis (Bti)</i> .
Pest Control	Mosquitoes	Standing water remains in the facility for more than three days following storms.	All inlets, overflows and other openings are protected with mosquito screens. No mosquito infestation present.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#30 – Maintenance Standards for Cisterns (BMP LID.16):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Roof	Debris Accumulation in Cistern	Debris has accumulated.	No debris in cistern.
Gutter	Debris Accumulation in Gutter	Debris has accumulated.	No debris in cistern or gutters.
Screens at the top of downspout and cistern inlet	Debris Accumulation in Cistern	Screen has deteriorated.	Screen is in place and functions as designed.
Screens at the top of downspout and cistern inlet	Debris Accumulation in Cistern	None. Preventative maintenance.	No debris in cistern or accumulated on screen.
Low flow orifice	Cistern Overflows Are Too Frequent	Debris or other obstruction of orifice.	Low flow orifice is clean.
Overflow pipe	Overflow Pipe	Pipe is damaged.	Overflow pipe is watertight and does not leak. Repair/replace.
Overflow pipe	Overflow Pipe	Pipe is clogged.	Debris removed. Overflow pipe can convey overflow to point of discharge.
Cistern	Accumulated Debris And/or Sediment	More than 6 inches of accumulation in bottom of cistern.	Accumulated debris and/or sediment removed.
Training and Documentation	NA	Training / written guidance is required for proper O&M.	Property owners and tenants are provided with proper training and a copy of the Maintenance and Source Control Manual.
Access and Safety	NA	Access to cistern required for maintenance or cleaning.	Any opening that could allow the entry of people is marked: "DANGER—CONFINED SPACE".
Pest Control	Mosquito Infestation	Standing water remains for more than three days following storms.	All inlets, overflows, and other openings are protected with mosquito screens. No mosquito infestation present.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#31 – Maintenance Standards for Vegetated Roof (BMP LID.10):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Soil / Growth Medium	Water is Not Infiltrating Properly	Water does not permeate growth media (runs off soil surface).	Facility infiltrates as designed. Aerate or replace media until stormwater infiltrates freely through growth media.
Soil / Growth Medium	Water is Not Infiltrating Properly	Growth medium thickness is less than design thickness (due to erosion and plant uptake).	Facility infiltrates as designed. Supplement growth medium to design thickness.
Soil / Growth Medium	Water is Not Infiltrating Properly	Fallen leaves or debris are present.	No leaves or debris present.
Soil / Growth Medium	Erosion/Scouring	Areas of potential erosion are visible.	Steps taken to repair or prevent erosion. Fill, hand tamp, or lightly compact, and stabilize with additional soil substrate/growth medium and additional plants.
Erosion Control Measures	Erosion/Scouring	Mat or other erosion control is damaged or depleted during plant establishment period.	Erosion control measures repaired/replaced until 90 percent vegetation coverage attained. Avoid application of mulch on extensive vegetated roofs.
System Structural Components	Deteriorating Flashing, Gravel Stops, Utilities, or Other Structures on Roof	Flashing, utilities or other structures on roof are deteriorating (can serve as source of metal pollution in vegetated roof runoff).	Structural components inspected for deterioration or failure. Repair/replace as necessary.
Roof Drain	Sediment, Vegetation, or Debris Accumulation	Sediment, vegetation, or debris blocks 20 percent or more of inlet structure.	Blockages cleared. Problems that led to blockage identified and corrected.
Roof Drain	Damaged Inlet Pipe	Inlet pipe is in poor condition.	Repaired/replaced.
Roof Drain	Clogged Inlet Pipe	Pipe is clogged.	Roots or debris removed.
Vegetation	Plant Coverage	Healthy vegetative coverage falls below 90 percent (unless design specifications stipulate less than 90 percent coverage).	Bare areas planted with vegetation. If necessary, install erosion control measures until percent coverage goal is attained.
Vegetation (sedums)	NA	Extensive roof with low density sedum population.	Sedums are mulch mowed, creating cuttings from existing plants to encourage colonization.

#31 – Maintenance Standards for Vegetated Roof (BMP LID.10):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Vegetation	Presence of Noxious Weeds	Listed noxious vegetation is present. See Thurston County Noxious Weed List .	No danger of poisonous vegetation where maintenance personnel or the public might normally be. Noxious and nuisance vegetation removed according to applicable regulations. By law, class A & B noxious weeds must be removed, bagged, and disposed as garbage immediately. Reasonable attempts must be made to remove and dispose of class C noxious weeds. It is strongly encouraged that herbicides and pesticides not be used in order to protect water quality. <i>(Coordinate with Thurston County.) Complete eradication of noxious weeds may not be possible. Compliance with state or local eradication policies required.</i>
Vegetation	Presence of Weeds	Weeds are present.	Weed material removed and disposed of, with roots manually removed with pincer-type weeding tools, flame weeders, or hot water weeders as appropriate. It is strongly encouraged that herbicides and pesticides not be used in order to protect water quality.
Vegetation (extensive vegetated roof)	Under Fertilization	Poor plant establishment and possible nutrient deficiency in growth medium.	Organic debris allowed to replenish and maintain long-term nutrient balance and growth medium structure. Conduct annual soil test 2-3 weeks prior to the spring growth flush to assess need for fertilizer. Utilize test results to adjust fertilizer type and quantity appropriately. Minimum amount slow-release fertilizer necessary to achieve successful plant establishment is applied. Apply fertilizer only after acquiring required approval from facility owner and operator. Note that extensive vegetated roofs are designed to require zero to minimal fertilization after establishment (excess fertilization can contribute to nutrient export).

#31 – Maintenance Standards for Vegetated Roof (BMP LID.10):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Vegetation (intensive vegetated roof)	Under Fertilization	Fertilization may be necessary during establishment period or for plant health and survivability after establishment.	Annual soil test conducted 2-3 weeks prior to the spring growth flush to assess need for fertilizer. Utilize test results to adjust fertilizer type and quantity appropriately. Apply minimum amount slow-release fertilizer necessary to achieve successful plant establishment. Apply fertilizer only after acquiring required approval from facility owner and operator. Intensive vegetated roofs may require more fertilization than extensive vegetated roofs.
Vegetation (trees and shrubs on an intensive vegetated roof)	NA	Pruning as needed.	All pruning of mature trees performed by or under the direct guidance of an ISA certified arborist.
Irrigation system (if any)	NA	Irrigation system is not working or routine maintenance is needed.	Manufacturer's instructions for O&M have been followed.
Vegetation (extensive vegetated roof)	NA	Summer watering – Plant establishment period (1-2 years).	Watered weekly during periods of no rain to ensure plant establishment (30 to 50 gallons per 100 square feet).
Vegetation (extensive vegetated roof)	NA	Summer watering – Longer term period (2+ years).	Watered during drought conditions or more often if necessary to maintain plant cover (30 to 50 gallons per 100 square feet).
Vegetation (intensive vegetated roof)	NA	Plant establishment period (1-2 years).	Watered deeply, but infrequently, so that the top 6 to 12 inches of the root zone is moist. Use soaker hoses or spot water with a shower type wand when irrigation system not present.
Vegetation (intensive vegetated roof)	NA	Longer term period (2+ years).	Watered during drought conditions or more often if necessary to maintain plant cover.
Spill Prevention and Response	NA	Storage or use of potential contaminants in the vicinity of facility.	Spill prevention measures exercised whenever handling or storing potential contaminants.
Spill Prevention and Response	Release of Pollutants.	Any evidence of contaminants such as oil, gasoline, concrete slurries, paint, etc.	Spills are cleaned up as soon as possible to prevent contamination of stormwater. No contaminants or pollutants present. <i>(Coordinate source control, removal, and/or cleanup with Thurston County Water Resources 360-754-4681 and/or Dept. of Ecology Spill Response 800- 424-8802.)</i>
Training and Documentation	NA	Training / written guidance is required for proper O&M.	Property owners and tenants provided with proper training and a copy of the Maintenance and Source Control Manual.

#31 – Maintenance Standards for Vegetated Roof (BMP LID.10):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Safety	NA	Insufficient egress /ingress routes and fall protection.	Egress and ingress routes maintained to design standards and fire codes. Ensure appropriate fall protection.
Aesthetics	Poor Aesthetics	Damage/vandalism/debris accumulation.	Facility restored to original aesthetic conditions.
Pest Control	Mosquitoes	Standing water remains for more than three days following storms.	Standing water removed. Cause of the standing water identified, and appropriate actions taken to address the problem (e.g., aerate or replace medium, unplug drainage).

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#32 – Maintenance Standards for Permeable Pavement (BMP LID.09):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	Unstable Adjacent Area	Runoff from adjacent pervious areas deposits soil, mulch, or sediment on paving.	No deposited soil or other materials on permeable pavement or other adjacent surfacing. All exposed soils that may erode to pavement surface mulched and/or planted.
Facility – General Requirements	Wearing Course Covered by Adjacent Vegetation	Vegetation growing beyond facility edge onto sidewalks, paths, and street edge.	Vegetation does not impede function of adjacent facilities or pose as safety hazard. Groundcovers and shrubs trimmed to avoid overreaching the sidewalks, paths and street edge.
Porous asphalt or pervious cement concrete	NA	None. Maintenance to prevent clogging with fine sediment.	Conventional street sweepers equipped with vacuums, water, and brushes or pressure washer used to restore permeability. Vacuum or pressure wash the pavement two to three times annually.
Porous asphalt or pervious cement concrete	NA	None. Maintenance to prevent clogging with fine sediment.	Use of sand and sealant application prohibited. Protect from construction runoff.
Porous asphalt or pervious cement concrete	Cracks	Major cracks or trip hazards.	Potholes or small cracks filled with patching mixes. Large cracks and settlement addressed by cutting and replacing the pavement section.
Porous asphalt or pervious cement concrete	NA	Utility cuts.	Any damage or change due to utility cuts replaced in kind.
All Pavement Types	Leaf and Debris Accumulation	Fallen leaves or debris.	Removed/disposed.
Interlocking concrete paver blocks	Missing or Damaged Paver Block	Interlocking paver block missing or damaged.	Individual damaged paver blocks removed and replaced or repaired per manufacturer's recommendations.
Interlocking concrete paver blocks	Settlement	Settlement of surface. When deviation from original grade impedes function.	Original grade re-established. May require resetting.
All pavement types	All Pavement Types	Sediment or debris accumulation between paver blocks, on surface of pavement, or in grid voids.	Sediment at surface does not inhibit infiltration. Remove/dispose of sediment.
Interlocking concrete paver blocks	Void material is missing or low	Loss of aggregate material between paver blocks.	Refill per manufacturer's recommendations.
Open-celled paving grid with gravel	Loss of Aggregate Material in Paving Grid	Loss of aggregate material in grid.	Aggregate gravel level maintained at the same level as the plastic rings or no more than 0.25 inch above the top of rings. Refill per manufacturer's recommendations.

#32 – Maintenance Standards for Permeable Pavement (BMP LID.09):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Open-celled paving grid with grass	Lack of Grass Coverage	Loss of soil and/or grass material in grid.	Refill and/or replant per manufacturer's recommendations. Growing medium restored, facility aerated and reseeded or planted, and vegetated area amended as needed.
Inlet/outlet pipe	Pipe is Damaged	Pipe is damaged.	Pipe is repaired/replaced.
Inlet/outlet pipe	Pipe is Clogged	Pipe is clogged.	Roots or debris is removed.
Inlet/outlet pipe	Erosion	Native soil exposed or other signs of erosion damage present.	No eroded or scoured areas Cause of erosion or scour is addressed.
Underdrain pipe	Blocked Underdrain	Plant roots, sediment or debris reducing capacity of underdrain (may cause prolonged drawdown period).	Underdrains and orifice free of sediment and debris. Jet clean or rotary cut debris/roots from underdrain(s). If underdrains are equipped with a flow restrictor (e.g., orifice) to attenuate flows, the orifice must be cleaned regularly.
Spill Prevention and Response	NA	Storage or use of potential contaminants in the vicinity of facility.	Spill prevention measures exercised whenever handling or storing potential contaminants.
Spill Prevention and Response	Release of Pollutants	Any evidence of contaminants such as oil, gasoline, concrete slurries, paint, etc.	Spills are cleaned up as soon as possible to prevent contamination of stormwater. No contaminants or pollutants present. <i>(Coordinate source control, removal, and/or cleanup with Thurston County Water Resources 360-754-4681 and/or Dept. of Ecology Spill Response 800- 424-8802.)</i>

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#33 – Maintenance Standards for Downspout, Sheet Flow, and Concentrated Dispersion Systems (BMP LID.05: Downspout Dispersion System, BMP LID.06: Sheet Flow Dispersion, BMP LID.07: Concentrated Flow Dispersion):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Splash block	Water Directed Toward Building	Water is being directed towards building structure.	Water directed away from building structure.
Splash block	Water Causing Erosion	Water disrupts soil media.	Blocks are reconfigured/ repaired and media is restored.
Transition zone	Erosion	Adjacent soil erosion; uneven surface creating concentrated flow discharge; or less than 2 foot of width.	No eroded or scoured areas. Cause of erosion or scour is addressed.
Dispersion trench	Concentrated Flow	Visual evidence of water discharging at concentrated points along trench (normal condition is a "sheet flow" from edge of trench; intent is to prevent erosion damage).	No debris on trench surface. Notched grade board or other distributor type is aligned to prevent erosion. Trench is rebuilt to standards, if necessary.
Surface of trench	Accumulated Debris	Accumulated trash, debris, or sediment on drain rock surface impedes sheet flow from facility.	Trash or debris is removed/disposed in accordance with local solid waste requirements.
Surface of trench	Vegetation Impeding Flow	Vegetation/moss present on drain rock surface impedes sheet flow from facility.	Freely draining drain rock surface.
Pipe(s) to trench	Accumulated Debris in Drains	Accumulation of trash, debris, or sediment in roof drains, gutters, driveway drains, area drains, etc.	No trash or debris in roof drains, gutters, driveway drains, or area drains.
Pipe(s) to trench	Accumulated Debris in Inlet Pipe	Pipe from sump to trench or drywell has accumulated sediment or is plugged.	No sediment or debris in inlet/outlet pipe screen or inlet/outlet pipe.
Pipe(s) to trench	Damaged Pipes	Cracked, collapsed, broken, or misaligned drain pipes.	No cracks more than 0.25-inch wide at the joint of the inlet/outlet pipe.
Sump	Accumulated Sediment	Sediment in the sump.	Sump contains no sediment.
Access lid	Hard to Open	Cannot be easily opened.	Access lid is repaired or replaced.
Access lid	Buried	Buried.	Access lid functions as designed (refer to record drawings for design intent).
Access lid	Missing Cover	Cover missing.	Cover is replaced.
Rock pad	Inadequate Rock Cover	Only one layer of rock exists above native soil in area 6 square feet or larger, or any exposure of native soil.	Rock pad is repaired/replaced to meet design standards.
Rock pad	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad is repaired/replaced to meet design standards.
Dispersal Area	Erosion	Erosion (gullies/ rills) greater than 2 inches deep in dispersal area.	No eroded or scoured areas. Cause of erosion or scour is addressed.
Dispersal Area	Accumulated Sediment	Accumulated sediment or debris to extent that blocks or channelizes flow path.	No excess sediment or debris in dispersal area. Sediment source is addressed (if feasible).

#33 – Maintenance Standards for Downspout, Sheet Flow, and Concentrated Dispersion Systems (BMP LID.05: Downspout Dispersion System, BMP LID.06: Sheet Flow Dispersion, BMP LID.07: Concentrated Flow Dispersion):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Ponded water	Ponded Water	Standing surface water in dispersion area remains for more than 3 days after the end of a storm event.	System freely drains and there is no standing water in dispersion area between storms. The cause of the standing water (e.g., grade depressions, compacted soil) is addressed.
Vegetation	Plant Survival	Dispersal area vegetation in establishment period (1-2 years, or additional 3rd year) during extreme dry weather).	Vegetation is healthy and watered weekly during periods of no rain to ensure plant establishment.
Vegetation	Lack of Vegetation Allowing Erosion	Poor vegetation cover such that erosion is occurring.	Vegetation is healthy and watered. No eroded or scoured areas are present. Cause of erosion or scour is addressed. Plant species are appropriate for the soil and moisture conditions.
Vegetation	Vegetation Blocking Flow	Vegetation inhibits dispersed flow along flow path.	Vegetation is trimmed, weeded, or replanted to restore dispersed flow path.
Vegetation	Presence of Noxious Weeds	Any noxious or nuisance vegetation which may constitute a hazard to county personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where county personnel or the public might normally be.
Pest Control	Mosquito Infestation	Standing water remains for more than three days following storms.	All inlets, overflows and other openings are protected with mosquito screens. No mosquito infestation present.
Rodents	Presence of Rodents	Rodent holes or mounds disturb dispersion flow paths.	Rodents removed or destroyed, holes are filled, and flow path is revegetated.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#34 – Maintenance Standards for Rain Gardens (LID.08A):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	Mosquitoes	Standing water remains for more than three days following storms.	All inlets, overflows and other openings are protected with mosquito screens. No mosquito infestation present. Rain garden drains freely and there is no standing water between storms. Cause of the standing water is addressed (see “Ponded water”).
Footprint area	Trash	Trash and debris present.	No trash or debris present.
Footprint area	Debris Accumulation	Accumulated leaves in facility.	No leaves clogging outlet structure or impeding water flow.
Earthen side slopes and berms	Erosion	Persistent soil erosion on slopes.	No eroded or scoured areas. Cause of erosion or scour is addressed.
Rockery sidewalls	Unstable Rockery	Rockery side walls are insecure.	Rockery sidewalls are stable (may require consultation with engineer, particularly for walls 4 feet or greater in height).
Rain garden bottom area	Sediment Accumulation	Visible sediment deposition in the rain garden that reduces drawdown time of water in the rain garden.	No sediment accumulation in rain garden, Source of sediment addressed.
Mulch	Lack of Mulch	Bare spots (without mulch cover) are present or mulch depth less than 2 inches.	Facility has a minimum 2- to 3-inch layer of an appropriate type of mulch and is kept away from woody stems.
Splash block inlet	Water Not Properly Directed to Rain Garden	Water is not being directed properly to the rain garden and away from the inlet structure. Water splashes adjacent buildings.	Blocks are reconfigured to direct water to rain garden and away from structure.
Pipe inlet/outlet	Erosion	Rock or cobble is removed or missing and concentrated flows are contacting soil.	No eroded or scoured areas. Cause of erosion or scour is addressed. Cover of rock or cobbles protects the ground where concentrated water flows into the rain garden from a pipe or swale.
Pipe inlet/outlet	Accumulated Debris	Accumulated leaves, sediment, debris or vegetation at curb cuts, inlet or outlet pipe.	Blockage is cleared.
Pipe inlet/outlet	Damaged Pipe	Pipe is damaged	Pipe is repaired/replaced.
Pipe inlet/outlet	Clogged Pipe	Pipe is clogged.	Pipe is clear of roots and debris.
Access	Blocked Access	Maintain access for inspections.	Vegetation is cleared or transplanted within 1 foot of inlets and outlets.
Ponded water	Ponded Water	Excessive ponding water: Ponded water remains in the rain garden more than 48 hours after the end of a storm.	Rain garden drains freely and there is no standing water in the rain garden between storms. Leaf litter/debris/sediment is removed.
Overflow	Blocked Overflow	Capacity reduced by sediment or debris.	No sediment or debris in overflow.
Vegetation	Blocking Site Distances and Sidewalks	Vegetation inhibits sight distances and sidewalks.	Sidewalks and sight distances along roadways and sidewalks are kept clear.

#34 – Maintenance Standards for Rain Gardens (LID.08A):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Vegetation	Vegetation Blocking Pipes	Vegetation is crowding inlets and outlets.	Inlets and outlets in the rain garden are clear of vegetation.
Vegetation	Unhealthy Vegetation	Yellowing: possible Nitrogen (N) deficiency Poor growth: possible Phosphorous (P) deficiency. Poor flowering, spotting or curled leaves, or weak roots or stems: possible Potassium (K) deficiency.	Plants are healthy and appropriate for site conditions.
Vegetation	Weeds	Presence of weeds.	Weeds are removed (manual methods preferred) and mulch is applied.
Summer watering (years 1-3)	Plant Establishment	Tree, shrubs and groundcovers in first three years of establishment period.	Plants are watered during plant establishment period (years 1-3).
Summer watering (after establishment)	Drought Conditions	Vegetation requires supplemental water..	Plants are watered during drought conditions or more often if necessary during post-establishment period (after 3 years).

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#35 – Maintenance Standards for Trees:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Tree	Excess or unhealthy growth	Health of tree at risk, or tree in conflict with other infrastructure.	Tree pruned according to industry standards to promote tree health and longevity.
Tree	NA	Young tree (i.e., within first three years).	Tree provided with supplemental irrigation and fertilization (as needed) during first three growing seasons.
Tree	NA	Evidence of pest activity affecting tree health.	Pest management activities implemented to reduce or eliminate pest activity, and to restore tree health.
Tree	Dead or Declining	Dead, damaged or declining.	Tree is replaced per planting plan or acceptable substitute.
Tree	Dead or Declining	Dead, damaged or declining.	Tree is replaced per planting plan or acceptable substitute.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

#36 – Maintenance Standards for Downspout Full Infiltration Systems (BMP LID.04):

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Rock trench/well	Inflow disruption	Accumulated trash, debris, or sediment on drain rock surface impeding sheet flow into facility.	Sheet flow re-established. Material removed and disposed of in accordance with applicable solid waste requirements.
Rock trench/well	Inflow disruption	Vegetation/moss present on drain rock surface impeding sheet flow into facility.	Material removed and sheet flow re-established.
Rock trench/well	Inflow disruption	Water ponding at surface, or standing water in subgrade observation port.	Inflow to facility is consistent and no ponding is observed. Inlet piping is clear and/or rock or sand reservoirs have been replaced.
Inlet/outlet pipe conveyance	Conveyance blockage	Accumulation of trash, debris, or sediment in roof drains, gutters, driveways drains, area drains, etc.	Conveyance systems are clear of debris and free-flowing.
Inlet/outlet pipe conveyance	Conveyance blockage	Pipes to or from sump, trench, or drywell have accumulated sediment or is plugged.	Pipe systems are clear of debris and free-flowing.
Inlet/outlet pipe conveyance	Conveyance damage	Pipes to or from sump, trench, or drywell is cracked, broken, or misaligned.	Pipe systems are undamaged and free-flowing.
Roof downspout	Splash pad malfunction	Splash pad missing or damaged.	Splash pad installed and functioning correctly
Storage sump	Sediment in sump	Excess sediment accumulate in sump.	Material removed and disposed of in accordance with applicable solid waste requirements.
Storage sump	Access lid problems	Access lid cannot be opened or is missing.	Access lid is functioning as designed. Refer to record drawings to confirm type, function, and required components.

#37 – Maintenance Standards for Dead-End Sump Vaults:

Drainage System Feature	Defect or Problem	Condition When Maintenance Is Needed	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet (includes floatables and non-floatables).	No trash or debris present. Any trash and debris removed from dead-end sump vault.
General	Sediment/ Liquid Accumulation in Vault	Sediment/liquid accumulation in vault exceeds the half the depth of the vault.	No sediment/liquid in dead-end sump vault. <i>(If sediment contamination is a potential problem, sediment should be tested regularly to determine leaching potential prior to disposal.)</i>
General	Damaged Pipe	Inlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
General	Access Cover Damaged/Not Working	Cover cannot be opened or removed, by one person. Corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
Vault Structure	Damage – Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	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.
Vault Structure	Damage – Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Cracks wider than one-half-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 one-fourth inch at the joint of the inlet/outlet pipe.

If you are unsure whether a problem exists, please contact Thurston County for technical assistance.

A vault is a confined space. Visual inspections should be performed aboveground. If entry is required, it should be performed by qualified personnel.

Appendix V-D – Access Roads and Ramps

Access roads provide access from streets and roads 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 vector 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 track hoe can load a truck parked at the pond edge or on the internal berm of a wet pond or combined pond (track hoes 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:

IN.04 Infiltration Basins

D.01 Detention Ponds

D.02 Detention Tanks

D.04 Detention Vaults

WP.02 Wet Ponds

WP.05 Presettling Basins

Design Criteria

The design guidelines for access road are given below.

D-1. 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.

D-2. 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.

D-3. 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 track hoe and truck.

Applicability

An access ramp shall be constructed extending to the bottom of the pond.

Design Criteria

D-4. 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).

D-5. 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:

D.01 Detention Ponds

IN.01 Infiltration Basins

WP.02 Wet Ponds

WP.04 Combined Detention/Wet Pool Facilities.

Design Criteria

Fencing of public drainage ponds shall consist of a minimum 6 foot high WSDOT Type 3 chain link fence, per State Standard Plan L-20.10-03. A minimum of one locking access road gate shall be provided that meets WSDOT Standard Plan L-30.10-02. 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 if the pond is located in an easement, 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-30.10-02.

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-20.10-03 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 V - E.1). Applicant shall submit sign design and proposed location for Administrator acceptance.



FigureV - E.1 Informational Sign for Wet Pond in Olympia, Washington

This section applies to the following BMPs:

LID.08 Bioretention

LID.09 Permeable Paving

LID.11 Full Dispersion

D.01 Detention Ponds

IN.01 Infiltration Basins

WP.02 Wet Ponds

WP.04 Combined Detention and 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:

E-1. 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 V – 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

E-2. 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.

E-3. 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 20-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.

E-4. Infiltration Facilities

The setbacks below apply to the following BMPs:

- LID.04 – Downspout Infiltration Systems
- LID.08 – Bioretention
- LID.09 – Permeable Paving
- IN.01 – Infiltration Basins
- IN.02 – Infiltration Trenches
- IN.03 – Infiltration Vaults and Drywells
- BF.01 – Basic Biofiltration Swale

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 unless different setbacks are noted in the specific BMP design guidelines. All setbacks shall be horizontal unless otherwise specified or modified with written approval of the Thurston County Environmental Health Division for wells and septic systems:

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. May be reduced to 30 feet for infiltration facilities serving a single family residence.

100 feet – from edge of septic drainfield and drainfield reserve area. Infiltration facility shall be located downgradient unless site topography clearly prohibits subsurface flow from intersecting drainfield. May be reduced to 30 feet for infiltration facilities serving a single family residence.

100 feet – from drinking water wells and springs used for drinking water supplies. May be reduced to 30-feet for downspout infiltration facilities serving a single family residence. In wellhead areas, for the siting of “high risk” activities as defined through implementation of the Northern Thurston County Groundwater Management Plan, recommendation HM-14, pp. 5-88, 5-97, and 5-98, the Administrator may require the proponent to supply hydrogeologic analysis and to calculate acceptable separation distances between the activity and the well. Higher setbacks may be required if the well serves a public water system and/or Washington State Department of Health requirements apply for locations within the 1, 5, or 10 year time of travel.

300 feet – from landslide hazard area (as defined by Thurston County Code Title 17.15.600 – Geologic Hazard Areas or Title 24) 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. May be reduced to 50 feet for infiltration facilities serving a single family residence.

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. May be reduced to 10 feet for infiltration facilities serving a single family residence.

Vertical Clearances

1 foot – vertical clearance from the maximum water surface elevation of any open water pond/facility to built structures within 25 feet.

E-5. Ponds

The setbacks below apply to the following BMPs:

- D.01 – Detention Ponds
- WP.01 – Stormwater Treatment Wetlands
- WP.02 – Wet Ponds
- WP.04 – Combined Detention and Wet Pool Facilities
- WP.05 – Presettling Basins and Pretreatment

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 drinking water 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:

- LID.08 Bioretention
- LID.08A Rain Gardens
- D.01 Detention Ponds
- 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.

E-6. 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.

E-7. 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.

E-8. 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.

E-9. 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 V – 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 V – E.2 through E.6 were 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 V – E.5 through E.6 provide planting recommendations for the different planting zones. Tables V – E.5 through E.6 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 V - E.1 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 V - E.2 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 V - E.3 Groundcovers and Grasses Suitable for the Upper Side Slopes of a Biofiltration Swale in Western Washington

Groundcovers	
kinnikinnick*	<i>Arctostaphylos uva-ursi</i>
Epimedium	<i>Epimedium grandiflorum</i>
creeping forget-me-not	<i>Omphalodes verna</i>
--	<i>Euonymus lanceolata</i>
yellow-root	<i>Xanthorrhiza simplissima</i>
--	<i>Genista</i>
white lawn clover	<i>Trifolium repens</i>
white sweet clover*	<i>Melilotus alba</i>
--	<i>Rubus calycinoides</i>
strawberry*	<i>Fragaria chiloensis</i>
broadleaf lupine*	<i>Lupinus latifolius</i>
Grasses (drought-tolerant, minimum mowing)	
dwarf tall fescues	<i>Festuca</i> spp. (e.g., Many Mustang, Silverado)
hard fescue	<i>Festuca ovina duriuscula</i> (e.g., Reliant, Aurora)
tufted fescue	<i>Festuca amethystine</i>
buffalo grass	<i>Buchloe dactyloides</i>
red fescue*	<i>Festuca rubra</i>
tall fescue grass*	<i>Festuca arundinacea</i>
blue oatgrass	<i>Helictotrichon sempervirens</i>

Table V - E.4 Plant Species Appropriate for Area of Periodic or Frequent Standing or Flowing Water (Zone 1)

Species	Common Name	Exposure	Mature Size/Spread	Comments
Trees				
<i>Alnus rubra</i> *	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)
<i>Fraxinus latifolia</i> *	Oregon ash	Sun/partial shade	30 ft. spread	Moist, saturated or ponded soils; flood tolerant; small green-white flowers
<i>Malus fusca</i> *	Pacific crabapple	Sun/partial shade	To 40 feet/35 ft. spread	Tolerant of prolonged soil saturation; produces fruit (do not plant near public walkways)
<i>Salix lucida</i> *	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				
<i>Cornus sericea</i> *	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
<i>Cornus sericea</i> '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.
<i>Cornus sericea</i>	'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
<i>Cornus sericea</i> '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
<i>Lonicera involucrata</i> *	Black twinberry	Partial shade/ Shade	2-8 feet	Moist soils; prefers loamy soils; tolerant of shallow flooding; yellow, tubular flowers attract hummingbirds
<i>Myrica californica</i> *	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, <i>Myrica gale</i> *
<i>Physocarpus capitatus</i> *	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)				
<i>Rosa pisocarpa</i> *	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
<i>Salix purpurea</i> 'Nana'	Dwarf Arctic willow	Sun/partial shade	3-5 feet	Grows well in poor soils; moderately drought tolerant; small yellow flowers in the fall
<i>Spiraea douglasii</i> *	Douglas spirea, Steeplebush	Sun/partial shade	4-7 feet	Moist or dry, to seasonally inundated soils; spikes of small, pink flower clusters
Emergents				
<i>Carex obnupta</i> *	Slough sedge	Sun/partial shade	1-5 feet	Moist to seasonally saturated soils; shiny foliage; excellent soil binder; drought tolerant
<i>Carex stipata</i> *	Sawbeak sedge	Partial shade	10 inches-3 feet	Wet soils; excellent soil binder
<i>Juncus effusus</i> *	Common rush	Sun/partial shade	1-2 feet	Wet soils; evergreen perennial; hardy and adaptable; drought tolerant; small, non-showy flowers
<i>Juncus ensifolius</i> *	Daggerleaf rush	Sun	12-18 inches	Wet soils; shallow water; excellent soil binder
<i>Juncus tenuis</i> *	Slender rush	Sun	.5–2.5 feet	Moist soils; tufted perennial
<i>Scirpus acutus</i> *	Hardstem bulrush	Sun	4-8 feet	Wet soils; favors prolonged inundation; excellent soil binder
<i>Scirpus microcarpus</i> *	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 V - E.5 Plant Species Appropriate for Bioretention Facility Areas Subject to Periodic Saturation During Large Storms (Zone 2)

Species	Common Name	Exposure	Mature Size	Comments
Trees				
<i>Acer truncatum</i>	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
<i>Amelanchier alnifolia</i> *	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
<i>Corylus cornuta</i> *	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
<i>Crataegus douglasii</i> *	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
<i>Fraxinus oxycarpa</i>	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
<i>Rhamnus purshiana</i> *	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
<i>Salix scouleriana</i> *	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
<i>Salix sitchensis</i> *	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
<i>Thuja plicata</i> *	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				
<i>Acer circinatum</i> *	Vine maple	Filtered sun/shade	To 25 feet	Dry to moist soils; tolerant of shade and clay soils; excellent soil binder; beautiful fall color
<i>Hamamelis intermedia</i>	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)				
<i>Oemleria cerasiformis</i> *	Indian plum/Osoberry	Sun/partial shade	5-16 feet	Moist to dry soils; prefers shade; tolerates fluctuating water table
<i>Philadelphus x lemoinei</i>	'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
<i>Ribes lacustre</i> *	Black swamp gooseberry	Partial shade	1.5–3 feet	Moist soils; deciduous shrub; reddish flowers in drooping clusters; dark purple berries; <i>R. divaricatum</i> * (Wild gooseberry) grows to 5 feet and is also an option; attracts butterflies, but is very thorny
<i>Rosa nutkana</i> *	Nootka rose	Sun/partial shade	6-10 feet	Moist to fairly dry soils; tolerates inundation and saturated soils; aggressive spreader; fruits persist; less thorny than <i>R. rugosa</i>
<i>Rosa rugosa</i>	Rugosa rose	Sun	To 8 feet	Drought resistant; hardy, vigorous and aggressive; highly prickly; fragrant white to purple flowers; fruits persist
<i>Rubus parviflorus</i> *	Thimbleberry	Sun/partial shade	4-10 feet	Moist to dry soils; white flowers; red berries; makes thickets and spreads easily
<i>Rubus spectabilis</i> *	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
<i>Sambucus racemosa</i> *	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
<i>Symphoricarpos albus</i> *	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
<i>Vaccinium parvifolium</i> *	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
<i>Aquilegia formosa</i> * / 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
<i>Asarum caudatum</i> * / Wild ginger	Partial shade/shade	To 10 inches	Mid spring	Moist organic soils; heart-shaped leaves; reddish-brown flowers
<i>Aster chilensis</i> * / Common California aster	Sun	1.5 – 3 feet	June - September	Moist soils; white to purple flowers
<i>Aster subspicatus</i> * / Douglas aster	Sun	.5 – 2.5 feet	June - September	Moist soils; blue to purple flowers
<i>Camassia quamash</i> * / 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
<i>Camassia leichtlinii</i> / 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
<i>Iris douglasiana</i> * / 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
<i>Iris foetidissima</i> / Gladwin iris	Sun/partial shade	1-2 feet	May	Moist to dry, well-drained soils; pale lilac flower; also called Stinking Iris
<i>Juncus tenuis</i> * / Slender rush	Sun	6 inches – 2.5 feet		Moist soils; yellow flowers
<i>Iris sibirica</i> / Siberian Iris	Sun	1-2.5 feet	Late spring – early summer	Moist soils; deep blue, purple to white flowers
<i>Tellima grandiflora</i> * / Fringecup	Partial sun/shade	1-3 feet	March - June	Perennial preferring moist soils; yellowish-green to pink flowers
<i>Tiarella trifoliata</i> * / 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
<i>Tolmiea menziesii</i> * / Youth-on-age/Piggy-back plant	Partial shade/shade	1-2 feet	April - August	Moist soils; brownish-purple flowers; also makes an effective groundcover
<i>Viola species</i> * / Violets	Partial shade/shade	6-12 inches	Late spring – early summer	Moist soils; yellow to blue flowers

Table V - E.6 Plant Species Appropriate for Rarely Inundated Areas of Bioretention Facility (Zone 3)

Trees				
Species / Common Name	Exposure	Mature Size	Time of Bloom	Comments
<i>Arbutus unedo</i> / 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
<i>Calocedrus decurrens</i> * / 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
<i>Chamaecyparis obtusa</i> / 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
<i>Cornus</i> 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 <i>C. florida</i> (Eastern dogwood), or <i>C. nuttallii</i> * (Pacific dogwood) or hybrid 'Eddie's White Wonder'. Also, <i>C. kousa</i> for small tree/ shrub which is resistant to anthracnose
<i>Pinus mugo</i> / 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
<i>Pinus thunbergiana</i> / Japanese black pine	Sun	To 100 feet/ 40 ft. spread		Dry to moist soils; hardy; fast growing
<i>Prunus emarginata</i> * / 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
<i>Prunus virginiana</i> / 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
<i>Pseudotsuga menziesii</i> * / 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
<i>Quercus garryana</i> * / 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
<i>Holodiscus discolor</i> * / Oceanspray	Sun/partial shade	To 15 feet	June - July	Dry to moist soils; drought tolerant; white to cream flowers; good soil binder
<i>Mahonia aquifolium</i> * / 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
<i>Philadelphus lewisii</i> * / 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
<i>Pinus mugo pumilio</i> / 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
<i>Potentilla fruticosa</i> / 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'
<i>Ribes sanguineum</i> * / 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
<i>Rosa gymnocarpa</i> * / 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
<i>Abelia x grandiflora</i> / 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
<i>Arbutus unedo</i> '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

<i>Cistus purpureus</i> / Orchid rockrose	Sun	To 4 feet	June - July	Moist to dry well-drained soils; drought resistant; fast growing; reddish purple flowers
<i>Cistus salvifolius</i> / 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
<i>Escallonia x exoniensis</i> '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
<i>Osmanthus delavayi</i> / 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
<i>Osmanthus x burkwoodii</i> / Devil wood	Sun/partial shade	4-6 feet	March - April	Drought tolerant once established; masses of small, white fragrant flowers
<i>Rhododendron</i> / 'PJM' hybrids	Sun/partial shade	To 4 feet	Mid – late April	Moist to fairly dry soils; well drained organic soil; lavender to pink flowers
<i>Stranvaesia davidiana</i>	Sun	6-20 feet	June	Moist soils; white flowers in clusters; showy red berries
<i>Stranvaesia davidiana</i> / undulata	Sun	To 5 feet	June	Moist soils; lower growing irregularly shaped shrub; great screening plant
<i>Vaccinium ovatum</i> * / 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
<i>Arctostaphylos uva-ursi</i> * / 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
<i>Gaultheria shallon</i> * / Salal	Partial shade/shade	3-7 feet	March - June	Dry and moist soils; white or pinkish flowers; reddish-blue to dark-purple fruit
<i>Fragaria chiloensis</i> * / Wild/Coastal strawberry	Sun/partial shade	10 inches	Spring	Sandy well drained soils; flowers white; small hairy strawberries; evergreen; aggressive spreader

Groundcover – Evergreen				
Species / Common Name	Exposure	Mature Size	Time of Bloom	Comments
<i>Helianthemum nummularium</i> / 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
<i>Lavandula angustifolia</i> / Lavender	Sun/partial shade	To 1.5 feet	June - August	Adaptable to various soils; blue, lavender, pink to white flowers, semi-evergreen aromatic perennial
<i>Mahonia nervosa</i> * / 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
<i>Mahonia repens</i> / Creeping mahonia	Sun/partial shade	3 feet	April - June	Dry to moist soils; drought resistant; yellow flowers; blue berries; native of Eastern Washington
<i>Penstemon davidsonii</i> * / 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
<i>Achillea millefolium</i> * / 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
<i>Anaphalis margaritaceae</i> / Pearly everlasting	Sun/partial shade	To 18 inches		Drought tolerant perennial; spreads quickly; attracts butterflies
<i>Bromus carinatus</i> * / Native California brome	Sun/partial shade	3-5 feet		Dry to moist soils; tolerates seasonal saturation
<i>Carex buchananii</i> / 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

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<i>Carex comans</i> / '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
<i>Coreopsis</i> spp. / Tick-Seed	Sun	1-3 feet		Dry to moist soils; drought tolerant; seeds attract birds; annual and perennial varieties; excellent cut flowers
<i>Echinacea purpurea</i> / Purple coneflower	Sun	4-5 feet		Prefers well drained soils; hardy perennial; may need occasional watering in dry months
<i>Elymus glaucus</i> * / 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
<i>Dicentra formosa</i> * / Pacific bleeding- heart	Sun/shade	6-20 inches	Early spring - early summer	Moist, rich soils; heart-shaped flowers
<i>Erigeron speciosus</i> * / Showy fleabane	Sun/partial shade	To 2 feet	Summer	Moist to dry soils; dark violet or lavender blooms; fibrous roots
<i>Festuca ovina</i> '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
<i>Festuca idahoensis</i> * / Idaho fescue	Sun/partial shade	To 1 foot		Bluish-green bunching perennial grass; drought tolerant
<i>Fragaria vesca</i> * / Wood strawberry	Partial shade	To 10 inches	Late spring - early summer	Dry to moist soils; white flowers
<i>Gaura lindheimeri</i> / Gaura	Sun	2.5-4 feet		Perennial; fairly drought tolerant and adaptable to varying soil types; long blooming period
<i>Geum macrophyllum</i> * / 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
<i>Geranium maculatum</i> / Spotted geranium	Sun/shade	To 1.5 feet	July	Moist, well-drained soils; low perennial; pale pink, blue to purple flowers
<i>Geranium sanguineum</i> / Cranesbill	Sun/partial shade	To 1.5 feet	May - August	Moist soils; deep purple almost crimson flowers

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<i>Helichrysum italicum</i> / Curry Plant	Sun	To 2 feet	Summer	Moist or dry soils; hardy evergreen perennial; a good companion to lavender; bright yellow flowers; fragrant
<i>Helictotrichon sempervirens</i> / 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
<i>Hemerocallis fulva</i> / 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
<i>Heuchera americana</i> / 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
<i>Heuchera micrantha</i> / '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 <i>H. sanguinea</i> for bright red flowers
<i>Lupinus</i> * 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
<i>Lupinus bicolor</i> * / Two-color lupine	Sun	4 inches - 1.5 feet	Spring	Dry gravelly soils; small-flowered; annual
<i>Lupinus latifolius</i> * / Broadleaf lupine	Sun	To 1 foot	June - August	Dry to moist soils; perennial; bushy herb; bluish flowers
<i>Lupinus polyphyllus</i> * / Large-leaved lupine	Sun	To 3 feet	Spring - summer	Dry to moist, sandy to gravelly soils; perennial
<i>Maianthemum dilatatum</i> * / False lily-of-the-valley	Partial shade/shade	3-12 inches	Spring	Prefers moist soils; small, white flowers; light-green to red berries

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<i>Pennisetum alopecuroides</i> / 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 <i>P. caudatum</i> (White-flowering fountain grass) and <i>P. alopecuroides</i> cultivars 'Hameln' and 'Little Bunny' (Dwarf fountain grass)
<i>Pennisetum orientale</i> / 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
<i>Penstemon fruticosus</i> / Shrubby penstemon	Sun	8–10 inches	May	Prefers well-drained soils; evergreen perennial; drought tolerant; violet-blue flowers 1 inch long attract hummingbirds
<i>Polystichum munitum</i> * / Swordfern	Partial shade/ Deep shade	2-4 feet		Prefers moist, rich soil conditions, but drought tolerant; large evergreen fern
<i>Potentilla gracilis</i> * / Graceful cinquefoil	Sun	1-2 feet	July	Moist to dry soils; yellow flowers
<i>Rudbeckia hirta</i> / 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
<i>Smilacina racemosa</i> * / False Solomon's seal	Partial sun/shade	1-3 feet	April - May	Moist soils; creamy white flowers; red berries