Washington State Department of Transportation

# Publications Transmittal

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## Remarks and Instructions

### *What's changed in the Highway Runoff Manual for 2012?*

The *Highway Runoff Manual* has undergone the following revisions for March 2012:

- For projects going to advertisement (AD) after July 1, 2012, WSDOT shall apply the technical standards in the 2011 version of the Washington State *Highway Runoff Manual* (HRM) for the planning, design, operation, and maintenance of stormwater facilities.
- Revisions to Chapters 2, 3, and 4 are marked with revision marks. The revisions to Chapters 5 and 6 were extensive enough to consider both chapters complete rewrites; therefore, revision marks are not shown in these chapters.

For more specific changes to the HRM, see the 2011 HRM Revision Summary on page 3.

### *Need more information?*

Contact the WSDOT HQ Highway Runoff Unit:
www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

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HQ Design Office Signature
/s/ Mark Maurer, L.A., P.E.

## *Remove/Insert instructions for those who maintain a printed manual:*

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## *General*

- The entire HRM has a new date of November 2011.
- All chapters and appendices with changes are marked with revision marks, except Chapters 5 and 6, which are considered complete rewrites. If using a printed manual, both chapters shall be removed in their entirety and replaced with the revised chapters.
- Revision marks (underlines and sidebars) are used as a convenience to show what has changed.

## 2011 HRM Revision Summary

- Added TMDL guidance, including a new Section 2-6.4 and a reference to the GIS layer in Chapter 3.
- Revised the Appendix 2A Engineering Economic Feasibility checklist to improve usability.
- Deleted repetitive conditions for minimum requirement exemptions.
- Revised the MGSFlood correlation factor to reflect 15-minute step interval.
- Moved the Chapter 4 detailed hydrology discussion for HSPF and SBUH to the *Hydraulics Manual*, Chapter 2.
- Revised retrofit guidance to improve clarity.
- Modified the Soil Suitability Criteria 5 to allow a 12 in/hr infiltration rate when bioretention soils are used.
- Added additional guidance for modeling infiltration ponds.
- Revised the definition and description of several key terms to improve clarity.
- Updated broken web links throughout the manual.
- Replaced the longitudinal and lateral slope limits for sheet flow BMPs with a resultant slope.
- Made improvements and updates to the BMP selection process flow charts.
- Added guidance for sizing MFD underdrains.
- Revised the MFD design guidance to improve constructability, including modifications to MFD figures.
- Added two new BMPs: Compost Amended Biofiltration Swale and Bioretention Area.
- Revised the embankment slope limits up from 15% to 33% for dispersion and vegetated filter strips.
- Modified constructed stormwater wetland guidance to improve constructability and vegetation establishment.
- Updated most of the figures in Chapter 5 to improve clarity.
- Added a one-page summary or "menu" to each BMP to provide a quick overview of the BMP: function, limitations, requirements, maintenance needs, and TMDLs applicability.
- Clarified the freeboard height requirement for biofiltration swales.
- Updated Chapter 6 for consistency with permit changes as well as general improvement for clarity.
- Removed the Straw Bale BMP from Chapter 6 as an approved BMP because it has been removed from the Department of Ecology's manual as an approved BMP.

Washington State
Department of Transportation

# Highway Runoff Manual

M 31-16.03

November 2011

**Environmental and Engineering Programs**
Design Office

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# Highway Runoff Manual Table of Contents

# CHAPTER 1

# Introduction

# Chapter 1 Table of Contents

# Chapter 1 Introduction

## 1-1 Basis for Manual Development

### 1-1.1 Purpose, Need, and Scope

The *Highway Runoff Manual* (HRM) was developed to direct the planning and design of stormwater management facilities for new and redeveloped Washington State highways, rest areas, park-and-ride lots, ferry terminals, and highway maintenance facilities throughout the state. The Washington State Department of Transportation (WSDOT) manages its stormwater discharges to protect water quality, beneficial uses of the state's waters, and the aquatic environment in general. Conformance to the provisions of this manual will result in consistent design procedures statewide and should support acceptance of WSDOT stormwater planning by regulatory agencies. Guidelines are provided for both western and eastern Washington, taking into account variations in climatic, geologic, and hydrogeologic conditions.

This manual's approach is consistent with WSDOT's objective of implementing a statewide highway runoff program that applies sound engineering principles to satisfy federal and state requirements. While federal and state stormwater requirements are subject to change, this manual is based on the best practicable engineering approaches to stormwater management currently available for WSDOT facilities.

The HRM establishes minimum requirements and provides uniform technical criteria for avoiding and mitigating impacts to water resources associated with the development of state-owned and -operated transportation infrastructure systems and for reducing and minimizing water resource impacts associated with the redevelopment of those facilities. The manual will receive periodic updates to enhance content clarity, as well as reflect changes in regulations, advances in stormwater management, and improvements in design tools. To ensure you are using the most current design criteria, users referencing printed copies and CD ROM versions of the manual should continually consult the HRM Resource Web Page (www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm) for postpublication updates. To receive e-mail announcements regarding HRM-related updates, training opportunities, and improvements in design tools, send a blank e-mail to: subscribe-stormwater_list@lists.wsdot.wa.gov. You will then receive an e-mail asking you to confirm your subscription.

Primary users of this manual include:

- WSDOT engineers who design drainage systems and develop Hydraulic Reports; temporary erosion and sediment control (TESC) plans; and spill prevention, control, and countermeasures (SPCC) plans.
- WSDOT project inspectors in construction project offices responsible for inspection and maintenance of TESC plans.

- WSDOT maintenance staff responsible for developing roadside management plans and roadway maintenance practices.
- Developers of projects adjacent to WSDOT right of way that are linked to roadway and drainage facilities within the right of way.
- Consultants hired to develop Hydraulic Reports, TESC plans, and SPCC plans or design stormwater facilities for WSDOT.
- Counties, municipalities, and other jurisdictions that design transportation projects supported by federal or state funding.

The Headquarters (HQ) Hydraulics Section and the HQ Environmental Services Office (ESO) are jointly responsible for manual revisions and implementation oversight. The design criteria and procedures presented in this manual supersede conflicting information presented in other previously published WSDOT manuals.

Many aspects of stormwater management for environmental protection relate to drainage collection and conveyance systems, culverts, drainage outfalls, and a variety of other hydraulic features. This manual makes frequent references to the *Hydraulics Manual*, which is dedicated in large part to addressing the analysis and design of hydraulic features. The intent is that the two manuals are to be used in tandem for complete analysis and design of stormwater facilities for roadway and other transportation infrastructure projects.

## 1-1.2 Review Process and Regulatory Standing of the Manual

The *Highway Runoff Manual* (HRM) covers the entire state and meets the level of stormwater management established by the Washington State Department of Ecology (Ecology) in its *Stormwater Management Manual for Western Washington* (SMMWW) and *Stormwater Management Manual for Eastern Washington* (SMMEW). Stormwater management requirements for Washington State were developed to protect receiving waters from the adverse hydrologic change and water quality degradation that can occur with project development. The requirements vary for western and eastern Washington due to differences in climate, soils, receiving water characteristics, and environmental concerns. Ecology has been involved in a review capacity throughout the development of this manual.

The guidelines and criteria in the HRM also support WSDOT in its efforts to comply with the requirements of the federal Endangered Species Act (ESA). National Oceanic and Atmospheric Administration (NOAA) Fisheries and the United States Fish and Wildlife Service (USFWS) did not formally review the Ecology stormwater management manuals for programmatic "concurrence" under the ESA. Thus, to accomplish WSDOT's objective to develop stormwater management design criteria that meet all regulatory requirements, NOAA and USFWS were invited to comment on the HRM during the development process.

## 1-1.3 Presumptive vs. Demonstrative Approaches to Protecting Water Quality

This manual is intended to provide project engineers and designers with technically sound stormwater management practices, equivalent to guidance provided in Ecology's stormwater management manuals, to achieve compliance with federal and state water quality regulations through the *presumptive approach*. Engineers and designers have the option of not following the stormwater management practices in this manual and seeking compliance via the *demonstrative approach*. However, this requires (1) demonstrating that the project will not adversely impact water quality by collecting and providing appropriate supporting data to show that the alternative approach protects water quality and satisfies state and federal water quality laws, and (2) performing the technology-based requirements of state and federal law.

Both the *presumptive* and *demonstrative approaches* are based on best available science and result from existing federal and state laws that require stormwater management systems to be properly designed, constructed, maintained, and operated to:

- Prevent pollution of state waters and protect water quality, including compliance with state water quality standards.
- Satisfy state requirements for all known available and reasonable methods of prevention, control, and treatment of wastes prior to discharge to waters of the state.
- Satisfy the federal technology-based treatment requirements under 40 CFR Part 125.3.

Under the *demonstrative approach*, the timeline and expectations for providing technical justification of stormwater management practices depend on the complexity of the individual project and the nature of the receiving water environment. In each case, the engineer or designer may be asked to document, to the satisfaction of Ecology or other approval authority, that the practices selected will result in compliance with the water quality protection requirements of the permit or of other local, state, or federal water quality-based project approval conditions. This approach may be more cost-effective for large, complex, or unusual types of projects.

Projects that follow the stormwater best management practices (BMPs) contained in this manual are presumed to have satisfied this demonstration requirement and do not need to provide technical justification to support the selection of BMPs. Following the stormwater management practices in this manual means adhering to the criteria provided for proper selection, design, construction, implementation, operation, and maintenance of BMPs. This approach will generally be more cost-effective for typical WSDOT projects.

## 1-1.4 Overview of Manual Development

The original *Highway Runoff Manual* was published in 1995 for primary application in the Puget Sound basin. The manual was designed to be consistent with Ecology's *Stormwater Management Manual for the Puget Sound Basin* (published in 1991), with specific guidance for transportation projects. The *Stormwater Management Manual for the Puget Sound Basin* became obsolete when Ecology published the SMMWW. Ecology's publication of the SMMEW provided the first comprehensive stormwater management manual for the eastern areas of the state. The guidance included in these two manuals forms the basis for this revised HRM and supports WSDOT's mission by providing technical and uniform criteria consistent with the intent of Ecology's stormwater guidance for all areas of the state.

This manual represents a culmination of years of extensive research, collaboration, and negotiation by an interdisciplinary technical team made up of water quality, stormwater, and erosion control specialists; designers; hydrologists; geotechnical and hydraulics engineers; landscape architects; and maintenance staff. The technical team also included several county representatives and benefited from a close working relationship with Ecology staff (with work also contributed by consultants and outside reviewers). The technical team recognized that it is inefficient, and in some instances ineffective, to attempt to emulate how local jurisdictions manage runoff from residential, commercial, and industrial land uses. Consequently, its approach to revising the manual took into consideration the following:

1. WSDOT needs a statewide approach for managing stormwater that recognizes the differences in climate, soils, and land uses in eastern and western Washington.

2. Highway projects are linear in nature and, as such, are faced with practical limitations in terms of locating and maintaining stormwater management facilities within state-owned right of way.

3. WSDOT has limited control over many pollution sources entering its right of way, such as pollutants generated from atmospheric deposition, vehicle operation, litter, organic debris, and surrounding land uses.

4. The option to discharge runoff to local jurisdictions' drainage systems is not always available.

5. WSDOT lacks funding mechanisms (such as stormwater utility fees) and land use controls (such as zoning and land use ordinances) available to local governments.

6. WSDOT must be accountable to taxpayers to provide cost-effective stormwater facilities. WSDOT cannot infringe on the Legislature's authority to allocate gasoline tax funds to transportation programs and projects by agreeing to measures that significantly increase project costs.

## 1-1.5 Overview of Federal, State, and Local Regulations Related to Stormwater

Water pollution control was formally established as a federal concern when Congress passed the first Water Pollution Control Act in 1948. For many years, the emphasis was on control of point source pollution; typically, outfalls from industrial factories and municipal sewage treatment plants. Since the early 1980s, water pollution control efforts have broadened to address non-point sources of pollution. Pollution collected and carried by stormwater often originates from nonpoint sources, but may be collected, conveyed, and discharged as a point source.

Major amendments to the Federal Water Pollution Control Act (which has become known as the Clean Water Act) in 1987 addressed stormwater pollution by extending the National Pollutant Discharge Elimination System (NPDES) permit program to include stormwater discharges. Also in 1987, the Puget Sound Water Quality Authority (now the Puget Sound Action Team) issued the Puget Sound Water Quality Management Plan. This plan called for a Highway Runoff Program, which was subsequently developed in detail by Ecology and codified in WAC 173-270.

### 1-1.5.1 Phase I NPDES Municipal Stormwater General Permits

In 1995, Ecology prepared NPDES municipal separate storm sewer permits for several municipalities with populations greater than 100,000. The Phase I NPDES permittees included the cities of Seattle and Tacoma; the counties of Clark, King, Pierce, and Snohomish; and WSDOT.

The Phase I NPDES Municipal Stormwater General Permit (originally effective through the year 2000 and subsequently extended by Ecology pending reissuance of the Phase I municipal permit and issuance of the WSDOT municipal permit) requires WSDOT to implement a stormwater program within the Phase I jurisdictional areas, including minimum requirements and BMPs equal to those found in the *Stormwater Management Manual for the Puget Sound Basin* or equivalent. The stormwater management plan developed in accordance with this Phase I permit requires WSDOT to "reduce pollutants in discharges to the maximum extent practicable (MEP)." To attain future compliance with its revised NPDES permit, and to continue to meet the general standards of all known, available, and reasonable technology (AKART) and MEP, WSDOT must implement a stormwater program that includes minimum requirements and best management practices consistent with those found in the SMMWW and the SMMEW.

### 1-1.5.2 NPDES Construction Stormwater General Permit

Beginning in 1995, WSDOT construction projects were also required to comply with the Ecology NPDES requirements specific to construction activities. The threshold for a site disturbance area that typically triggered an NPDES Construction Stormwater General Permit was 5 acres. Some large WSDOT projects with particularly sensitive environmental concerns are required to obtain individual NPDES construction stormwater permits from Ecology.

NPDES construction stormwater permits require:

- Detailed documentation of temporary erosion and sediment control (TESC) measures.
- Implementation of TESC measures.
- Other pollution prevention and control measures.

Activities at sites such as the Washington State Ferries Eagle Harbor maintenance facility are covered under the NPDES Industrial Stormwater General Permit. Beginning in 1999, several fish species in Washington State were listed as threatened or endangered under the ESA, thus expanding the necessity for stormwater runoff control at WSDOT project sites in many parts of the state. The ESA requires that a biological evaluation be conducted to determine potential project impacts on threatened or endangered species, including impacts associated with stormwater. Stormwater management measures implemented at many WSDOT sites have been shaped by requirements necessary to avoid, minimize, or reduce potential impacts to threatened and endangered species under the ESA. The Section 7 Consultation process serves as the primary ESA compliance pathway for WSDOT projects.

### 1-1.5.3 Phase II NPDES Municipal Stormwater General Permits

Beginning in March 2003, the U.S. Environmental Protection Agency (U.S. EPA) extended the NPDES permit program (Phase II) for municipal separate storm sewer systems to encompass many more jurisdictions. Ecology's issuance of permits under Phase II of the NPDES program extended requirements for effective stormwater management to most of the state's urbanized areas. Also in 2003, the NPDES permit program lowered the threshold for construction projects that require general NPDES construction stormwater permits to 1 acre of ground disturbance; thus encompassing a much higher percentage of WSDOT projects. Ecology's reissuance of the NPDES Construction Stormwater General Permit incorporates additional regulations of the U.S. EPA's nationwide Phase II program and requires implementation of construction site BMPs in conformance with the SMMWW and SMMEW.

Additional state regulations applicable to stormwater include:

- Implementation of Total Maximum Daily Load (TMDL) plans by Ecology and local partners, resulting in limitations on pollutants in stormwater discharges. TMDLs are addressed in Section 303(d) of the Clean Water Act.
- Conditions of the underground injection control (UIC) program (WAC 173-218). The UIC program is administered by Ecology to implement provisions of the federal Safe Drinking Water Act. It applies to subsurface drainage facilities (such as drywells) that discharge water to the ground.
- Site-specific Section 401 (of the Clean Water Act) Water Quality Certifications issued by Ecology in relation to projects that require federal Section 404 permits for in-water work. Section 404 of the Clean Water Act provides federal regulatory protection for wetlands and other waters of the United States.

- Conditions of aquatic lands use authorizations. The aquatic lands use authorization is administered by the Washington State Department of Natural Resources (DNR) and may apply to stormwater outfalls per RCW 79.90 through 79.96 and WAC 332-30.
- State surface water quality standards (WAC 173-201A).

In most instances, local stormwater management requirements will not override the requirements in this manual. RCW 47.01.260(1) grants WSDOT plenary power in planning, locating, designing, constructing, improving, repairing, operating, and maintaining state highways, including drainage facilities and channel changes necessary for the protection of such highways. This grant of authority means that, without express legislative direction, WSDOT is not subject to local ordinances in areas within WSDOT's purview, and attempts by local agencies to enforce such preempted ordinances are unconstitutional.

### 1-1.5.4 Local Requirements

With respect to all state highway right of way in the Puget Sound basin under WSDOT control, WSDOT must use the HRM to direct stormwater management for its existing and new facilities and rights of way, as addressed in WAC 173-270-030(1). Stated exceptions where more stringent stormwater management requirements may apply are addressed in WAC 173-270-030(3)(b) and (c).

- When a state highway is located in the jurisdiction of a local government that is required by Ecology to use more stringent standards to protect the quality of receiving waters, WSDOT will comply with the same standards to promote uniform stormwater management. The key emphasis here is that Ecology has to require the local government to use more stringent standards (such as via an existing TMDL) rather than the local jurisdiction simply doing so of its own accord.
- WSDOT will comply with standards identified in watershed action plans for WSDOT rights of way, as required by WAC 400-12-570. This is similar to the condition described above; however, its application is complicated by the fact that WAC 400-12-570 (*Action Plan Implementation*) was repealed on December 7, 1991.

Other instances where more stringent local stormwater standards can apply are projects subject to tribal government standards and to the stormwater management-related permit conditions associated with critical area ordinances (under the Growth Management Act) and shoreline master programs (under the Shoreline Management Act). In addition, if WSDOT elects and is granted permission to discharge stormwater runoff into a utility's storm sewer system, WSDOT will comply with the storm sewer utility's standards for stormwater quality and quantity.

Issuance of WSDOT's statewide municipal NPDES permit will further reduce the number of stormwater-related permits required by no longer regulating stormwater discharges under *Section 401 Water Quality Certification* and *Hydraulic Project Approval* permits.

This manual represents a set of tools and options that supports compliance with local, state, and federal regulations related to stormwater management. Incorporation of local and regional stormwater requirements into project design is further discussed in Sections 2-6 and 2-7.

# 1-2 The Importance of Stormwater Management

## 1-2.1 Background and Objectives

Land development can have a dramatic impact on the natural hydrologic cycle. In western Washington, land cover that once consisted primarily of mature forest has been replaced in many areas with impervious surfaces such as rooftops, parking areas, roadways, and manicured landscapes. Similar transitions have occurred in eastern Washington where prairies, pine forests, shrub-steppe landscapes, and channeled scablands have been replaced by farmland and urbanization. The creation of impervious surfaces has two main effects on the hydrologic cycle: a reduction in infiltration and an associated increase in surface runoff. Reducing land cover, mainly by tree removal, can also significantly increase runoff, even though pervious surfaces remain.

The creation of impervious surfaces increases both the volume of surface runoff and the peak rate of flow resulting from a storm event, leading to increased flooding rate, extent, and severity. Increasing impervious surfaces also decreases the time to peak discharge. The higher velocity and greater quantity of flow may cause streambank erosion and aquatic habitat destruction that could potentially result in geomorphological impacts. Sediment from cleared areas and eroded and unstable streambanks is deposited downstream, filling ponds, streambeds, and stormwater facilities. Construction projects with exposed and unstabilized soils, especially on slopes, can be significant sources of soil and sediment that adversely affect drainage systems and receiving waters.

Stormwater and snowmelt runoff function as the transport mechanisms for nonpoint sources of pollution, as well as for the atmospheric deposition of airborne pollutants. In addition to the hydrologic effects from runoff, land development significantly increases the amount of pollutants available for entrainment in stormwater and snowmelt runoff. Increased pollutant loadings resulting from human habitation and activity can result in the measurable degradation of receiving waters.

A more subtle impact of development on the hydrologic cycle is the reduction of infiltration. Infiltration of precipitation, stormwater, and snowmelt runoff recharges groundwater and produces interflow: the subsurface flow particularly common in many of the soils in Washington State. Shallow groundwater is typically the source of summer base flows in streams, and it sustains water levels in some wetlands. Reduction in infiltration can dry up small streams and wetlands in the summer and, in turn, render aquatic systems uninhabitable during these times.

## 1-2.2 Impacts of Roadway Runoff

Runoff from roadways and associated facilities may contain suspended solids; oil and grease (hydrocarbons); and heavy metals such as lead, copper, and zinc. Many of the pollutants in roadway runoff are attributed to motorized vehicle operation. The wearing of brake linings, thrust bearings, engine crankshafts, and tires results in the deposition of numerous heavy metal particles on the roadway surface. The dripping of oil and other engine fluids deposits additional heavy metals, phosphorus, hydrocarbons, and other toxic organic compounds on the roadway surface. Atmospheric deposition of airborne pollutants via rain and snow events also contributes to the pollutant content on roadways, particularly in heavily urbanized areas. Litter, organic debris, and other materials that are common in roadway corridors also contribute to the pollutant loading in roadway runoff. The motor vehicle industry is engaged in various efforts to reduce the extent to which vehicles produce pollutants. These include the manufacture of brake pads with less copper content and engines powered by alternative energy sources, which may reduce pollutant loadings in roadway runoff in the future.

Transportation projects, which tend to be linear in nature, may encompass multiple drainage basins and impact multiple receiving waters. While the runoff discharged from highways and other parts of the transportation infrastructure represents only a portion of the runoff affecting nearby water bodies, it contributes to the cumulative degradation of those waters. The effects of stormwater runoff on receiving waters are typically a function of the proximity of development site discharges to the receiving water body and the size of the receiving water body relative to discharge volumes and flow rates. The impacts of stormwater runoff from state-owned rights of way vary widely, depending on surrounding land use, climate patterns, soil characteristics, receiving water characteristics, and other local factors.

The construction of roadway improvement projects also contributes to surface runoff contamination, due mainly to suspended solids associated with soil erosion. Construction activities can also result in stormwater and nearby surface waters being contaminated with oil, heavy metals, and other pollutants resulting from vehicle operations and maintenance; runoff from areas where solvents, paints, and other liquid materials are used and stored; leaching of asphalt emulsion and concrete slurry; and a variety of other sources. Those impacts can be severe and long-lasting if appropriate actions are not taken to control construction site runoff quality.

## 1-2.3 Management of Runoff from Transportation Projects

The key to controlling problems created by stormwater is the application of best management practices (BMPs). BMPs are defined as physical, structural, and managerial practices that, when used individually or in combination, prevent or reduce pollution of water and attenuate peak flows and volumes. BMPs targeting the types of problems discussed above are typically categorized as *temporary* or *permanent*. Temporary BMPs are typically used only during the construction phase of a project. Permanent BMPs are used to control and treat runoff throughout operation of the highway, park-and-ride lots, rest areas, ferry terminals, or other transportation project sites. Some BMPs, such as detention ponds, may function in both temporary and permanent BMP capacities.

Temporary BMPs are designed to prevent the introduction of pollutants into runoff for the duration of the construction project and are concurrent with construction of the permanent BMPs. Common examples of temporary BMPs include mulching of bare ground, silt fencing, and spill control and containment. Permanent runoff treatment BMPs include facilities that remove pollutants from runoff by simple gravity settling of particulate matter and by filtration, biological uptake, and soil adsorption (typical examples include wet ponds and vegetated swales). Flow control BMPs reduce the peak rate of runoff during a storm event by storing the flow and releasing it at a slower rate, thus protecting stream ecosystems from excessive erosion (typical examples are detention ponds and dry vaults). Permanent BMPs are used to treat highway runoff for the design life of the project site.

Stormwater problems can be grouped into two categories: (1) impacts associated with existing impervious areas, and (2) impacts arising from new impervious areas if no stormwater controls are used. New projects that must comply with this manual are required to provide stormwater management for the new impervious surfaces.

Project designers should keep in mind that the ultimate goal is to provide practicable stormwater management for runoff from the existing impervious surfaces and protect the beneficial uses of receiving waters. Existing highway sections that have no stormwater treatment or flow control, or where treatment or flow control is substandard, may eventually be retrofitted in accordance with WSDOT's stormwater retrofit program. If it is cost-effective to include a BMP to address the entire project site, even though only a portion of the facility is undergoing expansion or redevelopment, the BMP should be designed and constructed to address the larger area. Guidelines for determining whether it is cost-effective to provide stormwater management beyond what is required are in Section 3-4.

In some cases, it may not be practicable to provide treatment or flow control for runoff from project-site areas, due to various constraints such as site limitations, costs, or other obstacles. If on-site mitigation is not feasible, opportunities that use this manual's off-site treatment options must be identified. Sections 2-7.3 and 2-7.4 present a process for analyzing off-site treatment options. WSDOT will continue to develop, pursue, and expand off-site options. However, these options are currently constrained to the "in-kind" variety, as Ecology has stated it will not authorize the use of "out-of-kind" mitigation options.

## 1-3 Organization of This Manual

The *Highway Runoff Manual* (HRM) is divided into six chapters. Chapter 1 provides background information on the development of the manual and an overview of the stormwater problems associated with highways and other parts of the transportation infrastructure.

Chapter 2 provides an overview of the WSDOT project design process and how the stormwater/drainage design elements should be integrated into that process. Guidelines are provided for gathering predesign data and analyzing design alternatives.

- Appendix 2A presents a method to assist in determining when site-specific factors could make constructing stormwater management facilities within or adjacent to the highway right of way infeasible.

Chapter 3 describes the minimum requirements that apply to the planning and design of stormwater facilities and best management practices. Guidelines are provided to determine which of the nine minimum requirements must be met for a given transportation project. The purpose and the applicability of the minimum requirements are described. Guidelines are also provided for assessing (1) whether project-driven stormwater retrofit obligations can be met off-site by retrofitting an equivalent area of state highway in targeted environmental priority locations, and (2) whether it is cost-effective to provide stormwater management retrofits beyond what is called for under these requirements.

Chapter 4 provides a description of the different hydrologic analysis methods that must be used to design stormwater runoff treatment and flow control facilities. This chapter also provides a detailed explanation of the analysis methods used as well as the supporting data and assumptions needed to complete the design.

- Appendix 4A contains the websites and web links related to Chapter 4.
- Appendix 4B contains the TR55 Curve Number Tables.
- Appendix 4C covers eastern Washington design storm events.

Chapter 5 guides the project designer through the selection of permanent stormwater treatment, infiltration, and flow control BMPs and their design processes. It includes a process for BMP selection in both western and eastern Washington. Criteria for the use of emerging technologies and discussions about operation and maintenance are included. Detailed design criteria for each permanent BMP are included in Section 5-4.

Chapter 6 guides the project designer through the process of selecting and designing temporary construction-related BMPs. It includes criteria for selecting appropriate erosion and sediment control (ESC), as well as spill prevention, control, and countermeasures (SPCC) BMPs (including operation and maintenance considerations). Chapter 6 also provides guidelines on water quality monitoring for projects required to monitor runoff quality and receiving water effects during construction.

- Appendix 6A includes the design criteria for each temporary BMP.

## 1-4 How to Use This Manual

The designer should follow the guidelines for integrating the planning and design of stormwater-related project elements into the context of WSDOT's project development process prior to using the guidelines in Chapter 3 to determine which minimum requirements must be satisfied for a specific project. In most instances, this process will spur the need to design construction and postconstruction BMPs according to the criteria provided in Chapters 4, 5, and 6.

Most projects lend themselves to relatively straightforward application of one or more of the BMP options presented in this manual. However, many WSDOT sites are not conducive to easy installation of any BMPs. When these types of problems arise, contact the following for assistance:

- **BMP Selection** – Region environmental or hydraulics staff, then the Hydraulics Section staff or the Stormwater & Watersheds Program staff at the HQ Environmental Services Office (ESO).
- **Outfall Inventory/Field Screening Results, Stormwater Retrofit Priorities, NPDES Municipal Stormwater Permit, and Water Quality Sampling** – Staff in the HQ ESO, Stormwater & Watersheds Program.
- **Spill Control, Containment, and Countermeasure Activities** – Region environmental staff, then staff in the HQ ESO, Hazardous Materials Program.
- **Temporary Erosion and Sediment Control Plans and Construction Site BMPs** – Region environmental staff, then staff in the HQ ESO, Stormwater & Watersheds Program.
- **Vegetation Management** – Region and HQ Landscape Architects, then HQ Highway Maintenance staff.
- **Roadway Maintenance Practices** – Region maintenance staff, then HQ Highway Maintenance environmental staff.
- **Emerging BMPs** – Region environmental staff and the HQ ESO, Stormwater & Watersheds Program staff.

For information about the HRM-related training curriculum, see the HRM Resource Web Page: www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

# CHAPTER 2

# Stormwater Planning and Design Integration

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# Chapter 2 Stormwater Planning and Design Integration

## 2-1 Introduction

This chapter provides guidelines for integrating the planning and design of stormwater-related project elements into the context of the Washington State Department of Transportation (WSDOT) project development process. How the process applies to a specific project depends on the type, size, and complexity of the project and individual WSDOT regional business practices.

## 2-2 Stormwater Management Objectives

Originally, the only function of highway stormwater management was to maintain safe driving conditions using engineering techniques designed to prevent stormwater from ponding on road surfaces. While maintaining safe driving conditions continues to be essential for any functional highway drainage system, WSDOT also acknowledges the state's vital interest in protecting and preserving natural resources and other environmental assets, as well as its citizens' health and safety. These interests have become integrated with other vital interests entrusted to the department, including the cost-effective delivery and operation of transportation systems and services that meet public needs. Thus stormwater management for WSDOT transportation facilities has two main objectives: (1) protect the functions of the transportation facility, and (2) protect ecosystem functions and the beneficial uses of receiving waters.

## 2-3 Project Development Overview

The integration of stormwater planning and design into WSDOT's project development process is shown in Table 2-1. While the process consists of the distinct phases described below, in practice the phases actually overlap and some design modifications may occur during the *Construction phase*.

- The initial phase of project development entails creation of the project scope referred to as scoping). The project S*coping and Programming phase* consists of determining a project description, schedule, and cost estimate. During the project scoping phase, Project Summary documents are produced and used to program the project. The environmental section of the Project Summary establishes the initial environmental classification and level of documentation for the project.
- After the project is programmed, it is further developed through the *Design and Environmental Review phase*. During this phase, much of the design work and environmental analysis and documentation requirements for a project are completed and work on permit applications often begins. A Design Documentation Package (DDP) that compiles the project's design

considerations and conclusions is also produced during this phase. Once the DDP is reviewed and approved, it becomes the project design.

- The process continues through the development of project environmental permits, plans, specifications, and estimates (the *Environmental Permitting and PS&E phase*), which leads to production of contract documents for construction. Region or Headquarters environmental staff should be consulted at each stage of the project design to review the permits and approvals that may be required. By following the *Highway Runoff Manual* minimum requirements (see Chapter 3) and selecting BMPs (see Chapter 5 and Appendix 6A) that are suggested for the specific highway setting, the design team plays a critical role in project development by avoiding costly design changes and delays in obtaining permits and keeping the project in compliance during construction, operation, and maintenance of the system.

**Table 2-1 Stormwater planning and design in the project development process.**

| ***Scoping*** → ***and Programming*** ↓ | ***Design Approval/*** → ***Environmental Documentation*** ↓ | ***Environmental Permitting and PS&E*** ↓ |
|---|---|---|
| Preliminary identification of water quality and hydrologic impacts and potential mitigation BMPs ↓ | Formal documentation of stormwater-related environmental impacts<br><br>Selection of stormwater mitigation BMPs: type, size, and location ↓ | Final design of stormwater BMPs: working plans<br><br>Obtain environmental permits ↓ |
| Project Summary supported by design file documentation:<br>▪ Stormwater scoping package<br>▪ Environmental Review Summary ↓ | Design report and environmental permit applications supported by design file documentation:<br>▪ Required environmental documentation (such as SEPA, NEPA, and ESA Biological Assessments)<br>▪ Hydraulic Report ↓ | Plans, Specifications, and Estimates package:<br>▪ TESC plan<br>▪ Provisions for SPCC plan<br>▪ Stormwater-related plans; General and Special Provisions ↓ |
| BMP cost allocation | Preliminary BMP cost estimate<br>Environmental commitments that arise from the DDP (such as use of experimental BMPs triggering costly and lengthy monitoring requirements through the demonstrative approach) | BMP cost estimate<br>Environmental commitments become permit requirements |

The level of effort invested during each phase of development and the extent to which the phases overlap for a specific project varies depending on the type, size, and complexity of that project. The project's design may also undergo modifications during the construction process. For further description and instruction related to the *Scoping and Programming*, *Design and Environmental Review*, *Environmental Permitting, and PS&E* phases, refer to the *Environmental Procedures Manual* and the *Design Manual*.

## 2-3.1 Development Team

Assessment and documentation of stormwater impacts and mitigation measures begin during project scoping. The scoping and design teams must involve appropriate participants (listed in alphabetical order in Table 2-2) as part of the scoping process. Project type, size, and complexity are key factors in determining who must be consulted for development of the stormwater strategy for a project.

**Table 2-2 Key contacts for development of project stormwater strategy**.

| Contact | Roles | Activities |
|---|---|---|
| Air and Noise | Performs air quality and noise analyses. | Conducts air and noise testing; determines wall locations. |
| Biologist | Performs biological analyses. | Delineates wetlands; prepares wetland reports, biological assessments, and mitigation recommendations. |
| Bridge and Structures Office | Structural design. | Assesses condition of existing structures; designs new structures; prepares PS&E for structures; coordinates backwater studies and pier placement. |
| Construction Offices | Manages project construction. | Contributes to design considerations; provides constructibility reviews. |
| Consultant Liaison | Consultant administration. | Issues request for proposal; assists in development of scopes of work; selects consultant; manages contract. |
| Developer Services | Coordinates development activity. | Provides information and contacts for other development activity in the area. |
| Geotechnical and Materials Laboratory | Determines geotechnical requirements; obtains data; provides analyses. | Provides scope and cost estimate of geotechnical work; reviews existing records and maps; performs soil borings; installs piezometers; conducts pH and resistivity testing. Assesses sources of materials and makes surfacing recommendations. |
| Local Programs Office and Local Agencies | Various | Provides funding and design criteria; develops maintenance agreements. |
| Maintenance | Provides recommendations. | Provides information on existing conditions; gives input on maintenance requirements of completed project. |
| Planning Office | Determines future plans for route location. | Determines route development plans; develops proposals. |
| Plans Office/Plan Review Office | Ensures compliance with plan standards. | Assists with preparation of Special Provisions and plans; provides final plan reviews. |

| Contact | Roles | Activities |
|---|---|---|
| Program Management (including program development) | Manages current biennial program; develops future biennial programs. | Manages set-up design and construction funding and assists with below-the-line costs; manages project definition process. |
| Project Design Office | Project management. | Participates in all aspects of project management and design. |
| Railroads | Manages design conflicts. | Identifies facilities, relocation requirements, and design considerations. |
| Real Estate Services | Real estate management. | Determines ownership; estimates property costs; procures rights of way, easements, rights of entry, and access management. |
| Regional Transit Authorities | Various | Coordinates regional issues, basin plans, construction projects, and route development. |
| Region and HQ Hydraulics | Provides assistance with hydraulic elements of design; provides approval or concurrence. | Determines hydraulic requirements; manages design, review, and approval of hydraulic and TESC design elements; assists with construction monitoring. |
| Region Environmental/ HQ Environmental Services | Performs analyses of environmental impacts and alternatives; assures compliance with environmental laws and regulations. | Prepares environmental (NEPA/SEPA) documents; coordinates with resource and permitting agencies; assists with public involvement; provides TMDL/303(d) assistance; obtains environmental permits. |
| Resource Agency (various) | Reviews reports; issues permits. | Provides endangered species list; approves biological assessments; issues permits that establish conditions for design and construction. |
| Right of Way Research and HQ Photogrammetry | Maintains as-built and right of way/access records. | Provides information regarding project location for inclusion in plans; provides aerial photos, survey, and photogrammetry development. |
| Roadside and Site Development Section | Provides landscape design plans. | Prepares landscaping plans, specifications, and estimates, including planting and irrigation work; inspects construction; manages plant establishment period until sign-off by regulators. |
| Safety Office | Applies safety standards. | Assists with designs and provisions for stormwater features to meet regulations and codes. |
| State Design Engineer | Approves design. | Reviews and approves overall design. |
| Survey | Collects survey information. | Compiles field data; performs surveys; stakes right of way; verifies existing conditions. |
| Traffic | Traffic analysis and design. | Collects traffic data; develops traffic models; reviews channelization plans/work zone traffic control plans. |
| Tribal Organizations | Various | May provide funding and comments on project. |
| Utilities | Manages existing and new utilities. | Determines utility requirements; prepares franchise inventory listing; reviews clear zone inventory; obtains utility as-built plans for inclusion on plan sheets; prepares relocation plan and utility agreements. |

## 2-3.2 Site Assessment

Stormwater facility design is a major element for many projects, and it requires significant advance data gathering and assessment to identify alternatives and develop accurate schedules and cost estimates. Data are needed to assess the project site in order to (1) determine project alignment alternatives, (2) assess impacts, (3) determine minimum requirements, and (4) develop conceptual stormwater management alternatives.

Characterizing the site and adjacent areas allows for a determination of the limiting factors controlling local hydrology. These limiting factors can then become the focus of the project's stormwater management strategies.

A three-dimensional picture of site hydrology will emerge during the site assessment. This picture will include natural and altered flow paths to the site from upstream areas and from the site to downstream areas. Natural drainage must be preserved (see Minimum Requirement 4, Section 3-3.4). The design team must identify all off-site flows coming to the site, including streams, seeps, and stormwater discharges. The transportation facility must allow for passage of all off-site flows; however, every effort should be made to keep off-site flows separate (via bypass) from the highway runoff. This may not be possible for flows that are currently permitted to discharge to WSDOT conveyance and treatment facilities.

Runoff from WSDOT rights of way must not adversely affect downstream receiving waters and properties. Existing drainage impacts on downstream waters and properties must be identified during scoping and must be either corrected as part of the project or recommended for a later retrofit. Drainage impacts are identified using multiple sources of information (see Section 2-3.2.1) and site visits during storms. Section 4-7 in the *Hydraulics Manual* provides guidelines on performing and documenting a downstream analysis. The preliminary downstream analysis is used for scoping purposes; however, a more detailed analysis may be needed during the project design phase. The final downstream analysis is included in the Hydraulic Report.

The scoping phase is the time to begin identifying natural areas within or adjacent to the project boundary that can be conserved. Conserving these areas helps to minimize project impacts. Some of these areas may be used as part of the project's stormwater management approach if they are appropriate areas for dispersion and infiltration. (See Chapters 4 and 5 for information regarding dispersion and infiltration.)

Conservation areas and their functions must be permanently protected under conservation easements or other locally acceptable means. If the conservation area falls within the right of way, it needs to be appropriately labeled on the right of way plan. If the conservation area is outside the right of way, then WSDOT needs to purchase a conservation easement or obtain another similar real estate protection instrument.

### 2-3.2.1 Information Sources

As a starting point, the following data and resources are generally necessary for site assessments:

- Project vicinity map and site map
- Land cover types and areas (aerial photographs)
- Topography (USGS quadrangle maps and other survey maps)
- Watershed or drainage basin boundaries
- Receiving waters
- Wetlands
- Stream flow data
- Ditches and open-channel drainage
- Enclosed drainage
- Floodplains
- Utilities
- Total maximum daily loads (TMDLs)/Water cleanup plans
- Clean Water Act Section 303(d)-listed impaired waters
- Drainage patterns and drainage areas
- Basin plan data (basin-specific needs)
- Soil types, depth, and slope (Natural Resources Conservation Service soil surveys)
- Existing stormwater outfalls (outfall inventory and site reconnaissance)
- Land use types and associated pollutants
- Groundwater data (including depth to seasonal high water table)
- Soil infiltration rates
- Vegetation surveys
- Land surveys
- Hazardous materials or wastes
- Average daily traffic (ADT)
- Roadway geometry (profiles/superelevations)
- Geotechnical evaluation (see Section 2-3.2.2)

The contacts in Table 2-2 can help in collecting this information. In addition, WSDOT's *GIS Workbench* (an ArcView geographic information system tool to provide staff with access to comprehensive, current, and detailed environmental and natural resource management data) can be used to gather some of these data and can provide maps to help with project assessment, selection of stormwater management alternatives, and maintenance applications.

### 2-3.2.2 Geotechnical Evaluations

Understanding the soils, geology, geologic hazards, and groundwater conditions at the project site is essential to optimizing stormwater design for a project. Contact the Region Materials Engineer (RME) and staff from the HQ Geotechnical Services Division as early as possible in the scoping phase for inclusion on the scoping and design team.

Infiltration is the preferred method for flow control of stormwater runoff. Chapters 4 and 5 provide direction on how to apply optimal infiltration for stormwater management on transportation projects. However, the extent to which infiltration can be used needs to be assessed during the scoping phase because of its direct impact on stormwater alternatives and costs. The degree to which runoff can be infiltrated depends on the project location and context. Limiting factors include soil characteristics, depth to groundwater, and designated aquifer protection areas.

The RME evaluates the geotechnical feasibility of stormwater facilities that may be needed for the project. With assistance from the HQ Geotechnical Engineer, as needed, the RME gathers all available geotechnical data pertinent to the assessment of the geotechnical feasibility of the proposed stormwater facilities. Some subsurface exploration may be required at this stage, depending on the adequacy of the geotechnical data available to assess feasibility. Refer to the *Design Manual* for additional details.

The scoping office develops the stormwater facility conceptual design using input from the RME and the HQ Geotechnical Engineer. Based on this design and investigation effort, fatal flaws in the proposed stormwater plan are identified as well as potential design and construction problems that could affect project costs or the project schedule. Critical issues to be considered include the following:

- Depth to water table (including any seasonal variations)
- Presence of soft or otherwise unstable soils
- Presence in soils of shallow bedrock or boulders that could adversely affect constructibility
- Presence of existing adjacent facilities that could be adversely affected by construction of the stormwater facilities
- Presence of geologic hazards such as earthquake faults, abandoned mines, landslides, steep slopes, or rockfall
- Adequacy of drainage gradient to ensure functionality of the system

- Potential effects of the proposed facilities on future corridor needs
- Maintainability of the proposed facilities
- Potential impacts on adjacent wetlands and other environmentally sensitive areas
- Presence of hazardous materials in the area
- Whether or not the proposed stormwater plan will meet the requirements of resource agencies
- Infiltration capacity (infiltration and percolation rates for project sites)

To characterize the seasonal variation of the groundwater table, it may be desirable to install piezometers at potential infiltration sites during scoping. One year of monitoring is desirable. At a minimum, one full rainy season is necessary to acquire the data needed to make a determination of site suitability.

### 2-3.2.3 Right of Way

Once the stormwater requirements for the project are understood, the general hydrologic site characteristics are known (including approximate groundwater table elevations), and the stormwater design alternatives are determined, the area necessary for stormwater facilities can be estimated. Refer to Chapters 4 and 5 to estimate the required area for each facility. Examine the proposed layout of the project, and determine the most suitable sites available to locate the stormwater facilities. Determine where facilities are proposed outside existing right of way and establish estimates for right of way acquisition areas and costs.

### 2-3.2.4 Utilities

The project design office must contact the Region Utilities Office to obtain information about whether existing utilities have franchises or easements within the project limits. Whenever proposed stormwater facilities conflict with an existing utility's right of way and facilities, a utility agreement is required. WSDOT may be responsible for the relocation costs, the utility owner may be responsible for the costs, or the costs may be shared. Further information about utility elements is available in the *Utilities Manual*.

## 2-3.3 Maintenance Review

Once a list of permanent stormwater BMPs is determined based on the site assessment, the designer must contact the Region Maintenance Office to discuss treatment options available for use. Overall maintenance costs must be considered when selecting BMPs. The project design office must consult with the region maintenance staff regarding the proposed drainage alternatives and evaluate maintenance needs, including personnel, equipment, and long-term costs through the BMP's expected life cycle. Review the general maintenance requirements in Section 5-3.6.1 and the maintenance guidelines in Section 5.5. Maintenance concurrence must be obtained prior to the final selection of the treatment BMP and documented in the Hydraulic Report.

## 2-3.4 Documentation

Thorough documentation of stormwater-related environmental impacts and tracking of stormwater design commitments is a required element of the State Environmental Policy Act (SEPA) and National Environmental Policy Act (NEPA), as well as other environmental laws, and environmental permit applications. To aid in the accurate exchange of stormwater information from the design team to workgroups preparing environmental documentation and permit applications, a Stormwater Design NEPA/SEPA Documentation Checklist and accompanying Stormwater Design Documentation Spreadsheet shall be prepared for each project. The Checklist and Spreadsheet are available separately at:
www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

For a general list of documents required to be preserved in the Design Documentation Package and the Project File, see the Design Documentation Checklist at:
www.wsdot.wa.gov/design/projectdev/

### 2-3.4.1 Stormwater Scoping Package

Stormwater documentation during the scoping phase of project development is referred to here as the *stormwater scoping package*. This package contains the information used to preliminarily determine project stormwater impacts and the initial selection of stormwater BMPs. It is the source of stormwater information needed to complete the Project Summary documents. This package must include a brief summary report that contains the following:

- Identification of the project program
- Brief project description
- Synopsis of data gathered during the site assessment
- Basin and subbasin identification
- Threshold discharge area delineations indicating flow paths and outfalls to receiving waters
- Area determinations
- Applicable minimum requirements
- Other applicable regulatory requirements related to stormwater (such as Endangered Species Act requirements, TMDL, or 303(d) considerations)
- Design criteria required for flow control and runoff treatment
- Known problems and commitments
- Retrofit recommendations
- Design alternatives and assumptions for flow control and runoff treatment
- Cost estimates

The stormwater scoping package is critical to the efficient continuation of project development and must be retained and easily retrievable. Once the project is programmed and assigned to a project office, the file and report become the starting point for the design phase. The stormwater scoping package must be kept and stored by the Region Program Management Office or scoping office. The package must remain with the overall project scoping file to ensure the project office to which the project is assigned for design receives the preliminary stormwater information.

### 2-3.4.2 Project Summary

As described in Section 2-3, the product of scoping is the *Project Summary,* which is developed and approved before the project is funded for design and construction and consists of the *Project Definition*, *Environmental Review Summary*, and *Design Decisions Summary*. All of these documents require stormwater-related information, as outlined in Table 2-3. The Project Summary is prepared to document results of the scoping process and define the overall scope of the proposed solution in terms of the work and material involved. This includes the level of environmental documentation and extent of permitting work and mitigation, as well as cost estimate and performance outcome and benefit/cost ratio for the project. This documentation is also used to link the project to the *Washington State Highway System Plan* and the *Capital Improvement and Preservation Program* (CIPP).

### 2-3.4.3 Environmental Documentation

For any project funded by the Legislature, environmental documentation begins after the Project Summary is approved and ends with the approval of any documents that must be completed for compliance with SEPA and NEPA, as well as other environmental laws, including, but not limited to, the Endangered Species Act and Section 6(f) of the Land and Water Conservation Fund Act. Environmental documents are drafted after analyzing environmental issues, comparing alternatives, developing mitigation measures, consulting with resource agencies about required permits, and making a determination about the significance of any remaining unmitigated environmental impacts. Much of the stormwater-related design information needed for permit applications can be obtained from the Project Summary and environmental documentation. Refer to the *Environmental Procedures Manual* for specific instructions on preparing environmental documents.

### 2-3.4.4 Hydraulic Report

The Hydraulic Report is intended to serve as a complete document record containing the engineering justification for all drainage modifications that occur as a result of project construction, including documentation of the analysis and design for the postconstruction stormwater management system. Refer to the *Hydraulics Manual* for additional details.

**Table 2-3 Stormwater-related information needed for the Project Summary.**

| | |
|---|---|
| Project Definition (PD) | ▪ Cost estimate and variance for preliminary engineering, right of way, and construction<br>▪ Right of way needs for stormwater facilities<br>▪ Preliminary environmental review: required environmental documentation, permits, and environmental commitments<br>▪ Design decisions regarding stormwater<br>▪ Public input regarding stormwater<br>▪ Project commitments for stormwater made to and by others<br>▪ Potential impacts of stormwater facilities on utilities<br>▪ Specialized workforce expertise required for geotechnical, biological, geomorphic, and other evaluations<br>▪ Other stormwater-related issues |
| Environmental Review Summary (ERS) and Environmental Classification Summary (ECS) | ▪ Required permits and approvals related to stormwater<br>▪ Critical or sensitive areas as designated by Growth Management Act ordinances<br>▪ TMDL and 303(d) considerations<br>▪ Floodplains or floodways within (or affecting) the project site<br>▪ Rivers and streams: crossing structures and types<br>▪ Water quality/stormwater: impacts and mitigation<br>▪ Previous environmental commitments made in project site related to stormwater<br>▪ Long-term maintenance commitments related to stormwater and necessary for project |
| Design Decisions Summary (DDS) | ▪ Roadway geometrics data affected by stormwater facilities<br>▪ Roadside character classification and treatment level: effect on stormwater facility design (forest, open, rural, semiurban, urban)<br>▪ Hydraulic decisions regarding stormwater facilities |

## 2-3.4.5 Construction Planning

During the design phase, key stormwater documents are produced to meet stormwater site planning requirements associated with Minimum Requirement 1 (see Section 3-3-1).

All projects require spill prevention, control, and countermeasures (SPCC) plans, which are prepared by the contractor after the project contract is awarded. The WSDOT Hazardous Materials Program (www.wsdot.wa.gov/environment/hazmat/default.htm) and Section 1-07.15(1) in the *Standard Specifications for Road, Bridge, and Municipal Construction* (*Standard Specifications*) provide more information regarding SPCC plan expectations. To ensure plan implementation, develop provisions of the SPCC plan during the PS&E phase.

For soil-disturbing projects, WSDOT must also prepare temporary erosion and sediment control (TESC) plans (see Chapter 6).

### 2-3.4.6 Contract Plan Sheets

Infiltration, dispersion, and conservation areas, as well as other drainage and environmental elements, need to be identified on the contract plan sheet. Development of the contract plan sheets is defined in Division 4 of the *Plans Preparation Manual*.

### 2-3.4.7 Plans, Specifications, and Estimates (PS&E)

For the PS&E phase of a project, a set of Plans, Specifications, and Estimates is prepared. These documents translate the stormwater management elements of the design into a contract document format for project advertisement, bidding, award, and construction.

### 2-3.4.8 Underground Injection Control Wells

Drywells and infiltration trenches that contain perforated pipe are considered injection wells and require registration per the Washington State Department of Ecology's (Ecology's) Underground Injection Control (UIC) Program. Registration information is available at:
http://www.ecy.wa.gov/biblio/ecy04047c.html

For further guidelines, consult region environmental staff or HQ Environmental Services Office staff.

## 2-4 Developer Projects

WSDOT must provide for the passage of existing off-site flows through its right of way to maintain natural drainage paths. If a private developer's project discharges off-site flow to WSDOT right of way, the developer needs to comply with state and local requirements, assuming all costs and liabilities associated with the design, construction, maintenance, and operation of the developer's stormwater management facilities. The developer must also demonstrate that WSDOT conveyance systems have adequate capacity to convey the developer's flows per *Hydraulics Manual* conveyance design standards. WSDOT will not concur with designs or allow discharges that do not comply with these requirements. WSDOT requires discharge water be managed, at a minimum, in accordance with the provisions of the *Highway Runoff Manual,* Ecology stormwater management manuals, or an Ecology-approved local equivalent manual used by the local government with primary jurisdiction over the project.

For details regarding the WSDOT requirements and the process for review and concurrence of private project drainage design, refer to the *Development Services Manual* and the *Utilities Manual*.

# 2-5 Stormwater Facility Design Approach

## 2-5.1 Context Sensitive Design

It is important to recognize the watershed context of a project to understand how transportation facilities, in combination with other development, can affect the natural hydrology of watersheds and the water quality of receiving waters. This understanding can guide the planner and designer in choosing stormwater management solutions that more successfully achieve the objective of protecting Washington's ecosystems.

Context sensitive design (CSD), also known as *context sensitive solutions* and *thinking beyond the pavement*, is an approach to transportation planning that broadens the focus of the project development process to look beyond the basic transportation issues and develop projects that are integrated with the unique context(s) within the project setting. This approach considers the elements of mobility, safety, environment, community, and aesthetics from the beginning to the end of the project development process. The CSD also involves a collaborative project development process that obligates participants to understand the impacts and trade-offs associated with project decisions. Further discussion of and guidance on the context sensitive design/context sensitive solutions approach can be found at: http://www.wsdot.wa.gov/design/policy/csdesign.htm

## 2-5.2 Stormwater Facility Design Strategy

Stormwater management facilities (runoff treatment and flow control) can be utilized to mitigate both the hydrologic impacts and the water quality impacts of a development project by applying the following fundamental strategy:

> *Maintain the preproject[1] hydrologic and water quality functions of the project site as it undergoes development.*

This strategy is accomplished through the following steps:

**Step 1** Avoid and minimize impacts on hydrology and water quality.

**Step 2** Compensate for altered hydrology and water quality by mimicking natural processes.

**Step 3** Compensate for altered hydrology and water quality by using end-of-pipe solutions.

Steps 1 and 2 can be achieved by minimizing impervious cover; conserving or restoring natural areas; mimicking natural drainage patterns (for example, using sheet flow, dispersion, infiltration, or open channels); disconnecting drainage structures to avoid concentrating runoff; and using many small redundant facilities to treat, detain, and infiltrate stormwater. This approach to site design reduces reliance on the use of structural management techniques.

[1] The term *preproject* refers to the actual conditions of the project site before the project is built.

Step 3 refers to the use of traditional engineering structural approaches (for example, detention ponds) to the extent that Steps 1 and 2 are not feasible.

The methods listed for achieving Steps 1 and 2 above are commonly referred to as low-impact development (LID) approaches. By using the project site's terrain, vegetation, and soil features to promote infiltration, the landscape can retain more of its natural hydrologic function. Low-impact development methods will not be feasible in all project settings, depending on the physical characteristics of the site, the adjacent development, and the availability and cost of additional right of way (if needed). However, the designer must always investigate the feasibility of using low-impact development methods. Low-impact development methods require understanding of soil characteristics, infiltration rates, water tables, native vegetation, and other site features. For this reason, it is important to gain the participation of design support services and others from the beginning through the end of the project development process.

# 2-6 Special Design Considerations

## 2-6.1 Critical and Sensitive Areas

The Washington Growth Management Act (RCW 36.70A), combined with Article 11 of the Washington State Constitution, requires local jurisdictions to adopt ordinances that classify, designate, and regulate land use in order to protect *critical areas*. Critical areas are defined as wetlands, floodplains, aquifer recharge areas, geologically hazardous areas, and those areas necessary for fish and wildlife conservation.

### 2-6.1.1 Wetlands

Altering land cover and natural drainage patterns may increase or decrease stormwater input into surrounding wetlands. Land use changes and stormwater management practices usually alter hydrology within a watershed. Hydrologic changes have more immediate and greater effects on the composition of vegetation and amphibian communities than do other environmental changes, including water quality degradation.

Wetland ecosystems can be highly effective managers of stormwater runoff; they can remove pollutants and also attenuate flows and recharge groundwater. Minimum Requirement 7 (see Section 3-3.7) addresses wetland protection. While natural wetlands for the most part may not be used as pollution control facilities in place of runoff treatment BMPs, Ecology's SMMEW allows the use of lower-quality wetlands as runoff treatment BMPs if requirements for hydrologic modification are met. For detailed guidance on this issue for eastern Washington projects, refer to *Use of Existing Wetlands to Provide Runoff Treatment* (Section 2.2.5, page 2-26) and *Application to Wetlands and Lakes* (Section 2.2.6, page 2-33) in Ecology's SMMEW and the *Eastern Washington Wetland Rating Form* at:
www.wsdot.wa.gov/nr/rdonlyres/41520679-f96d-47a9-9b70-3ee8bbec391f/0/wetlandratingform_easternwa.doc

For western Washington projects that may potentially alter the wetland hydroperiod, refer to *Guide Sheet 2B* in Appendix I-D of Ecology's SMMWW to review the recommended allowable limits for altering the hydroperiod of wetlands. Additional information on wetland hydroperiods is provided in Section 4-6 of this manual.

Region or Headquarters hydraulics and environmental staff can provide further assistance on hydroperiod modeling. For guidelines on wetland creation or restoration as mitigation for direct wetland impacts, contact the region's wetland biologist or consult the following website: www.wsdot.wa.gov/environment/wetlands/default.htm

### 2-6.1.2 Floodplains

Hydrologic storage that is displaced by roadway fill or other structures may result in increased stream flows, channel erosion, downstream flooding, and decreased infiltration and summer base flows. Projects may be required to mitigate loss of hydrologic storage by creating new hydrologic storage elsewhere in the watershed.

A decision to locate structural detention facilities in floodplains depends on the flow control benefits that can be realized. If a detention facility can be placed so that it is functional through at least the 10-year flood elevation, it will accomplish most of its function by controlling peaks during smaller, more frequent events that cumulatively cause more damage. Stormwater facilities that are located outside the 2-year, 10-year, and 25-year flood elevations do not compromise any flood storage during those floods. If it is not possible to locate stormwater facilities anywhere but within the 100-year floodplain, and if flood storage is an issue, consult with the Region Hydraulics Office to identify alternative mitigation opportunities.

### 2-6.1.3 Aquifers and Wellhead Protection Areas

To ensure highway improvement projects protect drinking water wells, WSDOT has entered into an agreement (http://www.wsdot.wa.gov/publications/manuals/fulltext/m31-11/agreements/ia_drinkingwell.pdf) with the State Department of Health (DOH). This agreement includes the following screening criteria to determine the conditions under which a highway project will not be considered a potential source of contamination to drinking water wells according to DOH:

1. Road location and construction setbacks are maintained such that the drinking water source intake structure is not in danger of physical damage.

2. All concentrated flows of untreated roadway runoff are directed via impervious channel or pipe and discharged outside the *Sanitary Control Area* (SCA).

3. If roadside vegetation management practices are identified as a potential source of contamination, the water purveyor will provide the location of the SCA to the appropriate WSDOT Maintenance Office for inclusion in the *Integrated Vegetated Management Plan* for that section of highway as necessary to protect the wellhead.

4. WSDOT complies with all National Pollutant Discharge Elimination System permits, as required per Section 402 of the federal *Water Pollution Control Act*.

5. WSDOT provides the well purveyor with contact information to be used in the event of any problems or questions that may arise.

The project design team must gather and document information on all drinking water wells along the project corridor. Refer to the local critical areas ordinances for details on aquifer and wellhead protection areas applicable to the project site. To locate wells in the project site, check Ecology's website for listed well logs: apps.ecy.wa.gov/welllog/. This website contains a database of wells constructed and registered since the 1930s and wells managed by Ecology since 1971. The WSDOT *GIS Workbench* can also provide a preliminary assessment of wellhead and aquifer protection areas in the vicinity of a given project. Recognize that some wells may not be registered and can only be identified through field investigations. Contact region environmental staff early in the project design phase if there are wells located within the radius of concern.

County health departments set well protection buffers (*Sanitary Control Areas*), presuming that the well protection buffer width will adequately protect wells from contamination. When highway projects encroach into well SCAs, however, WSDOT must document how the project will avoid impacting the well and water supply.

When a road project is expected to intersect a public water supply well's SCA, contact the water purveyor to confirm the location of the well and its SCA. If the project intersects the SCA, a licensed professional engineer, using the screening criteria listed above, needs to establish the conditions under which a highway project will not be considered a potential source of contamination to drinking water wells. Then, the engineer needs to attest to the well purveyor in writing, on WSDOT letterhead, that the screening criteria's conditions are satisfied. It is expected that the purveyor will identify and sign SCA-restrictive covenants and/or WSDOT will check for such covenants filed with the County Auditor's Office.

If a disagreement arises between the water purveyor and WSDOT region staff regarding the potential impacts of the project to a public water supply well that cannot be resolved, elevate the issue to HQ Environmental Services Office (ESO) Stormwater and Watersheds Program staff. Likewise, contact HQ ESO Stormwater and Watersheds Program staff to evaluate mitigation options if it is not possible to meet the screening criteria.

Projects that include large cuts or compaction of soil over shallow aquifers could potentially intercept groundwater flows and restrict the quantity of water reaching a well. Groundwater quantity issues are not covered by the State Department of Health agreement; thus, potential groundwater quantity impacts must be analyzed as a hydrogeologic issue in consultation with the HQ Materials Laboratory and the HQ Hydraulics Office.

### 2-6.1.4 Streams and Riparian Areas

To prevent direct impacts on stream channels and stream ecosystems, avoid encroachment into riparian areas. Removing riparian vegetation may directly result in channel instability and streambank erosion; loss of aquatic and wildlife habitat; loss of spawning gravels; increased sedimentation; increased water temperatures; decreased dissolved oxygen concentrations; and other water quality impacts. When a highway-widening project is located parallel to a stream, stormwater facility placement must occur away from the stream to the extent practicable and measures must be taken to preserve or enhance riparian buffers.

## 2-6.2 Endangered Species

Projects with a federal nexus (those with federal funding, permit, or approval) must go through consultation according to Section 7 of the federal Endangered Species Act (ESA). A biological evaluation or biological assessment must be prepared whenever it is suspected that ESA-listed species inhabit the vicinity of a project.

The design team works with a WSDOT region biologist to develop the required ESA documentation. The information needed to complete the biological evaluation or biological assessment can be obtained from existing documents and resources for the given conceptual project design alternatives. Ideally, the majority of the final information will be gathered during the scoping phase of project development. The scoping team must contact the biologist early in the scoping process to request assistance in determining ESA-related issues and how these issues and needs affect project design and cost considerations.

Information necessary to complete a biological evaluation or biological assessment for stormwater-related impacts is compiled in the ESA Stormwater Design NEPA/SEPA Documentation Checklist available at:
www.wsdot.wa.gov/environment/biology/ba/default.htm

## 2-6.3 Contaminated and Hazardous Waste Sites

If a project contains a contaminated or hazardous waste site, or if it is suspected that such a site exists within the project limits, contact Headquarters Hazardous Materials Program staff for further direction. Refer to the *Environmental Procedures Manual*, Section 447.05, Technical Guidance, for further information.

## 2-6.4 303(d)- and TMDL-Listed Water Bodies

The federal Clean Water Act requires states to prepare a list of water bodies that fail to meet water quality standards. If a water body segment does not meet water quality standards for a specific pollutant, it gets added to the Water Quality Assessment list, known as the 303(d) list. The 303(d) list consists of water bodies for which Total Maximum Daily Loads (TMDLs) must be developed to address the water quality impairment. A TMDL addresses pollution problems in the watershed by specifying pollution reduction targets and strategies to achieve clean water.

When a TMDL identifies a WSDOT discharge as a source of the pollutant of concern, specific action items, compliance timelines, and wasteload allocations (WLAs) may be assigned. EPA-approved TMDLs that include WLAs and/or actions for WSDOT are included in *Appendix 3 of WSDOT's NPDES Municipal Stormwater Permit*.

For 303(d) and EPA-approved TMDLs that do not specifically identify WSDOT discharges as a pollutant(s) source, efforts should still be made to avoid impacts where feasible. To determine whether a 303(d)- or TMDL-listed water body exists within or near the proposed project footprint, access WSDOT's GIS Environmental Workbench>Water Quality> "303(d), Basin Plans & TMDLs" dataset. View each layer in the dataset independently to identify listings that may overlap. Since 303(d) and TMDL listings and basin plans change frequently, these GIS layers should be reviewed at the start of each project to document all applicable listings/basin plans.

If stormwater will discharge to a 303(d)- or TMDL-listed water body, where feasible, BMPs should be selected that: (1) reduce the pollutant(s) of concern, and (2) do not adversely affect the listed water body (e.g., add the pollutant(s) of concern). The first page of each BMP section in Chapter 5 includes TMDL/303(d) considerations to aid in BMP selection when discharging to an impaired water body. As a general rule, infiltration and dispersion BMPs are the most desirable approach for 303(d)- or TMDL-listed situations.

For more information on TMDLs or 303(d) listings, contact the Stormwater and Watersheds Program in the Environmental Services Office, access the internal WSDOT TMDL webpage (http://wwwi.wsdot.wa.gov/environment/stormwater/tmdl.htm), or visit Ecology's website (http://www.ecy.wa.gov/programs/wq/tmdl/).

## 2-6.5 Airports

Special consideration must be given to the design of stormwater facilities for projects located near airports. Roadside features, including standing water (such as wet ponds) and certain types of vegetation, can attract birds both directly and indirectly. The presence of large numbers of birds near airports creates hazards for airport operations and must be avoided. Before planning and designing facilities for a project near an airport, contact WSDOT Aviation, the airport, and the Federal Aviation Administration for wildlife management manuals and other site-specific criteria.

## 2-6.6 Bridges

Because the over-water portion of the bridge surface captures only the portion of rainfall that otherwise would fall directly into the receiving water body, that portion of the bridge makes no contribution to the increased rate of discharge associated with surface runoff to the water body. This reasoning assumes that the conveyance system is constructed to prevent any localized erosion between the bridge surface and the outfall to the water body. While this fact may simplify needs for flow control, bridges present challenges associated with pollutant removal from runoff generated by their surfaces.

Bridges are typically so close to receiving waters that it is often difficult to find sufficient area in which to site a treatment solution. In the past, bridges were constructed with small bridge drains that discharged the runoff directly into the receiving waters by way of downspouts. This practice is no longer allowed, thus creating the challenge of incorporating runoff collection, conveyance, and treatment facilities into the project design.

Use of suspended pipe systems to convey bridge runoff must be avoided whenever possible because these systems have a tendency to become plugged with debris and are difficult to clean. The preferred method of conveyance is to hold the runoff on the bridge surface and intercept it at the ends of the bridge with larger inlets. This method requires adequate shoulder width to accommodate flows so that they do not spread farther into the travel way than allowed (see Chapter 5 of the *Hydraulics Manual* for allowable spread widths). In cases where a closed system must be used, it is recommended that bridge drain openings and pipe diameters be larger and that 90º bends be avoided to ensure the system's operational integrity. Early coordination with the HQ Bridge and Structures Office is essential if a closed system is being considered.

### 2-6.7 Ferry Terminals

A ferry dock consists of the bridge (trestle and span), piers, and some of the holding area (parking facility). The terminal is the dock and all associated upland facilities. Requirements and consideration for the terminal's upland facilities are the same as for park-and-ride lots, rest areas, and maintenance yards (where similarities exist) as described in Section 2-6.8. Requirements and considerations that apply to bridges also apply to the trestle, span, and other over-water portions (see Section 2-6.6).

### 2-6.8 Maintenance Yards, Park-and-Ride Lots, and Rest Areas

The Ecology stormwater management manuals for western (SMMWW) and eastern (SMMEW) Washington provide more specific stormwater BMP information related to parking lots and commercial and industrial land uses. Stormwater facility design must give consideration to the use of methods that emphasizes conservation and the use of on-site natural features to protect water quality and more closely mimic predevelopment hydrology. In addition to approaches in contained Ecology's stormwater management manuals, refer to Chapter 5 for other applicable BMPs.

## 2-7 How Stormwater Management Applies to a Project

### 2-7.1 HRM Minimum Requirements and Exemptions

Chapter 3 contains the manual's minimum requirements for stormwater management: Section 3-2 aids in determining the applicable minimum requirements and Section 3-3 provides further detailed direction regarding their application. Even when projects do not trigger a particular minimum requirement (such as flow control), the intent of the minimum requirement should still be considered in project design.

Section 3-2 provides information on projects that are exempt from the minimum requirements. Sections 3-3.5 and 3-3.6 provide specific information on limited exemptions from runoff treatment (Minimum Requirement 5) and flow control (Minimum Requirement 6), respectively.

## 2-7.2 Local Requirements

Section 1-1.5 explains the conditions under which local requirements apply to stormwater management on WSDOT projects. By state statute, WSDOT projects on state right of way are not subject to local permits, except for *shoreline* permits required by the local shoreline master program and permits required by *critical* or *sensitive areas* ordinances promulgated under the Growth Management Act (see Section 2-6.1).

Permitting staff in the Region Environmental Office must be consulted as to the individual permits required for a project. If the project will result in a new stormwater discharge to a municipal storm sewer system, a permit may be required by that jurisdiction's stormwater utility. Local agencies may have special design requirements for projects in which a portion of the local system will be replaced and turned over to the local jurisdiction for operation and maintenance.

The above information is intended to specify the local permits that may be applicable to WSDOT projects; it is not intended to preclude the need to work with local authorities to address concerns they may have regarding the potential impacts of a project. Additional information on applicable statutes, regulations, and environmental permitting can be found in the *Environmental Procedures Manual.*

## 2-7.3 Watershed and Basin Plans

Incorporating watershed and basin planning and local requirements into stormwater management is addressed in Minimum Requirement 8 (see Section 3-3.8). Project planners and designers need to familiarize themselves with the planning efforts for the watersheds and local jurisdictions in which the project is located and identify any specific requirements, recommendations, and opportunities that relate to stormwater management. Watershed plans may also identify priority mitigation needs within the watershed that may present off-site opportunities to mitigate project impacts. Local plans may have identified specific stormwater-related needs and/or contain useful analyses.

Statewide organized watershed planning efforts occur under two state laws: the Watershed Planning Act (2514 Planning) and the Salmon Recovery Act (2496 Planning). Each uses *water resource inventory areas* (WRIAs) as its basic geographic unit.

Basin planning conducted by local governments focuses on drainage basins at a sub-WRIA scale. Unfortunately, there are no uniform state standards defining an adequate basin plan. As stated in Minimum Requirement 8 (see Section 3-3.8), standards developed from basin plans cannot modify any minimum requirement until the basin plan is formally adopted and implemented by the local governments within the basin and has received approval or concurrence from Ecology.

Entities with basin planning responsibilities for an area where transportation projects are planned must be contacted as early as possible in the project planning process. Such groups include *lead entities* under the Salmon Recovery Act and *watershed planning units* under the Watershed Planning Act as well as city and county public works departments responsible for basin planning. There may be shared funding opportunities for local priority mitigation projects, which could significantly reduce project mitigation costs. Also, such entities may have data and analyses that can be used in the project planning process.

- Information on activities under the Watershed Planning Act, including a map of Washington's water resource inventory areas, is available at: www.ecy.wa.gov/watershed/index.html
- Information on activities under the Salmon Recovery Act is available at: http://wdfw.wa.gov/fishing/salmon/chum/pugetsound/recovery.html
- Watershed data, reports, and other related information is available at: www.ecy.wa.gov/programs/eap/wrias/index.html

Contact the Region Environmental Office or the HQ ESO Stormwater and Watersheds Program to arrange meetings and help coordinate watershed-related efforts.

### 2-7.3.1 Watershed-Based Approach

The Stormwater and Watersheds Program staff of the HQ Environmental Services Office has developed a project screening and watershed characterization process to identify alternatives to managing stormwater impacts within the right of way. The objectives in pursuing the watershed-based approach are to improve environmental benefits and reduce costs compared to standard runoff treatment and flow control facilities constructed within the right of way. Factors to consider with watershed-based options include the following:

1. *Have all source controls been included?* Source control may be the most cost-effective practice to control pollutants. This is the first step in the investigation of alternative treatment options.
2. *What size watershed scale is appropriate for this alternative mitigation approach?* While the smallest subbasin may be appropriate for healthy watersheds, a larger watershed scale may be more appropriate in highly degraded watersheds depending on the nature of the impairment(s).
3. *Can stormwater management be coordinated with habitat mitigation?* Stream restoration, floodplain restoration, riparian replanting, or other practices could provide both habitat mitigation and stormwater management.
4. *Has a regional facility been evaluated?* If on-site stormwater facilities are not feasible, combining several project stormwater treatment/control needs into one regional facility may be a more cost-effective option.
5. *Are there legal or regulatory constraints to off-site stormwater management?*

For information on the activities of WSDOT's Watershed Program, including the watershed-based mitigation method, see: www.wsdot.wa.gov/environment/watershed/default.htm

## 2-7.4 Engineering and Economic Feasibility for Stormwater Deviations to the HRM

The *Highway Runoff Manual* provides policy and guidelines for the majority of WSDOT stormwater-related design issues. However, there are instances where the HRM's policies and guidelines do not seem appropriate for a particular project situation. WSDOT and Ecology recognize that alternative ways may exist to meet the HRM's requirements. For these situations, WSDOT created the *Demonstrative Approach Team* (DAT), which includes staff from Ecology and WSDOT, to review and approve (if appropriate) alternative stormwater design proposals. While stormwater deviations rarely relieve the project from minimum requirement obligations, the DAT can approve an alternate compliance pathway to meeting the intent of the minimum requirements using a project-specific demonstrative approach.

Highway projects seeking an alternative compliance pathway typically experience site-specific limitations (e.g., infrastructural, geographical, geotechnical, hydraulic, environmental, or benefit/cost related) that present an obstacle to fully meeting minimum requirements, particularly runoff treatment and flow control, within the project right of way. An example might involve efforts to avoid building a detention pond in a heavily forested area and instead opting for an off-site in-kind (nonforested) location to achieve the required flow control obligation.

A project proponent must make a formal assessment to identify constraints on meeting the minimum requirements in the TDA. Appendix 2A includes guidelines for this assessment, referred to as an *engineering and economic feasibility* (EEF) evaluation. The EEF assessment must be performed as early as possible in project development to document reasons for seeking an alternative compliance pathway. The design team must also formulate a workable alternative stormwater design (deviation) that also meets the intent of the HRM (i.e., does not adversely affect the water quality and satisfies state and federal water quality laws). The design team should consult with the Region Hydraulics Office, HQ Highway Runoff Unit, or the HQ ESO Stormwater and Watersheds Program.

The steps below describe the general process for seeking a HRM deviation review and approval:

1. The design team identifies the policy(ies) or guidelines in the HRM that the project proposes to deviate from.

2. The design team provides the justification for the deviation using the EEF assessment. The design team also provides the alternative design and shows how it achieves the intent of the HRM policy or guidance.

3. The design team submits the documentation (#1 and #2 above) to the DAT for review and approval.

4. If approved, the DAT issues a joint WSDOT and Ecology letter to the project office authorizing the alternative stormwater compliance approach.

If approved, the design team shall include all of the above documentation in the appendix of the project's Hydraulic Report.

## 2-7.5 Stormwater Retrofit

Stormwater retrofit provides treatment/control improvements for existing and/or replaced impervious surfaces where existing treatment/controls do not exist or are substandard. The decision to apply current *Highway Runoff Manual* standards for runoff treatment and flow control to existing impervious surfaces within the project limits should occur during project scoping. Section 3-4 provides guidelines for assessing (1) whether project-driven stormwater retrofit obligations can be met off-site by retrofitting an equivalent area of state highway in targeted environmental priority locations, and (2) whether it is cost-effective to provide stormwater management retrofits beyond what is called for under these requirements.

Stormwater retrofit may also be accomplished as a stand-alone programmed project (I-4 Subprogram). Those responsible for scoping a highway project need to contact the Region or HQ Program Management Office to learn whether any such programmed retrofit actions apply to their project.

The extent and type of any stormwater retrofit activity needs to be documented in the Hydraulic Report and the Stormwater Design Documentation Spreadsheet available at:
www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

**APPENDIX 2A**

# Engineering and Economic Feasibility Evaluation

# Appendix 2A Table of Contents



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# Appendix 2A
# Engineering and Economic Feasibility for Construction of Stormwater Management Facilities

Stormwater runoff from highways should be treated and controlled adjacent to or within the right of way (ROW) when transportation improvement projects are constructed and trigger the HRM's Minimum Requirements. However, various site-specific factors (for example, lack of land availability; engineering constraints; health and safety issues associated with operations and maintenance activities; or other obstacles) could make constructing stormwater management facilities within or adjacent to the highway right of way (called *in-ROW treatment*) difficult, if not impossible.

This Engineering and Economic Feasibility (EEF) evaluation checklist presents a method to assist in determining when site-specific factors could make constructing stormwater management facilities within or adjacent to the highway right of way infeasible. Using the Engineering and Economic Feasibility (EEF) Evaluation Checklist (see Section 2A-2) to document the critical site-specific limiting factors is required if the project deviates from prescribed stormwater management design criteria, such as those contained in the *Highway Runoff Manual* (HRM) or the Washington State Department of Ecology's (Ecology's) stormwater management manuals for eastern (SMMEW) and western (SMMWW) Washington. This documentation is necessary, in addition to the analysis required to seek compliance through the *demonstrative approach.* The *demonstrative approach* requires approval of a site-specific stormwater management proposal and supporting data to show that the alternative approach protects water quality and satisfies state and federal water quality laws (see Sections 1-1.3 and 5-3.5.3). Another option is to determine whether the requirements can be met using an equivalent area approach as described in Sections 3-3.5 and 3-3.6.

## 2A-1 General Criteria: Engineering and Economic Feasibility (EEF) of Constructing Stormwater Control Facilities

The following four general criteria should be considered by the designer in the siting and selection of stormwater best management practices (BMPs). These criteria affect the feasibility of stormwater BMPs and are further explained in the EEF Checklist in Section 2A-2.

- **Physical site limitations.** In many cases, the amount of available right of way determines which types of stormwater controls are feasible for the project. When additional right of way can be acquired at market value, or when eminent domain condemnations can be demonstrably justified, then project proponents should explore these options to acquire additional land for stormwater control facilities. Historically, condemning land specifically for wetland mitigation (also triggered by the federal Clean Water Act) has been extremely difficult; hence, this option for stormwater control facilities will likely encounter the same difficulties.
- Additional site constraints could include geographic limitations, steep slopes, soil instability, proximity to water bodies, presence of significant cultural resources, and shallow water tables.

- **Treatment effectiveness.** Generally, BMPs with the highest pollutant-removal efficiencies should be considered first. These practices may require more land area, thus affecting space limitations.
- **Costs and associated environmental benefits.** Generally, the most cost-effective method of meeting environmental requirements should be chosen.
- **Legal and policy issues.** Washington State Department of Transportation (WSDOT) and Ecology stormwater requirements and design criteria, local ordinances, Endangered Species Act concerns, and tort liability issues must also be considered when selecting appropriate BMPs. If watershed-based stormwater management options are considered, legal and policy issues discouraging this approach may need to be overcome.

When identifying on-site treatment and control options, it is important to consider the site limitations preventing construction of stormwater control and treatment facilities. For physical or economic reasons, it may not be feasible to construct full-scale stormwater control facilities on-site.

## 2A-2 Engineering and Economic Feasibility (EEF) Evaluation Checklist

The following checklist is intended for use during the design stage to determine whether construction of stormwater control facilities is feasible within the immediate highway right of way. Factors that limit the feasibility of constructing in-ROW stormwater controls are listed, along with questions to help determine the feasibility of constructing in-ROW stormwater treatment and control systems based on site conditions.

### *2A-2.1 Collect Project Site Data to Identify Limiting Factors*

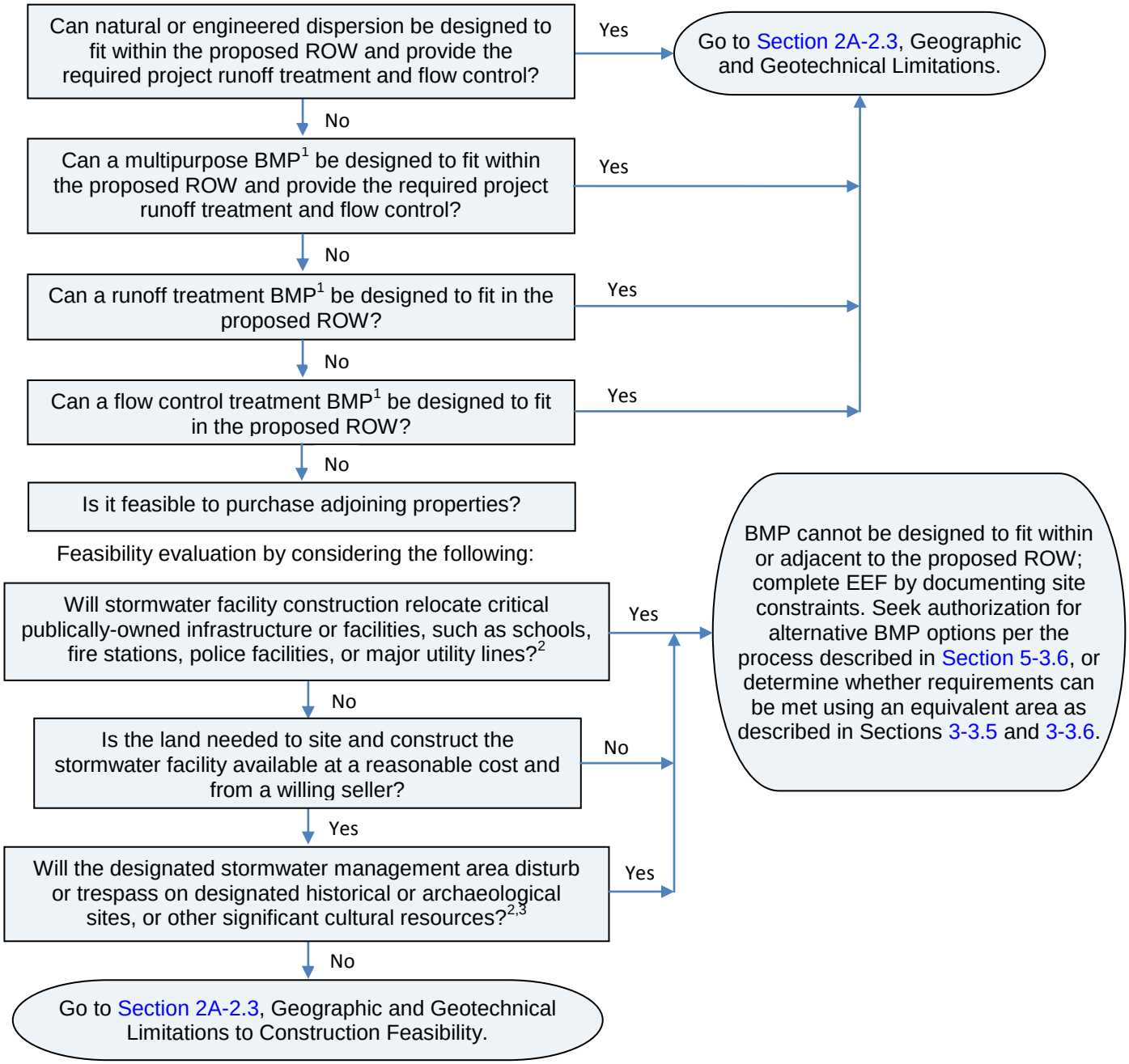
- ✓ Locate the proposed ROW and/or easement available for stormwater facilities.
- ✓ Determine the topographic and land cover characteristics of contributing basin areas.
- ✓ Estimate the required runoff treatment and flow control by completing the Stormwater Design and Documentation Spreadsheet:
  http://www.wsdot.wa.gov/nr/rdonlyres/6de749bc-209c-4bfd-80d9-bcc86dcb868a/0/stormwaterdesigndocumentation.xls
- ✓ Determine the proximity of the project site to water bodies and locate existing outfalls.
- ✓ Identify water bodies designated as "impaired" under the provision of Section 303(d) of the federal Clean Water Act, enacted by Public Law 92-500.
- ✓ Identify water supply well locations and associated well protection zones.
- ✓ Identify wildlife hazard management zones around airports.
- ✓ Determine the soil properties at the proposed stormwater facility location. For infiltration facilities, verify the site meets the requirements in Section 4-5.1, Site Suitability Criteria.
- ✓ Locate critical public infrastructure relative to the proposed ROW.

- ✓ Identify and locate the existing land use in and adjacent to the ROW including:
  - □ Protected cultural resources, historical sites, parklands, or wildlife and waterfowl refuges (Department of Transportation Act of 1966 §4[f] properties).
  - □ Areas designated as sensitive by a federal, state, local, or tribal government. These areas include, but are not limited to: designated "critical water resources" as defined in 33 CFR Part 330, Nationwide Permit Program, "Critical habitat" as defined in Section 3 of the Endangered Species Act of1973, and areas identified in local critical area ordinances or in an approved basin plan. (Additional items described in the SSC).
- ✓ Identify location(s) of established structure(s) on or adjacent to the proposed ROW.
- ✓ Identify slopes and location(s) of unstable slopes on or adjacent to the proposed ROW.
- ✓ Identify the presence and location of hazardous or dangerous materials on or adjacent to the proposed ROW.
- ✓ Identify and locate any well-established riparian tree canopies or vegetative buffers on or adjacent to the proposed ROW.
- ✓ Identify the presence and distribution of 100-year floodplains on or adjacent to the established or acquirable right of way.
- ✓ Verify the conveyance requirements specified in the *Hydraulics Manual* are met.
- ✓ For bridge projects: determine whether the bridge structure can be drained to land by gravity feed.
- ✓ Refer to Section 5-3.6, BMP Validation and Cost Effectiveness, for costs for constructing and maintaining the conceptual stormwater control facilities for the drainage area.

### *2A-2.2 Infrastructure Limitations to Construction Feasibility*

The density of the built environment adjacent to the established right of way may limit the amount of land available for acquisition to construct stormwater treatment and control systems. Once project limits, right of way, and stormwater runoff treatment and flow control needs are defined, a determination on whether it is feasible to construct stormwater management systems on-site can be made. Generally, wet vaults should be avoided when other BMP options are viable because of high construction and maintenance costs.

The following questions (see Figure 2A-1) should be considered when determining whether infrastructure or right of way limits the feasibility of designing and constructing stormwater BMPs within or adjacent to the right of way (in-ROW treatment). Each element evaluates potential fatal flaws that would preclude the feasibility of constructing stormwater management facilities within the proposed right of way.




1. See Figures 5.3.1 and 5.3.2 for BMP selection preference.
2. Identification of the location and nature of the critical public infrastructure(s) requires documentation to justify not constructing the BMP in the right of way.
3. Any projects involving disturbance of ground surfaces not previously disturbed should be reviewed for cultural resource study needs (such as site file searches at the Washington State Office of Archaeology and Historic Preservation, on-site surveys, and subsurface testing). Federal involvement (such as funding, permits, and lands) requires compliance with Section 106 of the National Historic Preservation Act and implementation of regulations in 36 CFR 800.

**Figure 2A-1 Infrastructure limitations to construction feasibility.**

## *2A-2.3 Geographic and Geotechnical Limitations to Construction Feasibility*

A project's topography and/or proximity to wetlands, sensitive water bodies, shorelines, riverfront areas, or steep slopes may physically or structurally preclude construction of BMPs on-site within required engineering standards. In situ geotechnical conditions can also limit the feasibility of constructing BMPs within the right of way (for example, the project is on unstable slopes, high shrink/swell soils, or karst topography). The questions shown in Figure 2A-2 should be considered when determining whether geography or geotechnical limits affect the feasibility of designing stormwater BMPs within the proposed ROW.

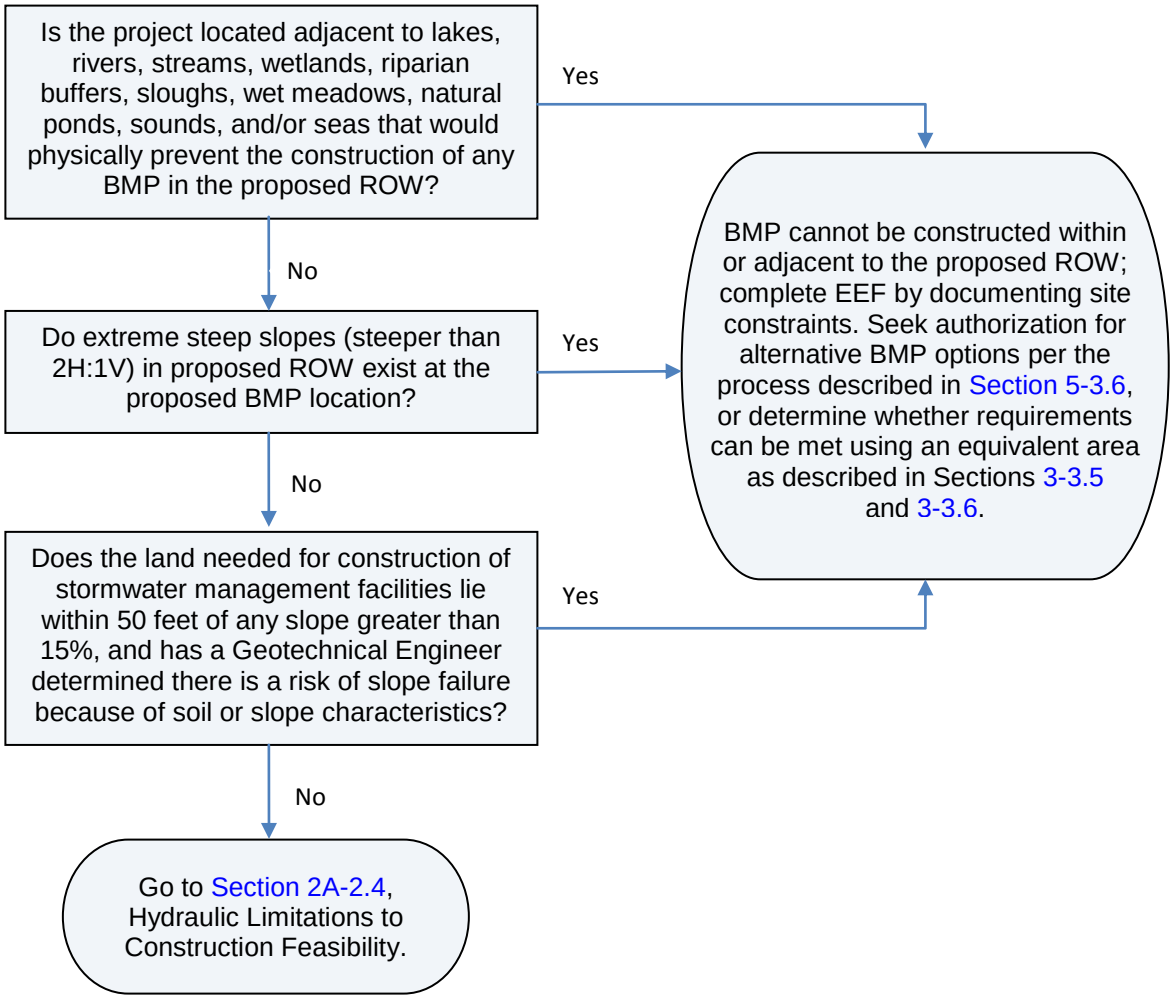



**Figure 2A-2 Geographic and geotechnical limitations to construction feasibility.**

## *2A-2.4 Hydraulic Limitations to Construction Feasibility*

Hydraulic limitations can include the lack of hydraulic head necessary to effectively operate stormwater control facilities or areas with very shallow water tables such as floodplains or seasonal wetlands. Alternatives such as spill control devices and frequent cleaning of road or bridge surfaces with high-efficiency vacuum sweepers should be considered in these areas in lieu of standard treatment facilities.

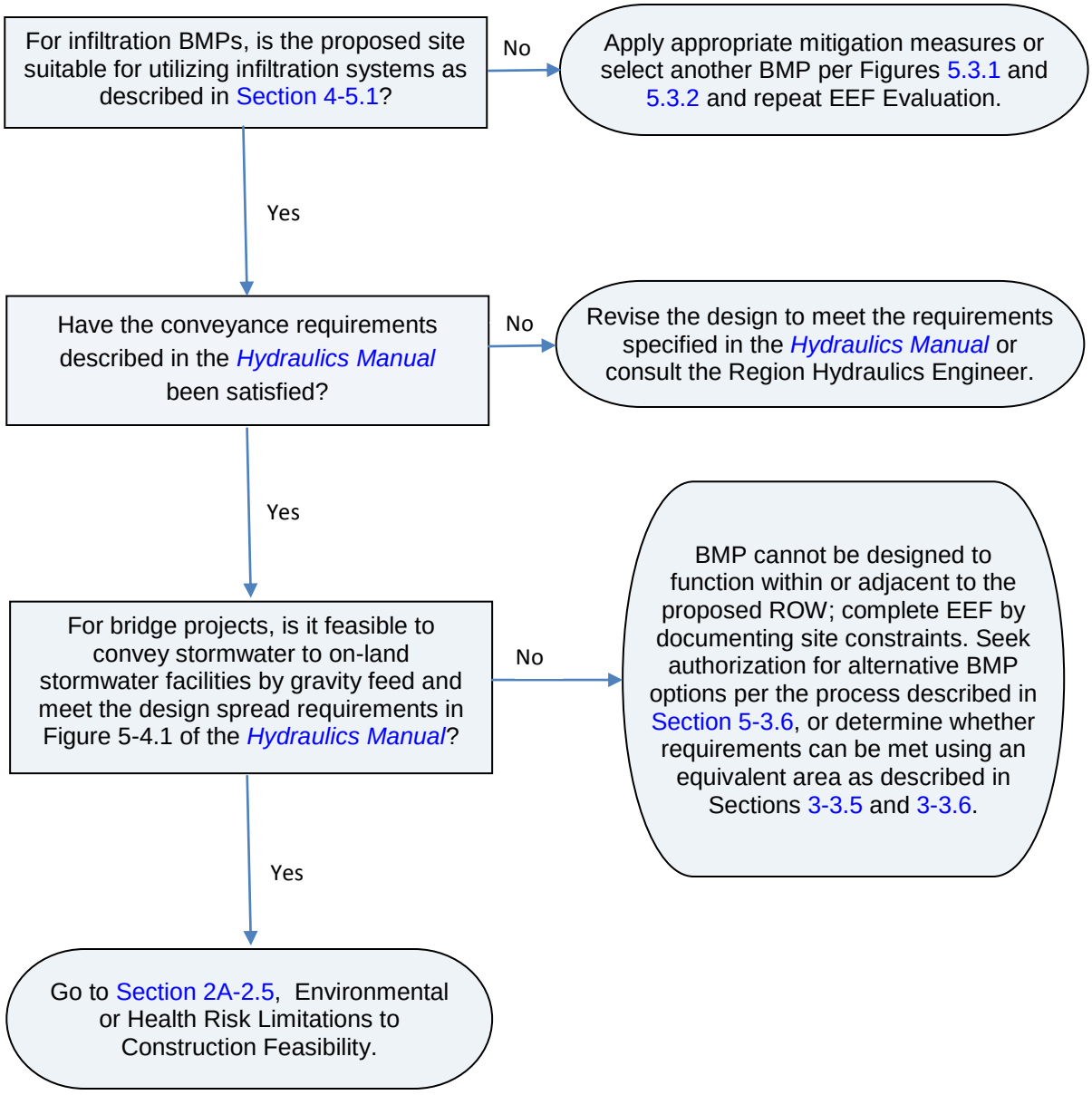



**Figure 2A-3 Hydraulic limitations to construction feasibility.**

## *2A-2.5 Environmental or Health Risk Limitations to Construction Feasibility*

Areas with intensive historic levels of industrial or commercial activity may have significant levels of soil, water, or fill contamination, which would prevent highway construction work from being conducted in a safe manner (as specified in the Washington Industrial Safety and Health Act or federal Occupational Safety and Health Administration regulations), or may be the subject of overriding Resource Conservation and Recovery Act (RCRA), state Model Toxics Control Act (MTCA), or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulations. Such significant safety, health, and environmental limitations would generally preclude construction of stormwater facilities on a particular site.

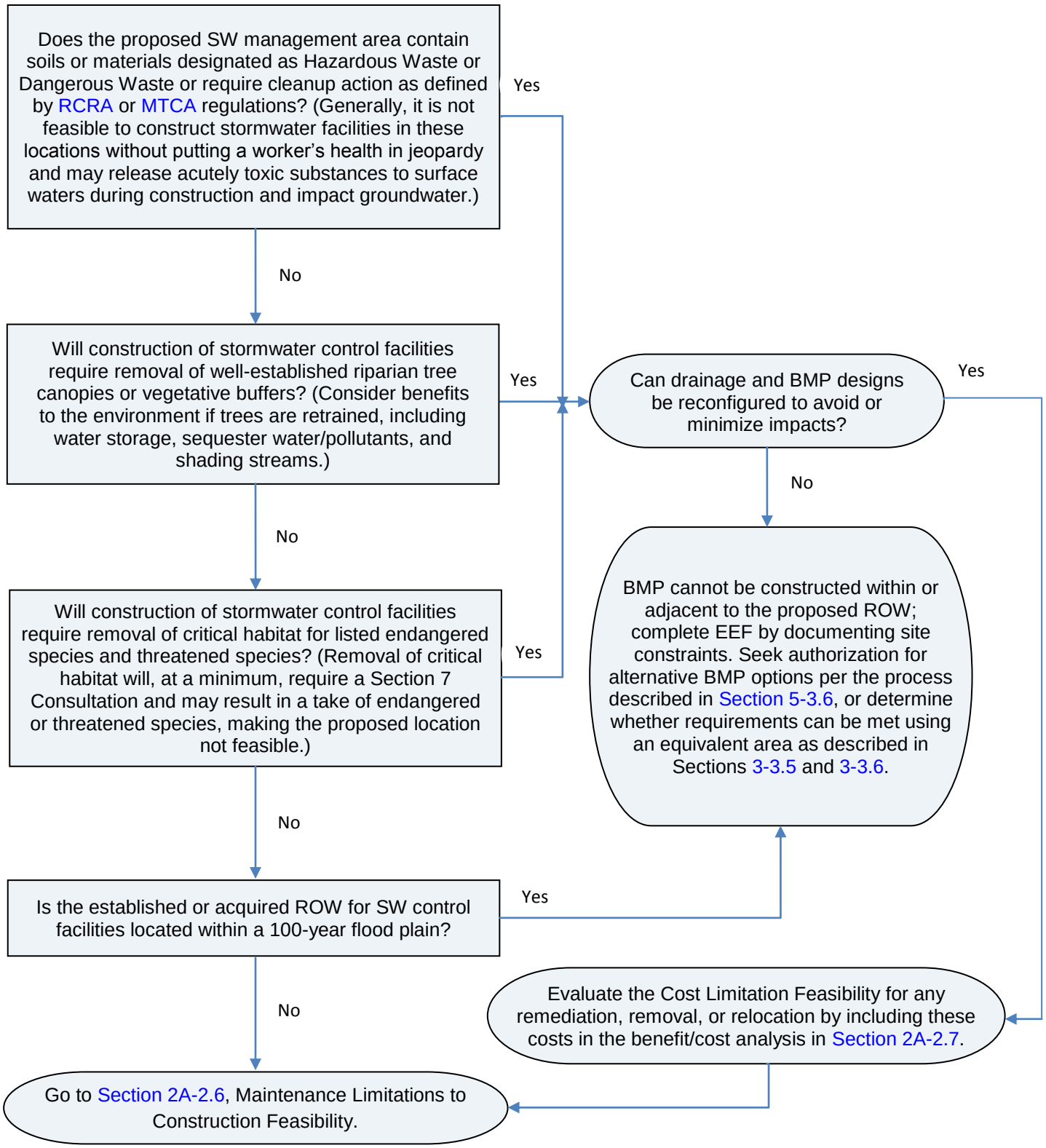



**Figure 2A-4 Environmental and health limitations to construction feasibility.**

## *2A-2.6 Maintenance Limitations to Construction Feasibility*

Maintenance is essential to the performance of runoff treatment and flow control BMPs and therefore needs to be discussed and reviewed with the local maintenance office prior to finalizing the design (see Figure 2A-5). Maintenance considerations to address during the design process include: specific site restrictions that prevent access, long-term operation and maintenance costs, and necessary equipment and training.

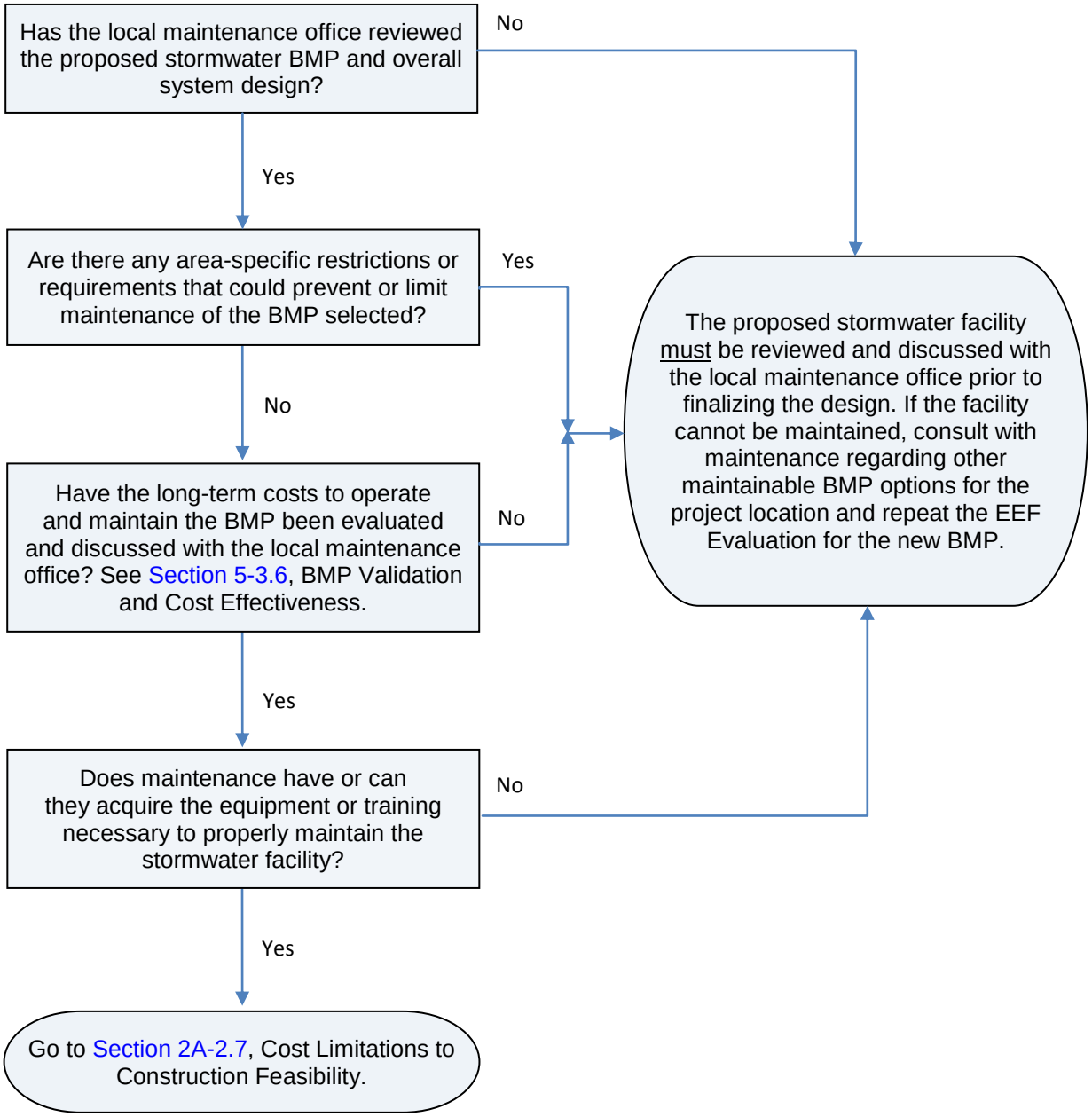
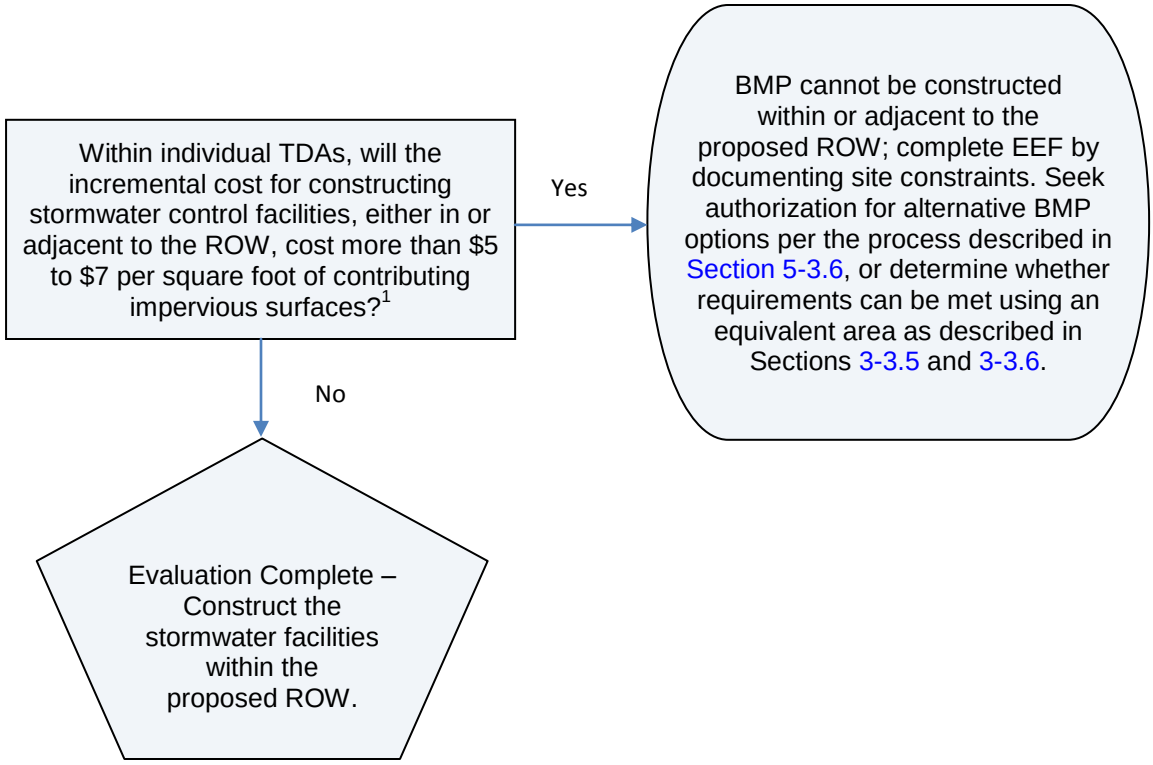



**Figure 2A-5 Maintenance limitations to construction feasibility.**

## *2A-2.7 Cost Limitations to Construction Feasibility*

In 2003, 2006, and 2009, WSDOT performed environmental costs analyses. Critical factors found to affect stormwater management costs included the location and setting of the specific projects relative to neighborhoods, streams, and wetlands. In addition, projects with poor soil conditions or high water tables generally had considerably higher costs for treating stormwater within the right of way. In discussions with the authors of the cost analysis, it was determined that project delivery would be impeded when stormwater costs exceeded a range of $5 to $7 per square foot of contributing impervious surface. Using a range of values allows project offices some flexibility to determine cost/benefit feasibility based on the project's setting.




1. Projects within highly urbanized areas or those that may impact significant areas of wetlands or floodplains should generally use the $7 per square foot criterion, while those projects in more rural areas should generally use the $5 per square foot criterion for evaluating benefit/cost feasibility.

**Figure 2A-6 Cost limitations to construction feasibility.**

CHAPTER 3

# Minimum Requirements

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# Chapter 3 Minimum Requirements

## 3-1 Introduction

*Note to the designer: It is extremely important to take the time to thoroughly understand the minimum requirements presented in this chapter when making stormwater design decisions. A firm grasp of the chapter's terminology is essential; consult the manual's Glossary to clarify the intent and appropriate use of these terms. Direct your questions regarding the minimum requirements and terminology to the region hydraulics representative, the Headquarters (HQ) Highway Runoff Office, or the HQ Environmental Services Office.*

This chapter describes the nine minimum requirements that apply to the planning and design of stormwater management facilities and best management practices (BMPs) for existing and new Washington State highways, rest areas, park-and-ride lots, ferry terminals, and highway maintenance facilities. In order to plan and design stormwater management systems appropriately, the designer must determine specific parameters related to the project, such as new impervious area created, converted pervious area, area of land disturbance, presence of wetlands, and applicability of basin and watershed plans. Projects that follow the stormwater management practices in this manual achieve compliance with federal and state water quality regulations through the *presumptive approach*. As an alternative, see Sections 1-1.3, 2-7.4, and 5-3.5.3 for a description of using the *demonstrative approach* to protect water resources in lieu of following the stormwater management practices in this manual.

This chapter provides information on applying the following minimum requirements to various types and sizes of projects:

1. Stormwater Planning
2. Construction Stormwater Pollution Prevention
3. Source Control of Pollutants
4. Maintaining the Natural Drainage
5. Runoff Treatment
6. Flow Control
7. Wetlands Protection
8. Watershed/Basin Planning
9. Operation and Maintenance

Not all of the minimum requirements apply to every project. The flowcharts in Figures 3-1, 3-2, and 3-3 are provided to assist in determining which requirements **may** apply. **Consulting the flowcharts is the initial step in the process. The next critical step involves reviewing Section 3-2 for the detailed information provided for each minimum requirement in terms of its objective, applicability (and potential exemptions), and guidelines for application**. Consult the Glossary to ensure complete understanding of the minimum requirements. Additional guidelines for retrofits are provided in Section 3-4.

Note: For the purposes of this manual, the boundary between eastern and western Washington is the Cascade Crest, except in Klickitat County, where the boundary line is the 16-inch mean annual precipitation contour (isopleth).

# 3-2 Applicability of the Minimum Requirements

## 3-2.1 Project Thresholds

Unless otherwise noted, all minimum requirements apply throughout the state. However, in some instances, design criteria, thresholds, and exemptions for eastern and western Washington differ due to different climatic, geologic, and hydrogeologic conditions. Regional differences for each minimum requirement are presented in Section 3-3 under the *Applicability* sections. Additional controls may be required, regardless of project type or size, as a result of adopted basin plans or to address special water quality concerns via a critical area ordinance or a requirement related to the total maximum daily load (TMDL).

WSDOT projects shall use the Stormwater Design Documentation Spreadsheet (SDDS) to analyze HRM Minimum Applicability to the project. The spreadsheet is located at www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

All nonexempt projects are required to comply with Minimum Requirement 2. In addition, projects that exceed certain thresholds are required to comply with additional minimum requirements. Use Figures 3-1, 3-2, and 3-3 as the **initial step** in determining which requirements might apply. The **next critical step** involves reviewing the detailed information provided for each applicable minimum requirement in Section 3-3. Consult the Glossary to gain a clear understanding of the following terms, which are essential for correctly assessing minimum requirement applicability.

- New impervious surface
- Converted pervious surface
- Pollution-generating impervious surface (PGIS)
- Pollution-generating pervious surface (PGPS)
- Land-disturbing activity
- Native vegetation
- Non-road-related projects
- Existing roadway prism
- Project limits
- Replaced impervious surface
- Effective impervious surface
- Noneffective impervious surface
- Effective PGIS

- Noneffective PGIS
- Threshold discharge area (TDA)
- Net-new impervious surface

Upgrading by resurfacing state facilities from gravel to bituminous surface treatment (BST or "chip seal"), asphalt concrete pavement (ACP), or Portland cement concrete pavement (PCCP) is considered to be adding new impervious surfaces and is subject to the minimum requirements that are triggered when the thresholds are met.

Basin planning is encouraged and may be used to tailor applicable minimum requirements to a specific basin (see Minimum Requirement 8).

## 3-2.2 Exemptions

Some types of activities are fully or partially exempt from the minimum requirements. These include some road maintenance/preservation practices and some underground utility projects. The road maintenance and preservation practices that are exempt from all the minimum requirements are:

- Upgrading by resurfacing Washington State Department of Transportation (WSDOT) facilities from BST to ACP or PCCP without expanding the area of coverage.[1]

The following practices are subject only to Minimum Requirement 2, Construction Stormwater Pollution Prevention:

- Underground utility projects that replace the ground surface with in-kind material or materials with similar runoff characteristics.
- Removing and replacing a concrete or asphalt roadway to base course, or subgrade or lower, without expanding or upgrading the impervious surfaces.
- Repairing the roadway base or subgrade.

[1] This exemption is applicable only to WSDOT projects; whereas, the "gravel-to-BST" exemption in Ecology's stormwater management manuals is available to local governments. For local governments, upgrades that involve resurfacing from BST to ACP or PCCP are considered new impervious surfaces and are not categorically exempt.

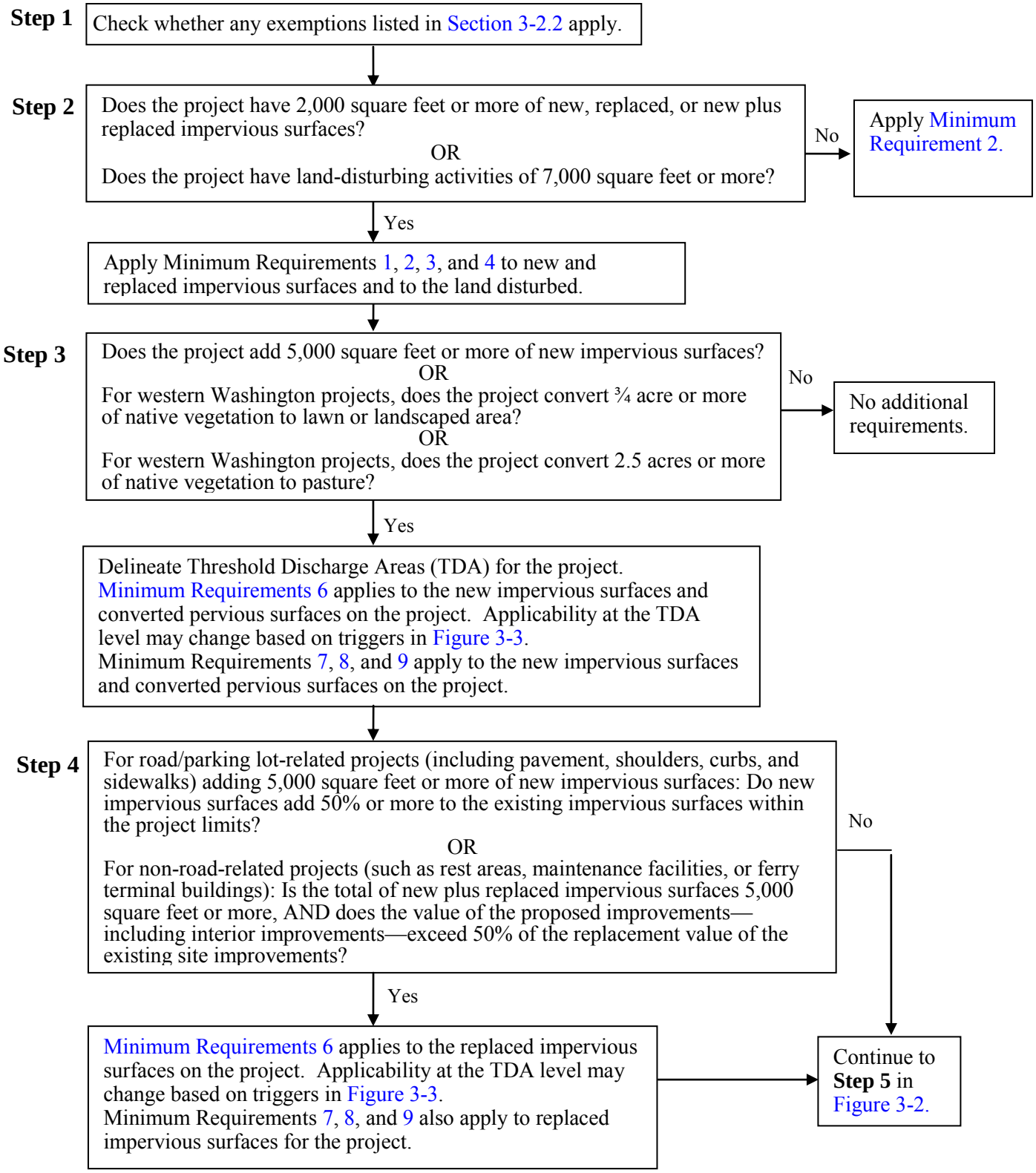



**Figure 3-1 Minimum requirement applicability at project level.**

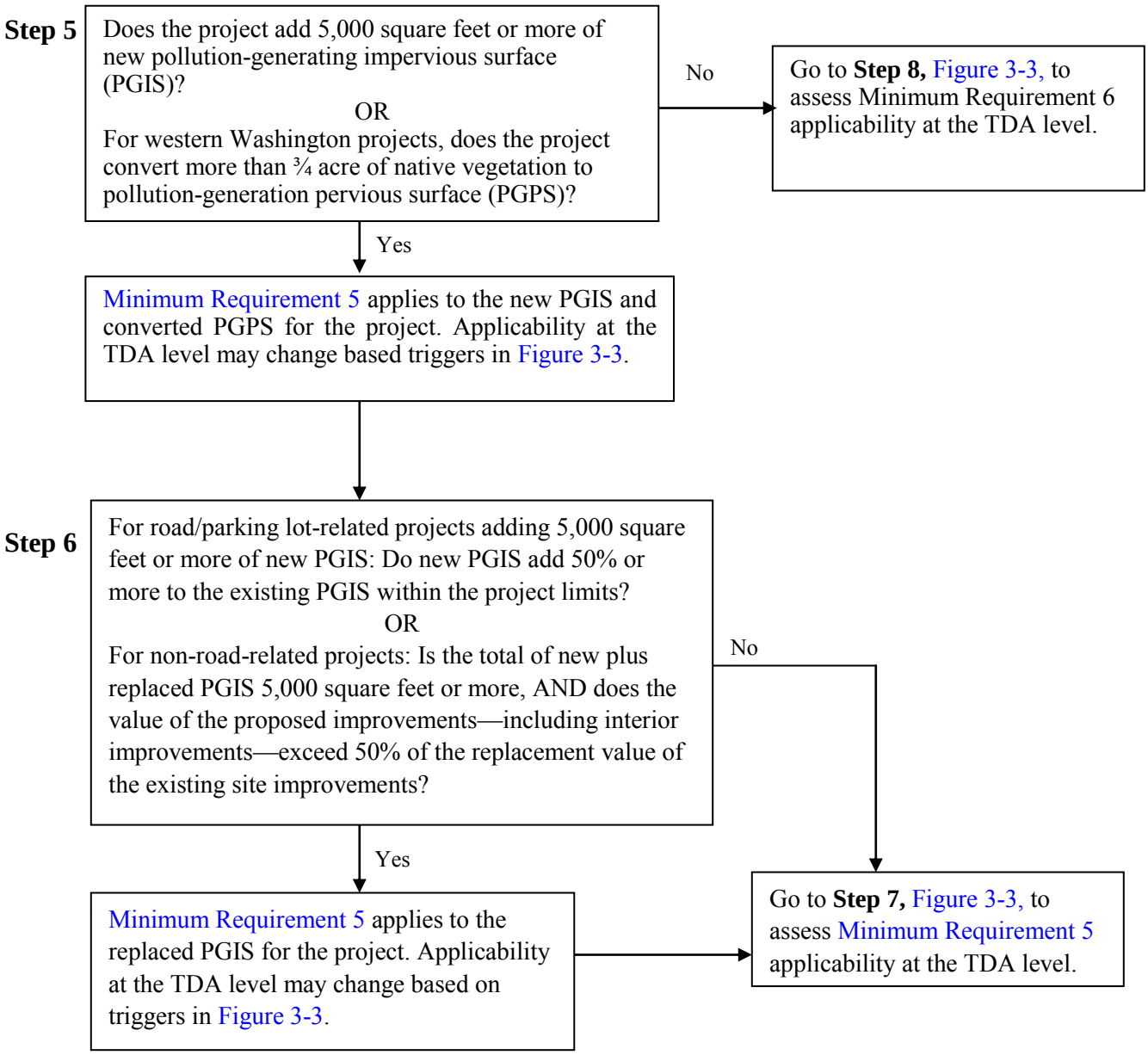
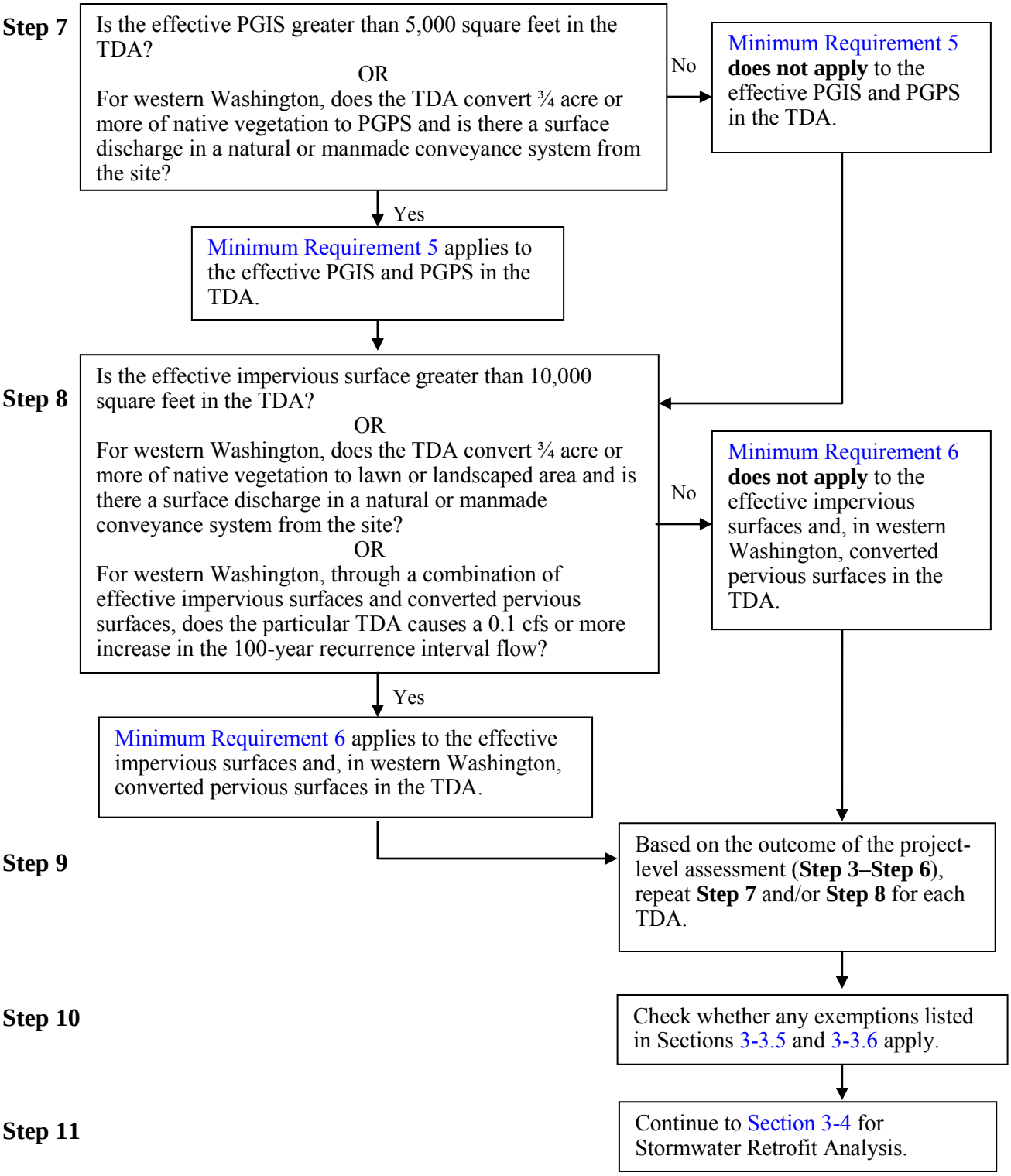



**Figure 3-2 Minimum requirement applicability at project level (continued).**




Note: For Figure 3-3, Minimum Requirements 1–4 and 7–9 still apply to all TDAs on the project, even though Minimum Requirements 5 and/or 6 may not apply to each TDA.

**Figure 3-3 Minimum requirement applicability at TDA level.**

# 3-3 Minimum Requirements

This section describes the minimum requirements for stormwater management at project sites. Consult Section 3-2 to determine which requirements apply to any given project. (See Chapter 5 for BMPs to use in meeting Minimum Requirements 3, 5, 6, 7, and 9, and Chapter 6 for BMPs to use in meeting Minimum Requirement 2.)

## 3-3.1 Minimum Requirement 1 – Stormwater Planning

The two main stormwater planning components of Minimum Requirement 1 are: (1) Construction Stormwater Pollution Prevention Planning, and (2) Permanent Stormwater Control Planning.

Multiple documents are used to fulfill the objective of this requirement, since addressing stormwater management needs is thoroughly integrated into WSDOT's design, construction, and maintenance programs. WSDOT's construction stormwater pollution prevention planning components consist of Spill Prevention, Control, and Countermeasures (SPCC) plans and Temporary Erosion and Sediment Control (TESC) plans. WSDOT's permanent stormwater control planning components include Hydraulic Reports and aspects of the *Maintenance Manual*.

### 3-3.1.1 Objective

The stormwater planning components collectively demonstrate how stormwater management will be accomplished, both during project construction and in the final, developed condition.

### 3-3.1.2 Applicability

Minimum Requirement 1 applies to all nonexempt projects that meet the thresholds described in Figure 3-1. Contractors are required to prepare SPCC plans for all projects, since all projects have the potential to spill hazardous materials. All projects that disturb soil must comply with the 12 TESC elements (see Section 6-2.1.2) and must apply the appropriate best management practices (BMPs) presented in Chapter 6. WSDOT prepares a TESC plan if a construction project adds or replaces (removes existing road surface down to base course) more than 2,000 square feet of impervious surface or disturbs more than 7,000 square feet of soil. Projects that disturb fewer than 7,000 square feet of soil must address erosion control and the 12 TESC elements; however, a stand-alone TESC plan is optional and plan sheets are not required. Both the SPCC and TESC plans must be kept on-site or within reasonable access of the site during construction and may require updates with changing site conditions.

To meet the objectives of the permanent stormwater control planning requirements, WSDOT prepares Hydraulic Reports and follows guidelines in the *Maintenance Manual*. The Hydraulic Report provides a complete record of the engineering justification for all drainage modifications and is prepared for all major and minor hydraulic projects based on guidelines in this manual as well as the *Hydraulics Manual*. As noted in the *Hydraulics Manual*, the Hydraulic Report must contain detailed descriptions of the following items:

- Existing and developed site hydrology
- Flow control and runoff treatment systems
- Conveyance system analysis and design
- Wetland hydrology analysis, if applicable
- Downstream analysis, if applicable

### 3-3.1.3 Guidelines

Instructions on how to prepare SPCC and TESC plans are provided in Minimum Requirement 2 and in Chapter 6.

Stormwater runoff treatment and flow control BMP maintenance criteria for each BMP in Chapter 5 are included in Section 5-5. Additional standards for maintaining stormwater BMPs are found in the *Regional Road Maintenance/Endangered Species Act Program Guidelines* (www.wsdot.wa.gov/maintenance/roadside/esa.htm). The criteria and guidelines are designed to ensure all BMPs function at design performance levels and that the maintenance activities themselves are protective of water quality and its beneficial uses.

## 3-3.2 Minimum Requirement 2 – Construction Stormwater Pollution Prevention

The two components of construction stormwater pollution prevention are as follows:

- Temporary Erosion and Sediment Control (TESC) planning
- Spill Prevention, Control, and Countermeasures (SPCC) planning

Erosion control is required to prevent erosion from damaging project sites, adjacent properties, and the environment. The emphasis of erosion control is to prevent the erosion process from starting by preserving native vegetation, limiting the amount of bare ground, and protecting slopes. A TESC plan must address the following elements:

- Element 1: Mark clearing limits
- Element 2: Establish construction access
- Element 3: Control flow rates
- Element 4: Install sediment controls
- Element 5: Stabilize soils
- Element 6: Protect slopes
- Element 7: Protect drain inlets
- Element 8: Stabilize channels and outlets
- Element 9: Control pollutants

- Element 10: Control dewatering
- Element 11: Maintain BMPs
- Element 12: Manage the project

All projects that involve mechanized equipment or construction materials that could potentially contaminate stormwater or soils require SPCC plans. The SPCC plan is a stand-alone document prepared by the contractor and contains the following:

- Site information and project description
- Spill prevention and containment
- Spill response
- Material and equipment requirements
- Reporting information
- Program management
- Plans to contain preexisting contamination, if necessary

Detailed requirements for each of these elements are provided in Sections 6-2 and 6-3. The TESC and SPCC plans must (1) demonstrate compliance with all of those detailed requirements, or (2) when site conditions warrant the exemption of an element(s), clearly document in the narrative why a requirement does not apply to the project.

#### 3-3.2.1 Objective

The objective of construction stormwater pollution prevention is to ensure construction projects do not impair water quality by allowing sediment to discharge from the site or allowing pollutant spills.

#### 3-3.2.2 Applicability

All nonexempt projects must address Construction Stormwater Pollution Prevention per Standard Specification 1.07.15(1). All projects that disturb 7,000 square feet or more of land or add 2,000 square feet or more of new, replaced, or new plus replaced impervious surface must prepare a TESC plan in addition to an SPCC plan.

#### 3-3.2.3 Guidelines

Instructions on how to prepare SPCC and TESC plans are provided in Sections 6-2 and 6-3.

### 3-3.3 Minimum Requirement 3 – Source Control of Pollutants

All known, available, and reasonable source control BMPs must be applied and must be selected, designed, and maintained in accordance with this manual.

### 3-3.3.1 Objective

The intention of source control is to prevent pollutants from coming into contact and mixing with stormwater. In many cases, it is more cost-effective to apply source control than to remove pollutants after they have mixed with runoff. This is certainly the case for erosion control and spill prevention during the construction phase.

### 3-3.3.2 Applicability

Minimum Requirement 3 applies to all nonexempt projects that meet the thresholds described in Figure 3-1. Source control (erosion control and spill prevention) applies to all projects during the construction phase per Minimum Requirement 2. Postconstruction source controls are employed programmatically via WSDOT's maintenance program. Thus, in instances where structural BMPs may not be sufficient, consult with the environmental support staff of the HQ Maintenance and Operations Office to explore operational source control options that may be available to meet regulatory requirements.

Certain types of activities and facilities may require source control BMPs. Determine whether there are pollutant-generating activities or facilities in the project that warrant source controls. Source control BMPs for the activities listed in Section 5-2.1 must be specified to reduce pollutants. For detailed descriptions of the source control BMPs, see Chapter 2 of Volume IV of Ecology's *Stormwater Management Manual for Western Washington* (SMMWW) or Chapter 8 of the *Stormwater Management Manual for Eastern Washington* (SMMEW). Any deviations from the source control BMPs listed in either the SMMWW or the SMMEW must provide equivalent pollution source control benefits. The Project File must include documentation for why the deviation is considered equivalent. Section 5-3.5.3 describes the process for seeking approval of such deviations. The project may have additional source control responsibilities as a result of area-specific pollution control plans (such as watershed/basin plans, water cleanup plans, groundwater management plans, or lake management plans), ordinances, and regulations.

### 3-3.3.3 Guidelines

Source control BMPs include operational and structural BMPs.

- Operational BMPs are nonstructural practices that prevent (or reduce) pollutants from entering stormwater. Examples include preventative maintenance procedures; spill prevention and cleanup; and inspection of potential pollutant sources.
- Structural BMPs are physical, structural, or mechanical devices or facilities intended to prevent pollutants from entering stormwater. Examples include installation of vegetation for temporary and permanent erosion control; putting roofs over outside storage areas; and putting berms around potential pollutant source areas to prevent both stormwater run-on and pollutant run-off.

Many source control BMPs combine operational and structural characteristics. A construction phase example is slope protection using various types of covers: temporary covers (structural) and the active inspection and maintenance needed for effective use of the covers (operational). A postconstruction phase example is street sweeping: a sweeper (mechanical) and the sweeping schedule and procedures for its use (operational) collectively support the BMP.

For criteria on the design of construction-related source control BMPs, see Chapter 6 and Appendix 6A. For criteria on the design of source control BMPs for the postconstruction phase, see Section 5-2.1.

## 3-3.4 Minimum Requirement 4 – Maintaining the Natural Drainage System

To the maximum extent practicable, natural drainage patterns must be maintained and discharges from the site must occur at the natural outfall locations. The manner by which runoff is discharged must not cause downstream erosion in receiving waters and downgradient properties. Outfalls require dispersal systems and/or energy-dissipation BMPs per *Hydraulics Manual* guidelines.

### 3-3.4.1 Objective

The intent of maintaining the natural drainage system is to (1) preserve and utilize natural drainage systems to the fullest extent because of the multiple benefits such systems provide, and (2) prevent erosion at, and downstream of, the discharge location.

### 3-3.4.2 Applicability

Minimum Requirement 4 applies to all nonexempt projects that meet the thresholds described in Figure 3-1, to the maximum extent practicable.

### 3-3.4.3 Guidelines

When projects affect subsurface and/or surface water drainage, use strategies that minimize impacts and maintain hydrologic continuity. For example, road cuts on hill slopes or roads bisecting wetlands or ephemeral streams can affect subsurface water drainage. Ditching, channel straightening, channel lining, channel obliteration, and roads that bisect wetlands or perennial streams change surface water drainage and stream channel processes. The designer must use the best available design practices to maintain hydrologic function and drainage patterns based on site geology, hydrology, and topography.

If flows for a given outfall are not channeled in the preproject condition, runoff concentrated by the proposed project must be discharged overland through a dispersal system or to surface water through an energy dissipater BMP before leaving the project outfall. Typical *dispersal systems* are rock pads, dispersal trenches, level spreaders, and diffuser pipes. Typical *energy dissipaters* are rock pads and drop structures. These systems are listed in Sections 5-4.3.5 and 5-4.3.6.

In some instances, a diversion of flow from the existing (preproject) discharge location may be beneficial to the downstream properties or receiving water bodies. Examples of where the diversion of flows may be warranted include (1) areas where preproject drainage conditions are contributing to active erosion of a stream channel in a heavily impervious basin, and (2) areas where preproject drainage patterns are exacerbating flooding of downstream properties. If it is determined that a diversion of flow from the natural discharge location may be warranted, contact region or Headquarters hydraulics staff.

## 3-3.5 Minimum Requirement 5 – Runoff Treatment

Runoff treatment must be provided for all nonexempt projects that meet the threshold described in Figures 3-1, 3-2, and 3-3.

### 3-3.5.1 Objective

The purpose of runoff treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms to maintain or enhance beneficial uses of receiving waters. When site conditions are appropriate, infiltration can potentially be the most effective BMP for runoff treatment. Meeting runoff treatment requirements may also be achieved through regional stormwater facilities.

### 3-3.5.2 Runoff Treatment Exemptions

Any of the runoff treatment exemptions below may be negated by requirements set forth in a Total Maximum Daily Load (TMDL) or a TMDL-related water cleanup plan.

- Runoff treatment is not required where no new pollution-generating impervious surface (PGIS) is added. These include:
  - Projects where the only work involved is the addition of paved surfaces not intended for use by motor vehicles (such as sidewalks or bike/pedestrian trails) and that are separated from adjacent roadways.
  - Projects where the only work involved is an overlay or upgrade of existing bituminous surface treatment (BST or "chip seal"), asphalt concrete pavement (ACP), or Portland cement concrete pavement (PCCP) without an increase in impervious area. Note: Upgrading a facility from gravel surface to BST, ACP, or PCCP is considered an addition of new impervious surface and is subject to runoff treatment if the thresholds are met.
- Discharges to underground injection control (UIC) facilities may be exempt from basic runoff treatment requirements if the vadose zone matrix between the bottom of the facility and the water table provides adequate treatment capacity (see Section 4-5.4).

### 3-3.5.3 Applicability[2]

Minimum Requirement 5 applies to all nonexempt projects that meet the thresholds described in Figures 3-1, 3-2, and 3-3. Even if the threshold is not triggered, runoff from the applicable pollution-generating impervious surfaces (PGIS) and pollution-generating pervious surfaces (PGPS) must be dispersed and infiltrated to adjacent pervious areas when practicable. The extension of the roadway edge and the paving of gravel shoulders and lanes are new PGIS.

Projects not triggering the runoff treatment minimum requirement may still require treatment if a specific deficiency within the project limits is identified through the I-4 Stormwater Retrofit program. The decision to retrofit is made by the project office in collaboration with region and Headquarters program management and environmental services staff.

Natural dispersion areas meeting the requirements of BMP FC.01 must be identified along the project as a part of determining whether the particular TDA exceeds thresholds in Figure 3-3, Step 7. Those effective PGIS areas that are flowing to an existing (preproject) dispersion area can be subtracted as noneffective PGIS.

Equivalent area treatment is allowable for PGIS areas that drain to the same receiving waters and have the same pollutant loading characteristics. While the equivalent area will receive treatment, the new or expanded discharge must not cause a violation of surface water quality standards. Additional information on equivalent area treatment is provided in Section 4-3.6.1.

### 3-3.5.4 Guidelines

Runoff treatment design involves the following three steps:

1. Determine the specific runoff treatment requirements (basic treatment, enhanced treatment, oil control, and/or phosphorus control). Refer to *Treatment Targets* below.
2. Choose the method(s) of runoff treatment that will best meet the treatment requirements, taking into account the constraints/opportunities presented by the project's context and operation and maintenance. Refer to Sections 2-5, 2-6, 2-7.4, 4-3.1, 5-3.5, and 5-5.
3. Design runoff treatment facilities based on the sizing criteria. Refer to *Criteria for Sizing Runoff Treatment Facilities* below and Section 5-4.1.

WSDOT's stormwater management design philosophy (see Section 2-5.2) seeks to mimic natural hydrology, where feasible, through the dispersal and infiltration of runoff. The extent to which runoff flow rates and volumes can be (or remain) dispersed and then infiltrated determines the types and sizing of runoff treatment options available. This aspect of runoff treatment planning and design is discussed in detail in Sections 2-3.2, 4-3.6.1, 5-2, and 5-3.

[2] Consult the Glossary for the following key terms: *converted pervious surface*, *impervious surface*, *new PGIS*, *PGPS*, *project limits*, *replaced impervious surface*, *effective PGIS*, *noneffective PGIS*, and *threshold discharge area (TDA)*.

Stormwater facilities are not allowed within a jurisdictional wetland or its natural vegetated buffer, except for conveyance systems allowed by applicable permit(s) or as allowed in a wetland mitigation plan. Wetlands may be considered for runoff treatment if the wetland meets the criteria for hydrologic modification (see Minimum Requirement 6 and Section 4-6 on wetland hydroperiods) and Minimum Requirement 7.

Sections 4-3 (western Washington) and 4-4 (eastern Washington) provide design criteria for sizing runoff treatment facilities, including a description on how to conduct the hydrological analysis to derive treatment volumes and flow rates for treatment facilities. Section 5-4 provides direction on how to design the treatment facilities chosen for the project.

## *Treatment Targets*

There are four runoff treatment targets: *Basic Treatment* (total suspended solids removal), *Enhanced Treatment* (dissolved metals removal), *Oil Control*, and *Phosphorus Control*. Table 3-1 describes applicable treatment targets and performance goals for roadway projects. For nonroadway applications, refer to Ecology's SMMEW or SMMWW. Table 3-2 identifies receiving waters that do not require *Enhanced Treatment* for direct discharges.

Section 5-3.5 provides information on alternative options available to meet each of the four treatment targets. Per Figure 5-3.2, the designer must exhaust all approved runoff treatment BMP options before using a BMP from Section 5-3.5. Treatment facilities, designed in accordance with the design criteria presented in this manual, are presumed to meet the applicable performance goals.

An adopted and implemented Basin Plan, Total Maximum Daily Load (TMDL), or Water Cleanup Plan may also be used to set runoff treatment requirements that are tailored to a specific basin. However, treatment requirements must not be less than those achieved by facilities designed for Basic Treatment.

## Table 3-1 Runoff treatment targets and applications for roadway projects.

| Treatment Target | Application | Performance Goal |
|---|---|---|
| Basic Treatment | All project threshold discharge areas (TDAs) where runoff treatment threshold is met. | 80% removal of total suspended solids (TSS) |
| Enhanced Treatment (dissolved metals) | Same as for Basic Treatment and does not discharge to Basic Treatment receiving water body AND<br>Roadways within *Urban Growth Areas* (UGAs) with ADT[1] ≥ 7,500 OR<br>Roadways outside of UGAs with ADT ≥ 15,000 OR<br>Required by an adopted basin plan or water cleanup plan/TMDL, as described in Sections 2-6.4 and 2-7.3.<br>(See Table 3-2 for Basic Treatment receiving water bodies.) | Provide a higher rate of removal of dissolved metals than Basic Treatment facilities for influent concentrations ranging from 0.003 to 0.02 mg/L for dissolved copper and 0.02-0.3 mg/L for dissolved zinc |
| Oil Control | Same as for Basic Treatment AND<br>There is an intersection where either ≥15,000 vehicles (ADT) must stop to cross a roadway with ≥25,000 vehicles (ADT) or vice versa[2] OR<br>Rest areas with an expected trip end count greater than or equal to 300 vehicles per day OR<br>Maintenance facilities that park, store, or maintain 25 or more vehicles (trucks or heavy equipment) that exceed 10 tons gross weight each OR<br>Eastern Washington roadways with ADT >30,000. | No ongoing or recurring visible sheen and 24-hr average total petroleum hydrocarbon concentration of not greater than 10 mg/L with a maximum of 15 mg/L for a discrete (grab) sample |
| Phosphorus Control | Same as for Basic Treatment AND<br>The project is located in a designated area requiring phosphorus control as prescribed through an adopted basin plan or water cleanup plan/TMDL.[3] | 50% removal of total phosphorus (TP) for influent concentrations ranging from 0.1 to 0.5 mg/L TP |

[1]Average daily traffic (ADT) is generally the design year ADT and not the current ADT. A possible exception to this rule is where road ADT would likely never reach levels that would exceed its design capacity (such as with rural portions of the state). Contact region hydraulics staff for more information.

[2] Treatment is required for these high-use intersections for lanes where vehicles accumulate during the signal cycle, including left- and right-turn lanes from the beginning of the left-turn pocket. If no left-turn pocket exists, the treatable area must begin at a distance equal to three car lengths from the stop line. If runoff from the intersection drains to more than two collection areas that do not combine within the intersection, treatment may be limited to any two of the collection areas where the cars stop.

[3]Contact region hydraulics or environmental staff to determine whether phosphorus control is required for a project.

## Table 3-2 Basic Treatment receiving water bodies.[1]

| | |
|---|---|
| **1. All saltwater bodies** | |
| **2. Rivers (only Basic Treatment applies below the location)** | |
| Baker (Anderson Creek) | Quillayute (Bogachiel River) |
| Bogachiel (Bear Creek) | Quinault (Lake Quinault) |
| Cascade (Marblemount) | Sauk (Clear Creek) |
| Chehalis (Bunker Creek) | Satsop (Middle and East Fork confluence) |
| Clearwater (Town of Clearwater) | Similkameen |
| Columbia (Canadian Border) | Skagit (Cascade River) |
| Cowlitz (Skate Creek) | Skokomish (Vance Creek) |
| Elwha (Lake Mills) | Skykomish (Beckler River) |
| Green (Howard Hanson Dam) | Snake |
| Grand Ronde | Snohomish (Snoqualmie River) |
| Hoh (South Fork Hoh River) | Snoqualmie (Middle and North Fork confluence) |
| Humptulips (West and East Fork confluence) | Sol Duc (Beaver Creek) |
| Kalama (Italian Creek) | Spokane |
| Kettle | Stillaguamish (North and South Fork confluence) |
| Klickitat | North Fork Stillaguamish (Boulder River) |
| Lewis (Swift Reservoir) | South Fork Stillaguamish (Canyon Creek) |
| Methow | Suiattle (Darrington) |
| Moses | Tilton (Bear Canyon Creek) |
| Muddy (Clear Creek) | Toutle (North and South Fork confluence) |
| Naches | North Fork Toutle (Green River) |
| Nisqually (Alder Lake) | Washougal (Washougal) |
| Nooksack (Glacier Creek) | White (Greenwater River) |
| South Fork Nooksack (Hutchinson Creek) | Wenatchee |
| Okanogan | Wind (Carson) |
| Pend Oreille | Wynoochee (Wishkah River Road Bridge) |
| Puyallup (Carbon River) | Yakima |
| Queets (Clearwater River) | |
| **3. Streams with a Strahler order of 4 or higher (as determined using 1:24,000 scale maps to delineate stream order) receiving discharges from roadway outside UGAs with ADT <30,000** | |
| **4. Non-fish-bearing streams tributary to Basic Treatment receiving waters** | |
| **5. Lakes (county location)** | |
| Banks (Grant) | Silver (Cowlitz) |
| Chelan (Chelan) | Whatcom (Whatcom) |
| Moses (Grant) | Washington (King) |
| Potholes Reservoir (Grant) | Union (King) |
| Sammamish (King) | |
| **6. Discharges to groundwater via rule-authorized UIC facilities or surface infiltration[2]** | |

[1] Receiving waters not requiring Enhanced Treatment for direct discharges (or, indirectly through a municipal storm sewer system). The initial criteria for this list are rivers whose mean annual flow exceeds 1,000 cubic feet per second and lakes whose surface area exceeds 300 acres. Local governments may petition Ecology for the addition of waters to this list, but waters should have sufficient background dilution capacity to accommodate dissolved metals additions from build-out conditions in the watershed under the latest Comprehensive Land Use Plan and zoning regulations.

[2] Contact region hydraulics or environmental staff to determine whether an underground injection control (UIC) facility is authorized by the rules under the UIC program (WAC 173-218). In western Washington, surface infiltration must meet the soil suitability criteria (SSC-7) when within ¼ mile of surface waters that require the application of Enhanced Treatment. In certain situations, Ecology may approve surface infiltration that would not need enhanced runoff treatment on a case-by-case basis.

### *Criteria for Sizing Runoff Treatment Facilities*

Two sets of criteria exist for sizing runoff treatment facilities—one for western Washington (Table 3-3) and one for eastern Washington (Table 3-4). (See Sections 4-3.1 and 4-4.1 for a detailed discussion of on-line and off-line BMPs.)

**Table 3-3 Criteria for sizing runoff treatment facilities in western Washington.**

| Facility Type | Criteria | Model |
|---|---|---|
| Flow-based: upstream of flow control facility (on-line and off-line) | Size treatment facility so that 91% of the annual average runoff will receive treatment at or below the design loading criteria, under postdeveloped conditions for each TDA. If the flow rate is split upstream of the treatment facility, use the off-line flow rates. | Approved continuous simulation model using 15-minute time steps |
| Flow-based: downstream of flow control facility | Size treatment facility using the full 2-year release rate from the detention facility, under postdeveloped conditions for each TDA. | Approved continuous simulation model using 1-hour time steps |
| Volume-based (on-line) | *Wetpool* – Size the wetpool to store the 91st percentile, 24-hour runoff volume.<br>Other volume based infiltration and filtration facilities – Size the facility to treat 91% of the estimated runoff file for the postdeveloped condition. | Approved continuous simulation model with 1-hour time steps |

**Table 3-4 Criteria for sizing runoff treatment facilities in eastern Washington.**

| Facility Type | Criteria | Model |
|---|---|---|
| Volume-based | Size facility using the runoff volume predicted for the 6-month, long-duration* storm event under postdeveloped conditions for each TDA. | Single-event model (SCS or SBUH)<br>Climatic Regions 1–4 Regional Storm; OR Type 1A for Climatic Regions 2 & 3 (10-minute time step) |
| Flow-based: upstream of detention/retention facility | Size facility using the peak flow rate predicted for the 6-month, short-duration storm under postdeveloped conditions for each TDA. | Single-event model (SCS or SBUH)<br>Short-duration storm (5-minute time step) |
| Flow-based: downstream of detention facility | Size facility using the full 2-year release rate from the detention facility, under postdeveloped conditions for each TDA. | Single-event model (SCS or SBUH)<br>Short-duration storm OR the appropriate long-duration storm depending on the Climate Region, whichever produces the greatest flow |

* For more information on long-duration and short-duration storms, see Section 4-4.7.

If runoff from areas other than the total new PGIS and that portion of any replaced PGIS that requires treatment cannot be separated from the total new PGIS runoff, treatment facilities must be sized to treat this additional runoff.

## 3-3.6 Minimum Requirement 6 – Flow Control

This requirement applies to all nonexempt projects that discharge stormwater directly or indirectly through a conveyance system to a surface freshwater body.

### 3-3.6.1 Objective

The objective of flow control is to prevent increases in the stream channel erosion rates beyond those characteristic of natural or reestablished conditions. The intent is to prevent cumulative future impacts from increased stormwater runoff volumes and flow rates on streams. Wherever possible, infiltration is the preferred method of flow control. Meeting flow control requirements may also be achieved through regional stormwater facilities.

### 3-3.6.2 Flow Control Exemptions

Flow control is not required for all discharges to surface waters, because it is not always needed to protect stream morphology. Regardless of whether an exemption applies, projects need to take advantage of on-site opportunities to infiltrate storm runoff to the greatest extent feasible.

The following projects and discharges are exempt from flow control requirements; however, runoff treatment may still be required per Minimum Requirement 5:

1. A project able to disperse stormwater without discharging runoff either directly or indirectly through a conveyance system to surface waters per guidelines in Section 5-2.2.2.
2. Projects discharging stormwater directly or indirectly through a conveyance system into any of the exempt water bodies shown in Table 3-5.
3. Projects discharging stormwater from over-the-water structures such as bridges, docks, and piers in or over fresh water are exempt up to the 2-year flood plain elevation; OR that portion of an over-the-water structure that is over the ordinary high water mark.
4. Portions of a roadway that cut through the 2-year flood plain elevation.
5. Projects discharging stormwater directly or indirectly through a conveyance system into a wetland. However, flow control may still be required to maintain wetland hydrology (depth/duration of inundation) per Minimum Requirement 7. (See other applicable wetland protection criteria under Minimum Requirement 4.)

Any of the exempted areas must meet the following requirements:

- Direct discharge to the exempt receiving water does not result in the diversion of drainage area from perennial streams classified as Types 1, 2, 3, or 4 in the
- State of Washington Interim Water Typing System; or Types “S,” “F,” or “Np” in the Permanent Water Typing System; or from any Category I, II, or III wetland; AND
- Flow-splitting devices or drainage BMPs are applied to route natural runoff volumes from the project site to any downstream Type 5 stream or Category IV wetland:
    - Design of flow-splitting devices or drainage BMPs will be based on continuous hydrologic modeling analysis. The design will assure that flows delivered to Type 5 stream reaches will approximate, but in no

case exceed, durations ranging from 50% of the 2-year to the 50-year peak flow.

- Flow-splitting devices or drainage BMPs that deliver flow to category IV wetlands will also be designed using continuous hydrologic modeling to preserve preproject wetland hydrologic conditions unless specifically waived or exempted by regulatory agencies with permitting jurisdiction; AND

- The project site must be drained by a conveyance system that is comprised entirely of constructed conveyance elements (such as pipes, ditches, or drainage channels) and that extends to the ordinary high water mark of the exempt receiving water, unless, in order to avoid construction activities in sensitive areas, flows are properly dispersed before reaching the buffer zone of the sensitive or critical area; AND

- The conveyance system between the project site and the exempt receiving water must have a hydraulic capacity sufficient to convey discharges under future build-out conditions from all project and nonproject areas, if applicable (see the *Utilities Manual,* Section 1-18, for storm drainage requirements), from which runoff is collected; AND

- Any erodible elements of the constructed conveyance system for the area must be adequately stabilized to prevent erosion under future build-out conditions from areas that contribute flow to the system; AND

- If the discharge is to a stream that leads to a wetland, or to a wetland that has an outflow to a stream, both this requirement and Minimum Requirement 7 apply**.**

The following **additional** exemptions (or partial exemptions) are available in eastern Washington:

1. A site with less than 10-inch average annual rainfall that discharges to a seasonal stream that is not connected via surface flow to a nonexempt surface water by runoff generated during the 2-year regional storm for Climatic Regions 1–4 OR during the 2-year Type 1A storm for Climatic Regions 2 and 3.
2. Discharges to a stream that flows only during runoff-producing events. The runoff carried by the stream following the 2-year regional storm in Climatic Regions 1–4 OR during the 2-year Type 1A storm for Climatic Regions 2 and 3, must not discharge via surface flow to a nonexempt surface water. The stream may carry runoff during an average annual snowmelt event, but must not have a period of base flow during a year of normal precipitation.
3. Discharges to stream reaches consisting primarily of irrigation return flows and not providing habitat for fish spawning and rearing. Projects must match the predeveloped 2-year and 25-year peak runoff rates for these discharges. Local irrigation districts may impose other requirements.

Petitions to seek exemptions in additional geographic areas can be submitted to Ecology for consideration. Such a petition must justify the proposed exemption based on a hydrologic

analysis demonstrating that the potential stormwater runoff from the exempted area will not significantly increase the erosion forces on the stream channel, nor have near-field impacts. Contact the Region Hydraulics Office to determine the feasibility of potential exemption candidates.

Diversions of flow from perennial streams and from wetlands can be considered if significant existing (preproject) flooding, stream stability, water quality, or aquatic habitat problems would be solved or significantly mitigated by bypassing stormwater runoff, rather than providing stormwater detention and discharge to natural drainage features. Bypassing is not an alternative to applicable flow control or treatment if the flooding, stream stability, water quality, or habitat problem to be solved would be caused by the project. In addition, the proposal must not exacerbate other water quality/quantity problems such as inadequate low flows or inadequate wetland water elevations.

A stormwater engineer or scientist must document the existing problems and their solutions or mitigation as a result of the direct discharge after review of any available drainage reports, basin plans, or other relevant literature. The restrictions in this minimum requirement on conveyance systems that transfer water to exempt receiving waters are applicable in these situations. Approvals by all regulatory authorities with permitting jurisdiction are necessary.

Additional streams in eastern Washington may be exempt by applying the following criteria:

- Any river or stream that is fifth order or greater as determined from a 1:24,000 scale map; OR
- Any river or stream that is fourth order or greater as determined from a 1:100,000 or larger scale map.

### 3-3.6.3 Applicability[3]

Minimum Requirement 6 applies to all nonexempt projects that meet the thresholds described in Figures 3-1, 3-2, and 3-3. The threshold for triggering the flow control requirement takes into account the project's effective impervious surfaces and converted pervious surfaces.

Application of the "net-new impervious surface" concept only applies to Minimum Requirement 6 at the TDA level (Figure 3-3, Step 8). Application of the concept does not extend to any other minimum requirement. When applying the net-new impervious approach, the pavement permanently removed by the project needs to be reverted to a pervious condition per the guidelines in Section 4-3.6.1.

[3]Consult the Glossary for the following key terms: *converted pervious surface*, *new impervious surface*, *effective impervious surface*, *net-new impervious surface*, *project limits*, *replaced impervious surface*, and *threshold discharge area (TDA)*.

## Table 3-5 Flow control exempt surface waters list.

| **Water Body** | **Upstream Point/Reach for Exemption** (if applicable) |
|---|---|
| Alder Lake | |
| Asotin Creek | Downstream of confluence with George Creek |
| Baker Lake | |
| Baker River | Baker River/Baker Lake downstream of confluence with Noisy Creek |
| Banks Lake | |
| Bogachiel River | 0.4 miles downstream of Dowans Creek |
| Bumping Lake | |
| Bumping River | Downstream of confluence with American River |
| Calawah River | Downstream of confluence with South Fork Calawah River |
| Carbon River | Downstream of confluence with South Prairie Creek |
| Cascade River | Downstream of Found Creek |
| Cedar River | Downstream of confluence with Taylor Creek |
| Chehalis River | 1,500 feet downstream of confluence with Stowe Creek |
| Chehalis River, South Fork | 1,000 feet upstream of confluence with Lake Creek |
| Cispus River | Downstream of confluence with Cat Creek |
| Clearwater River | Downstream of confluence with Christmas Creek |
| Cle Elum River | Downstream of Cle Elum Lake |
| Columbia River | Downstream of Canadian border |
| Columbia River Reservoirs | |
| Colville River | Downstream of confluence with Chewelah Creek |
| Conconully Reservoir | |
| Coweman River | Downstream of confluence with Gobble Creek |
| Cowlitz River | Downstream of confluence of Ohanapecosh River and Clear Fork Cowlitz River |
| Crescent Lake | |
| Dickey River | Downstream of confluence with Coal Creek |
| Dosewallips River | Downstream of confluence with Rocky Brook |
| Dungeness River, main channels | Downstream of confluence with Gray Wolf River |
| Elwha River | Downstream of confluence with Goldie River |
| Grande Ronde River | Entire reach from the Oregon to Idaho border |
| Grays River | Downstream of confluence with Hull Creek |
| Green River (WRIA 26 – Cowlitz) | 3.5 miles upstream of Devils Creek |
| Hoh River | 1.2 miles downstream of Jackson Creek |
| Humptulips River | Downstream of confluence with West and East Forks |
| Kalama River | 2.0 miles downstream of Jacks Creek |
| Kettle River | Downstream of confluence with Boulder Creek |
| Klickitat River | Downstream of confluence with West Fork |
| Latah Creek (formerly Hangman Creek) | Downstream of confluence with Rock Creek (in Spokane County) |
| Lake Chelan | |
| Lake Cle Elum | |
| Lake Cushman | |
| Lake Kachess | |
| Lake Keechelus | |
| Lake Quinault | |
| Lake Shannon | |
| Lake Sammamish | |
| Lake Union | King County |
| Lake Wenatchee | |

| **Water Body** | **Upstream Point/Reach for Exemption** (if applicable) |
|---|---|
| Lake Washington | |
| Lake Whatcom | |
| Lewis River | Downstream of confluence with Quartz Creek |
| Lewis River, East Fork | Downstream of confluence with Big Tree Creek |
| Lightning Creek | Downstream of confluence with Three Fools Creek |
| Little Spokane River | Downstream of confluence with Deadman Creek |
| Little White Salmon River | Downstream of confluence with Lava Creek |
| Lower Crab Creek | Entire reach |
| Mayfield Lake | |
| Methow River | Downstream of confluence with Early Winters Creek |
| Moses Lake | |
| Muddy River | Downstream of confluence with Clear Creek |
| Naches River | Downstream of confluence with Bumping River |
| Naselle River | Downstream of confluence with Johnson Creek |
| Newaukum River | Downstream of confluence with South Fork Newaukum River |
| Nisqually River | Downstream of confluence with Big Creek |
| Nooksack River | Downstream of confluence of North and Middle Forks |
| Nooksack River, North Fork | Downstream of confluence with Glacier Creek, at USGS gage 12205000 |
| Nooksack River, South Fork | 0.1 miles upstream of confluence with Skookum Creek |
| North River | Downstream of confluence with Vesta Creek |
| Ohanapecosh River | Downstream of confluence with Summit Creek |
| Okanogan River | Downstream of Canadian border |
| Osoyoos Lake | |
| Pacific Ocean | |
| Palouse River | Downstream of confluence with South Fork Palouse River |
| Pend Oreille River | Idaho to Canadian border |
| Pend Oreille River Reservoirs | |
| Pothole Reservoir | |
| Puget Sound | |
| Puyallup River | Half-mile downstream of confluence with Kellog Creek |
| Queets River | Downstream of confluence with Tshletshy Creek |
| Quillayute River | Downstream of Bogachiel River |
| Quinault River | Downstream of confluence with North Fork Quinault River |
| Riffe Lake | |
| Rimrock Lake | |
| Rock Creek | In Whitman County, downstream of confluence with Cottonwood Creek |
| Ruby Creek | Ruby Creek at State Route 20 crossing downstream of Granite and Canyon Creeks |
| Sammamish River | Downstream of Lake Sammamish |
| Sauk River | Downstream of confluence of North and South Forks |
| Satsop River | Downstream of confluence of Middle and East Forks |
| Satsop River, East Fork | Downstream of confluence with Decker Creek |
| Silver Lake | Cowlitz County |
| Similkameen River | Downstream of Canadian border |
| Skagit River | Downstream of Canadian border |
| Skokomish River | Downstream of confluence of North and South Forks |
| Skokomish River, South Fork | Downstream of confluence with Vance Creek |
| Skokomish River, North Fork | Downstream of confluence with McTaggert Creek |
| Skookumchuck River | 1 mile upstream of Bucoda at State Route 507, milepost 11.0 |

| **Water Body** | **Upstream Point/Reach for Exemption** (if applicable) |
|---|---|
| Skykomish River | Downstream of South Fork |
| Skykomish River, South Fork | Downstream of confluence of Tye and Foss Rivers |
| Snake River | Entire reach along Idaho border to the Columbia River |
| Snake River Reservoirs | |
| Snohomish River | Downstream of confluence of Snoqualmie and Skykomish Rivers |
| Snoqualmie River | Downstream of confluence of the Middle Fork |
| Snoqualmie River, Middle Fork | Downstream of confluence with Rainy Creek |
| Sol Duc River | Downstream of confluence of North and South Fork Soleduck River |
| Spokane River | Downstream of Idaho border |
| Spokane River Reservoirs | |
| Stillaguamish River | Downstream of confluence of North and South Forks |
| Stillaguamish River, North Fork | 7.7 highway miles west of Darrington on State Route 530, downstream of confluence with French Creek |
| Stillaguamish River, South Fork | Downstream of confluence of Cranberry Creek and South Fork |
| Suiattle River | Downstream of confluence with Milk Creek |
| Sultan River | 0.4 miles upstream of State Route 2 |
| Swift Creek Reservoir | |
| Teanaway River | Downstream of confluence of North and West Forks |
| Thunder Creek | Downstream of confluence with Neve Creek |
| Tieton River | Downstream of Rimrock Lake |
| Tilton River | Downstream of confluence with North Fork Tilton River |
| Toppenish Creek | Downstream of confluence with Wanity Slough |
| Touchet River | Downstream of confluence with Patit Creek |
| Toutle River | North and South Fork confluence |
| Toutle River, North Fork | Downstream of confluence with Hoffstadt Creek |
| Toutle River, South Fork | Downstream of confluence with Thirteen Creek |
| Tucannon River | Downstream of confluence with Pataha Creek |
| Walla Walla River | Downstream of confluence with Mill Creek |
| Wenatchee River | Downstream of confluence with Icicle Creek |
| White River | Downstream of confluence with Huckleberry Creek |
| White Salmon River | 0.15 miles upstream of confluence with Trout Lake Creek |
| Willapa River | Downstream of confluence with Mill Creek |
| Wind River | Downstream of confluence with Cold Creek |
| Wynochee Lake | |
| Wynoochee River | Downstream of confluence with Schafer Creek |
| Yakima River | Downstream of Lake Easton |

Natural dispersion areas meeting the requirements of BMP FC.01 must be identified within the project limits as a part of determining whether the particular TDA exceeds thresholds in Figure 3-3, Step 8. Those effective impervious surface areas that are flowing to an existing (preproject) dispersion area can be subtracted as noneffective impervious surfaces.

The analysis for Step 8 in Figure 3-3 is based on preproject (what is currently seen at the project site) land cover conditions for the predeveloped modeling condition and the postconstruction (after the project is completed) land cover conditions for the developed modeling conditions. When using the Single Scaling Factor Approach (called "Station Data" option in MGSFlood) to perform this analysis, contact the HQ Hydraulics Office, since the data station may not be able to produce the 100-year flow due to insufficient rainfall data.

Refer to Section 4 of the MGSFlood User's Manual for additional information on the Single Scaling Factor Approach: www.wsdot.wa.gov/design/hydraulics/training.htm

### 3-3.6.4 Guidelines

Infiltration is the preferred method to control flow. If infiltration cannot be achieved at the project site, refer to the appropriate design criteria listed below and in Chapter 4.

Flow control BMPs or the live storage portion of a combination flow control/runoff treatment BMP must not be placed below the seasonal high water table. As an alternative, first look for equivalent areas within the same threshold discharge area (TDA) to provide the necessary flow control. If a feasible location cannot be found within the TDA, seek out equivalent areas—within WSDOT right of way—upstream of the TDA that discharges to the same receiving water body to provide the necessary flow control. Lastly, if a feasible location cannot be found upstream of the TDA, seek out equivalent areas—within WSDOT right of way—downstream of the TDA that discharges to the same receiving water body to provide the necessary flow control. Document these constraints using the Engineering and Economic Feasibility (EEF) Evaluation Checklist (Appendix 2A).

If none of the above options is feasible within the project site, then explore alternative flow control mitigation in the watershed (for example, purchasing land and converting it back to a forested condition or restoring wetlands in close proximity to the project site). Refer to Section 2-7.3 for more information on watershed-based approaches.

Avoid placing BMPs in wetlands, 100-year floodplains, and intertidal areas. These natural systems have a higher net environmental benefit than engineered stormwater management systems. If the placement of a required flow control BMP would impact such a sensitive area, consult the Region Hydraulics Office as early as possible for aid in properly analyzing the effects of various flow control options. The Region Hydraulics and Environmental offices will also coordinate with the appropriate state, local, tribal, and federal agencies to ensure adequate protection of all natural resources.

Design specifications for conveyance and flood prevention are reviewed with the assistance of the Region or HQ Hydraulics Office.

#### *Western Washington Design Criteria*

Stormwater discharges must match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. Also, check the 100-year peak flow rate for downstream flooding and property damage using an approved continuous simulation model.

Refer to Section 4-3.6.1 for the appropriate modeling process. Also, reference the same section for the modeling process to address mitigated and nonmitigated areas on projects in on-site and off-site flow bypass situations.

## Predeveloped Condition for Stormwater Hydrology Modeling

The project site's predeveloped conditions are to assume "historic" land cover conditions unless one of the following conditions applies:

- Reasonable, historic information is provided that indicates the site was prairie prior to settlement (modeled as "pasture" in MGSFlood).
- The drainage area of the immediate stream and all subsequent downstream basins has had at least 40% total impervious area since 1985. In this case the predeveloped condition to be matched must be the existing land cover condition. Where basin-specific studies determine a stream channel to be unstable, even though the above criterion is met, the predeveloped condition assumption must be the "historic" land cover condition or a land cover condition commensurate with achieving a target flow regime identified by an approved basin study. More information on qualifying basins is available at: www.ecy.wa.gov/programs/wq/stormwater/flowcontrol.html

For WSDOT projects, the designer can assume an existing land cover condition if following the Stormwater Retrofit Analysis procedure outlined in Section 3-4 and Figure 3-4 and Figure 3-5. This process was created through an agreement between WSDOT and DOE for WSDOT projects.

Table 3-6 summarizes flow control criteria for western Washington. The duration standard does not apply to infiltration facilities that will reliably infiltrate all the runoff from impervious surfaces and converted pervious surfaces.

**Table 3-6 Western Washington flow control criteria.**

| Facility Type | Criteria | Model |
|---|---|---|
| Detention/combination treatment and detention facilities | Provide storage volume required to match the duration of predeveloped peak flows from 50% of the 2-year up to the 50-year storm flow, using a flow restrictor (such as an orifice or weir), and check the 100-year peak flow for property damage. | Continuous simulation model using 1-hour time steps |
| Infiltration facilities | Size facility to infiltrate sufficient volumes so that the overflow matches the duration standard, and check the 100-year peak flow to estimate the potential for downstream property damage, or infiltrate the entire runoff file. | Continuous simulation model using 1-hour time steps |

An alternative flow control standard may be established through applying watershed-scale hydrologic modeling and supporting field observations. Possible justifications for an alternative flow control standard include:

1. Establishment of a stream-specific threshold of significant bedload movement other than the assumed 50% of the 2-year peak flow; OR

2. Zoning and Land Clearing Ordinance restrictions that, in combination with an alternative flow control standard, maintain or reduce the naturally occurring erosive forces on the stream channel, with local jurisdiction approval; OR
3. A duration control standard is not necessary for protection, maintenance, or restoration of designated beneficial uses or Clean Water Act compliance.

## *Eastern Washington Design Criteria*

Using a single-event model, flow control design requirements for projects must limit the peak release rate of the postdeveloped 2-year runoff volume to 50% of the predeveloped 2-year peak and maintain the predeveloped 25-year peak runoff rate. The 100-year event must be checked for downstream flooding and property damage.

## *Predeveloped Condition for Stormwater Hydrology Modeling*

The project site's predeveloped conditions are to assume an existing land cover. Table 3-7 summarizes flow control criteria for eastern Washington. The peak flow matching standard does not apply to infiltration facilities that will reliably infiltrate all the runoff from impervious surfaces and converted pervious surfaces.

**Table 3-7 Eastern Washington flow control criteria.**

| Facility Type | Criteria | Model |
|---|---|---|
| Detention/combination treatment and detention facilities | Provide storage volume required to match ½ of the 2-year predeveloped peak flow rate, match the predeveloped 25-year peak flow rate, and check the 100-year peak flow for property damage. | Single-event model (SCS or SBUH) Climatic Regions 1–4 Regional Storm; OR<br><br>Type 1A Storm for Climatic Regions 2 & 3 only |
| Infiltration facilities | Size facility to infiltrate sufficient runoff volumes that the overflow does not exceed the 25-year peak flow requirement. Check the 100-year peak flow to estimate the potential for downstream property damage, or infiltrate the entire runoff file. | Single-event model (SCS or SBUH) Climatic Regions 1–4 Regional Storm; OR<br><br>Type 1A Storm for Climatic Regions 2 & 3 only |

Predevelopment and postdevelopment runoff volumes and flow rates must be estimated in accordance with Table 3-7 and Section 4-4.2 using the Regional Storm for Climatic Regions 1–4; OR Type 1A Storm for Climatic Regions 2 and 3.

In some instances, the 2-year predeveloped flow rate is zero cubic feet per second or the flow rate is so small that it is impracticable to design a pond to release at the prescribed flow rate from an engineered outlet structure. In these cases, the total postdeveloped 2-year storm runoff volume must be infiltrated (preferred) or stored in a retention pond for evaporation and the detention pond designed to release the predeveloped 10- and 25-year flow rates. (See BMP FC.03, Detention Pond, in Section 5-4.2.3 for pond and release structure design information.)

Infiltration facilities for flow control must be designed based on postdeveloped runoff volumes, and must be designed to infiltrate the entire volume of the criteria noted in Table 3-7. If full infiltration is not possible, all surface discharges must match the following criteria:

- If the 2-year postdeveloped outflow volume discharged to a surface water and is less than or equal to the 2-year predeveloped outflow volume, then the postdeveloped 2-year flow rate must be less than or equal to the 2-year predeveloped flow rates. The flows for the 25- and 100-year events must meet the criteria in Table 3-7, row 1.
- If the 2-year postdeveloped outflow volume is greater than the 2-year predeveloped outflow volume, then all surface water discharges must match the flow rate standards in Table 3-7, row 1.

The justification from Ecology for matching one-half the preexisting flow rate is the added work done on the natural channel by the excess volume released in a typical "detention/ retention" pond system. If infiltration disposes of the extra volume produced by the added impervious areas, then releasing flow at the preexisting 2-year rate mimics the existing hydrologic conditions.

## 3-3.7 Minimum Requirement 7 – Wetlands Protection

Stormwater discharges to wetlands must maintain the wetland's hydrologic conditions (particularly hydroperiod), hydrophytic vegetation, and substrate characteristics that are necessary to maintain existing wetland functions and values.

### 3-3.7.1 Objective

The objective of wetlands protection is to ensure wetlands receive the same level of protection as any other waters of the state.

### 3-3.7.2 Applicability

Minimum Requirement 7 applies to all nonexempt projects that meet the thresholds described in Figure 3-1 and where stormwater discharges into a wetland, either directly or indirectly, through a conveyance system.

All stormwater discharges to wetlands must comply with this manual's runoff treatment requirements.

### 3-3.7.3 Guidelines

Steps must be taken during design to maximize natural water storage and infiltration opportunities within the project site and outside existing wetlands. Natural wetlands may not be used as pollution control facilities in lieu of runoff treatment BMPs.

Building stormwater runoff treatment and flow control facilities within a wetland or its natural vegetated buffer is discouraged, except for:

- Necessary conveyance systems as allowed by applicable permit(s); OR
- As allowed in wetlands approved for hydrologic modification or treatment in accordance with Ecology guidance. For western Washington projects, refer to *Guide Sheet 1B* in Appendix I-D of Ecology's SMMWW. For eastern Washington projects, refer to *Use of Existing Wetlands to Provide Runoff Treatment* (in Section 2.2.5) and *Application to Wetlands and Lakes* (in Section 2.2.6) in Ecology's SMMEW, and the *Eastern Washington Wetland Rating Form*: www.wsdot.wa.gov/nr/rdonlyres/41520679-f96d-47a9- 9b70-3ee8bbec391f/0/wetlandratingform_easternwa.doc); OR
- Projects with approved permits from the appropriate resource agencies.

An adopted and implemented basin plan (see Minimum Requirement 8), or a Total Maximum Daily Load (TMDL) Water Cleanup Plan may be used to develop requirements for wetlands that are tailored to a specific basin.

The thresholds identified in Minimum Requirement 5 (Runoff Treatment) and Minimum Requirement 6 (Flow Control) must also be applied for discharges to wetlands. In addition, a hydroperiod analysis must be performed and must show that the discharge will not adversely affect the wetland hydroperiod.

When considering constructing new wetlands or using existing wetlands for flow control or runoff treatment, or when looking for guidelines on protecting wetlands from stormwater impacts, seek input from the appropriate in-house experts in the environmental, biological, wetlands, and landscape architectural disciplines. For projects in the Puget Sound basin, refer to *Guide Sheet 2B* in Appendix I-D of Ecology's SMMWW. Refer to Section 2-6.1.1 regarding special wetland design considerations, Section 4-6 for additional information on wetland hydroperiod analysis, and Section 5-4.1.4 for additional information on the Constructed Stormwater Treatment Wetland (see BMP RT.13).

## 3-3.8 Minimum Requirement 8 – Incorporating Watershed/Basin Planning Into Stormwater Management

Watershed/basin plans may subject projects to different minimum requirements for erosion control; source control; runoff treatment; and operation and maintenance; and to alternative requirements for flow control and wetlands hydrologic control. Watershed/basin plans must evaluate and include, as necessary, retrofitting urban stormwater BMPs into existing development or redevelopment in order to achieve watershed-wide pollutant reduction and flow control goals consistent with the requirements of the federal Clean Water Act. Standards developed from basin plans cannot modify any of the above minimum requirements until the basin plan is formally adopted and implemented by the local governments within the basin and has received approval or concurrence from Ecology.

### 3-3.8.1 Objective

The objective of incorporating watershed-based/basin planning into stormwater management is to promote the development of watershed-based resource plans as a means to develop and implement comprehensive water resource protection measures. The primary objective of basin planning is to reduce pollutant loads and hydrologic impacts to surface waters and groundwaters in order to protect water resources.

### 3-3.8.2 Applicability

Minimum Requirement 8 applies where watershed and basin plans are in effect for all nonexempt projects that meet the thresholds described in Figure 3-1.

### 3-3.8.3 Guidelines

While Minimum Requirements 1 through 7 establish general standards for individual sites, they do not evaluate the overall pollution impacts and protection opportunities that could exist at a watershed scale. For a basin plan to serve as a means of modifying the minimum requirements, the following conditions must be met:

- The plan must be formally adopted by all jurisdictions with implementation responsibilities under the plan; AND
- All ordinances or regulations called for by the plan must be in effect.

Basin planning provides a mechanism by which the minimum requirements and implementing BMPs can be evaluated and refined based on an analysis of an entire watershed. Basin plans are especially well suited for developing control strategies to address impacts from future development and to correct specific problems whose sources are known or suspected. Basin plans can be effective in addressing both long-term and cumulative impacts of pollutant loads; short-term acute impacts of pollutant concentrations; and hydrologic impacts to streams, wetlands, and groundwater resources. (See Section 2-7.3 for further guidelines on basin/watershed planning.) Refer to Appendix I-A of Ecology's SMMWW for examples of how basin planning can alter the minimum requirements of this manual.

## 3-3.9 Minimum Requirement 9 – Operation and Maintenance

An operation and maintenance manual that is consistent with the criteria in Section 5-5 will be provided for all proposed stormwater facilities and BMPs. The party (or parties) responsible for such maintenance and operation must be identified and a record of maintenance activities kept.

### 3-3.9.1 Objective

The objective of operation and maintenance is to achieve appropriate preventive maintenance and performance checks to ensure stormwater control facilities are adequately maintained and properly operated to:

- Remove pollutants and/or control flows as designed.

- Permit the maximum use of the roadway.
- Prevent damage to the highway structure.
- Protect natural resources.
- Protect abutting property from physical damage.

### 3-3.9.2 Applicability

Minimum Requirement 9 applies to all projects that require stormwater control facilities or BMPs and is accomplished programmatically via WSDOT's maintenance program.

### 3-3.9.3 Guidelines

Inadequate maintenance is a common cause of stormwater management facility degraded performance or failure. Section 5-5 provides criteria for BMP maintenance. The *Maintenance Manual* provides further guidelines on stormwater management-related operation and maintenance activities.

## 3-4 Stormwater Retrofit Guidelines

This section provides guidelines to assess stormwater retrofit obligations for WSDOT projects and identify stormwater retrofit opportunities, and provides guidance on how to document stormwater retrofits after they occur. Section 3-4.1 contains the guidelines for WSDOT projects within the Puget Sound basin. Sections 3-4.2 to 3-4.5 contain guidelines for WSDOT projects outside of the Puget Sound basin. These sections provide guidelines to assess (1) whether project-driven stormwater retrofit obligations can be met off-site by retrofitting an equivalent area of state highway in targeted environmental priority locations (see Figure 3-5 for the Stormwater Retrofit Process for projects), and (2) whether it is cost-effective to provide stormwater management retrofits beyond what are called for under these requirements. All WSDOT stormwater retrofits must be documented on the Stormwater Design Documentation Spreadsheet (SDDS) found at:
www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

The following are the five general situations where a project may incur a stormwater retrofit:

1. Where WSDOT can retrofit existing impervious surfaces.
2. In areas identified as a stand-alone high-priority stormwater retrofit.
3. Where a TDA does not provide all the required flow control for replaced impervious surfaces after providing as much flow control as possible on the project site.
4. Where a TDA does not provide all the required runoff treatment for replaced pollution-generating impervious surfaces (PGIS) after providing as much runoff treatment as possible on the project site.
5. In western Washington, where the project provides flow control to predeveloped "existing land cover" conditions.

## 3-4.1 Retrofitting Existing Impervious Surfaces and Stand-Alone Stormwater Retrofit Projects Within the Puget Sound Basin

Highway projects in the Puget Sound basin that add 5,000 square feet or more of new impervious surfaces, and are located in medium- to high-priority locations for stormwater retrofit, shall retrofit all existing impervious surfaces within the project limits for both flow control and runoff treatment if feasible and cost-effective. The project shall perform a stormwater retrofit cost-effectiveness and feasibility (RCEF) analysis to determine the extent to which retrofit obligations must occur within the project limits. The details of the RCEF analysis are explained below.

Retrofitting for stormwater treatment and flow control **is feasible if** there are no physical site limitations such as geographic or geologic constraints, steep slopes, soil instability, proximity to water bodies, presence of significant cultural resources, shallow water tables, or other applicable factors contained in Appendix 2A, Engineering and Economic Feasibility for Construction of Stormwater Management Facilities.

Retrofitting for stormwater treatment and flow control **is cost-effective if** the cost to retrofit all the existing impervious surfaces does not exceed 20% of the cost to meet stormwater treatment and flow control requirements for the new impervious surfaces. The WSDOT region may request a variance to exceed this limit for extenuating circumstances such as the project is in a high-priority location for retrofit, the project has realized reduced costs in other project elements, and/or the cost is not significantly above 20% (see Figure 3-4). The RCEF analysis does not apply to any project-triggered retrofit requirements needed to comply with Section 3-2.

If retrofitting is not feasible or cost-effective, one of the following must occur:

1. Retrofit the amount of existing impervious surface within the project limits that can be retrofitted for the amount of money equal to 20% of the cost to meet stormwater requirements for the new impervious surfaces, as outlined in the paragraphs above.
2. Retrofit an equivalent amount of existing impervious surface off-site, at a high-priority stormwater retrofit location, at a cost of up to 20% of the cost to meet stormwater requirements for the new impervious surfaces as outlined in the paragraphs above.
3. Transfer an amount of money equal to 20% of the cost to meet stormwater requirements for the new impervious surfaces, as outlined in the paragraphs above, to fund stand-alone stormwater retrofit projects (Subprogram I-4, Stormwater Retrofit Category).

Highway projects in the Puget Sound basin that add more than 5,000 square feet of new impervious surface, and are located in low-priority locations for stormwater retrofit, shall transfer an amount of money, as specified below, to the stand-alone stormwater retrofit program.

When retrofitting all existing areas is deemed either infeasible per Appendix 2A or not cost-effective, or if the money is transferred to fund stand-alone retrofit projects, the cost information developed to ensure compliance with this requirement shall be included in the *Stormwater Design Documentation Spreadsheet*.

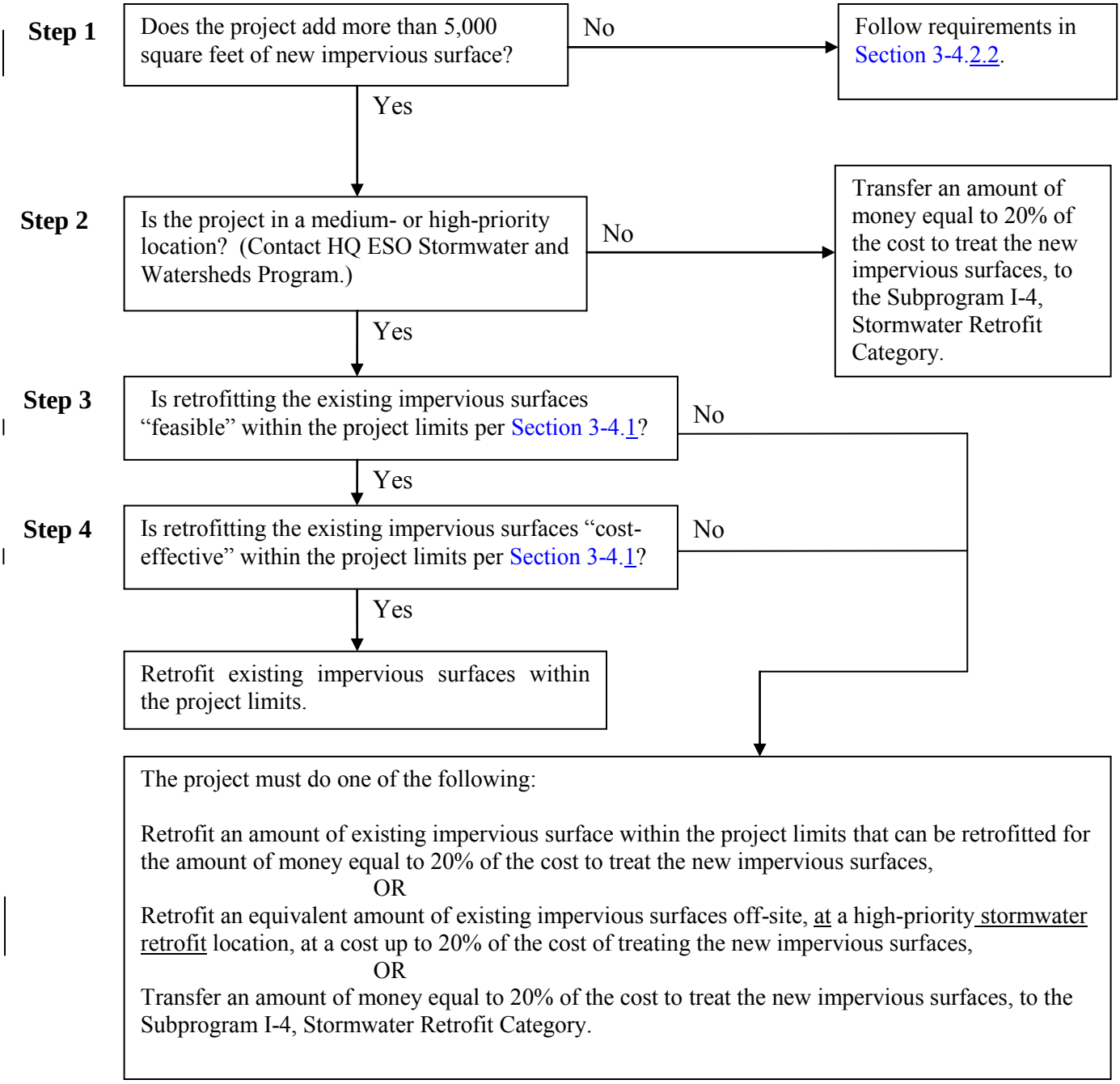



**Figure 3-4 Stormwater retrofit process for WSDOT projects within the Puget Sound basin.**

## 3-4.2 Retrofitting Existing Impervious Surfaces and Stand-Alone Stormwater Retrofit Projects Outside the Puget Sound Basin

Figure 3-5 outlines the decision-making process for determining stormwater retrofit obligations and opportunities for WSDOT projects outside of the Puget Sound basin.

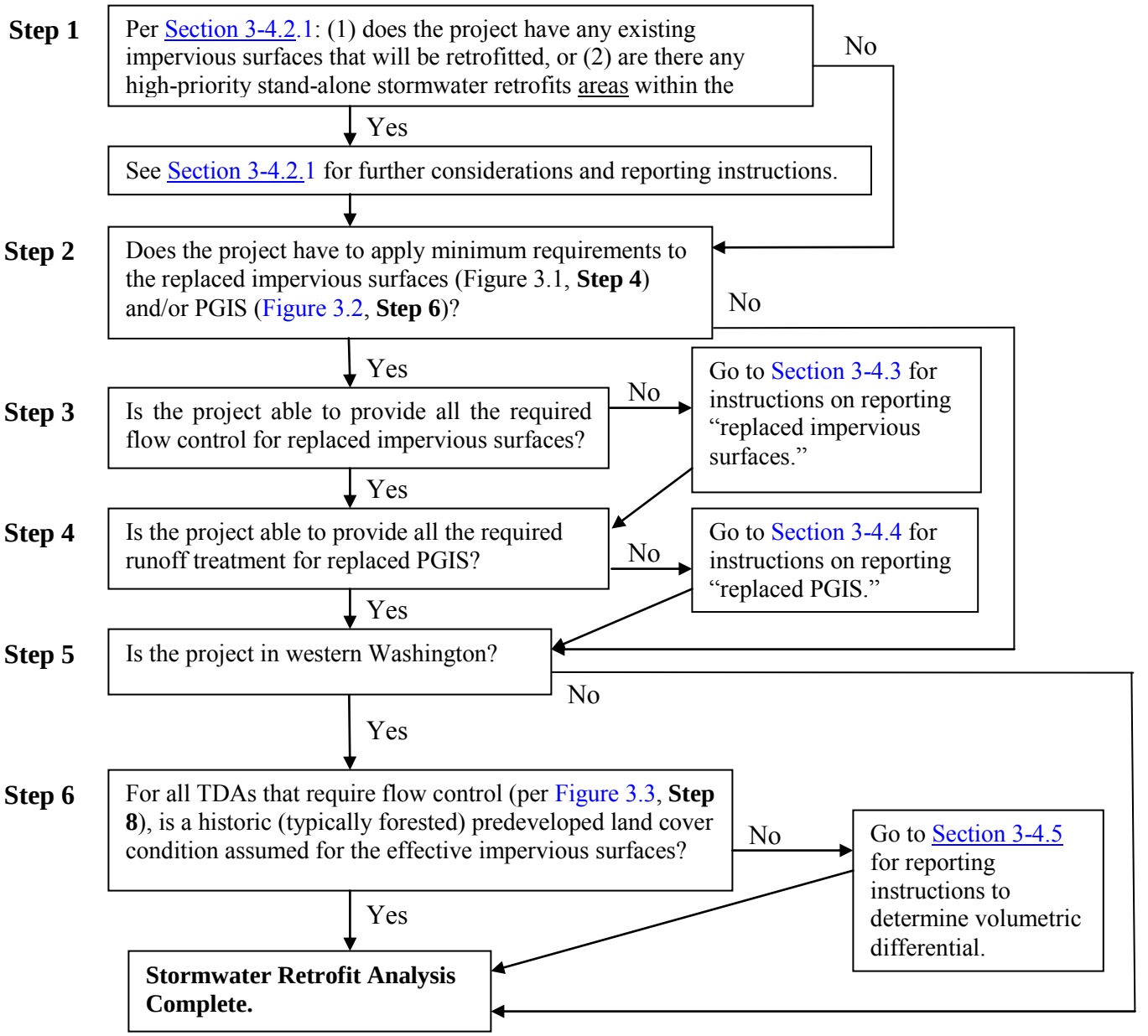



**Figure 3-5 Stormwater retrofit process for WSDOT projects outside of the Puget Sound basin.**

### 3-4.2.1 Existing Impervious Surfaces

As described in Section 1-2.3, the ultimate goal is to provide practicable stormwater management for runoff from existing impervious surfaces that do not have treatment or flow control or for which treatment or flow control is substandard. As designers scope (or revise the scope of) affected projects, they will need to determine whether it is cost-effective to provide stormwater management retrofits beyond what is called for under the HRM's minimum requirements. In making this decision, WSDOT needs to follow an approach that ensures it does not circumvent the Legislature's authority to determine where to invest financial resources. At the same time, the department's goal is to retrofit existing impervious surfaces where a significant amount of pavement is added on a project.

WSDOT has adopted a departmental budget structure with a specific category for retrofitting existing impervious surfaces in order to meet one of the requirements of WAC 173-270-060. This budget structure allows the department to include the work from one project category in another category if it does not add significant cost to the project. In accordance with this guideline, the HQ Strategic Planning and Programming Office has established the following guidelines when making decisions about adding stormwater retrofits of existing impervious surfaces into new improvement and preservation projects:

1. Mobility projects (I-1 subprogram) can always consider including the cost of retrofitting existing impervious surfaces.
2. Safety projects (I-2 subprogram) can include the retrofitting of existing impervious surfaces only if the cost to retrofit all existing impervious surfaces does not exceed an additional 20% of the cost of treating new impervious surfaces. The region may request a variance from this limit for extenuating circumstances.
3. Economic Initiatives (I-3 subprogram, *except for* Four-Lane Trunk projects) can include the retrofitting of existing impervious surfaces only if the cost to retrofit all existing impervious surfaces does not exceed an additional 20% of the cost of treating new impervious surfaces. The region may request a variance from this limit for extenuating circumstances.
4. Four-Lane Trunk projects in the I-3 subprogram can always consider including the retrofitting of existing impervious surfaces.
5. Environmental Retrofit projects (I-4 subprogram, *except for* the Stormwater Retrofit category) do not add new impervious surfaces and cannot retrofit existing impervious surfaces. The region may request a variance from this limit for extenuating circumstances.
6. For those safety and economic initiative projects that exceed the 20% limit, and where the HQ Project Control and Reporting Office and region concur, the region can submit a request for funding from the I-4 Stormwater Retrofit category. These requests will be prioritized with the other stormwater retrofit needs already identified for funding by the Legislature.
7. Paving projects (P-1 subprogram) can only consider retrofitting existing impervious surfaces for projects involving the total replacement of existing concrete lanes. On

projects that only replace the existing asphalt shoulder with concrete, retrofitting is not required.

Questions on applying the above guidelines should be directed through the Region Program Management Office, with backup (if needed) to the HQ Strategic Planning and Programming Systems' Analysis and Program Development Office. Finally, budget implications and Ecology-approved basin plan status must be considered prior to including retrofit as part of a project's scope.

Associated costs for providing flow control for all the runoff from new, replaced, and existing impervious areas must be recorded in the project's Hydraulic Report. The extent and type of any stormwater retrofit activity needs to be documented in the Hydraulic Report and the Stormwater Design Documentation Spreadsheet (SDDS) at: www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

### 3-4.2.2 I-4 Subprogram Environmental Retrofit Stormwater Projects

I-4 subprogram environmental retrofit stormwater projects located within the project limits must be evaluated for incorporation by the project office.

## 3-4.3 Replaced Impervious Surface

If thresholds in Figure 3-1, Step 4**,** are exceeded and for each TDA that exceeds thresholds in Figure 3-3, Step 8, after providing as much flow control as possible on the project site, the designer must record the amount of replaced impervious surface that does not receive flow control. The designer must record quantities to the nearest tenth of an acre using the SDDS at: www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

The amount of replaced impervious surface that does not receive flow control within the project area can be met off-site by retrofitting an equivalent area of state highway for flow control in a targeted stormwater retrofit priority location. Contact the HQ ESO Stormwater and Watersheds Program for assistance in identifying eligible highway segments to meet this off-site retrofit obligation.

## 3-4.4 Replaced PGIS

If thresholds in Figure 3-2, Step 6**,** are exceeded and for each TDA that exceeds thresholds in Figure 3-3, Step 7, after providing as much runoff treatment as possible on the project site, the designer must record the amount of replaced PGIS that does not receive runoff treatment. Designers must record quantities to the nearest tenth of an acre using the SDDS at: www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

The type of treatment needed in the TDA must also be recorded along with the TDA's projected ADT and other information supporting the required runoff treatment type (basic, enhanced, phosphorous control, and/or oil control).

The extent and type of any stormwater retrofit activity needs to be documented in the Hydraulic Report and the SDDS.

The amount of replaced PGIS that does not receive runoff within the project area can be met off-site by retrofitting an equivalent area of state highway for runoff treatment in a targeted stormwater retrofit priority location. Contact the HQ ESO Stormwater and Watersheds Program for assistance in identifying eligible highway segments to meet this off-site retrofit obligation.

## 3-4.5 Effective Impervious Surface in Western Washington

For every TDA that requires flow control per Figure 3-3, Step 8, the predeveloped conditions for the effective impervious surfaces need to be determined. Where the predeveloped condition for the effective impervious surfaces is considered to be an "existing land cover" (usually pasture or grass) and not assumed to be a "historic land cover," determine and document the flow control volumetric difference between the two land cover conditions.

Using MGSFlood or another Ecology-approved continuous simulation model, perform two analyses to determine the required flow control volumes for the two different predeveloped conditions in the TDA. Subtracting the two volumes gives the volumetric difference between using "existing land cover" conditions and "historic land cover" conditions for the TDA. This number needs to be recorded as part of the Stormwater Retrofit Analysis. The designer must record the quantity in cubic feet on the SDDS at:
www.wsdot.wa.gov/environment/waterquality/runoff/highwayrunoffmanual.htm

This volumetric difference constitutes a stormwater retrofit obligation for the project that can be met off-site by providing an equivalent volume of detention in a targeted stormwater retrofit priority location. Contact the HQ ESO Stormwater and Watersheds Program for assistance in identifying eligible highway segments to meet this off-site retrofit obligation.

# CHAPTER 4

# Hydrologic Analysis

# Chapter 4 Table of Contents

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# Chapter 4 Hydrologic Analysis

## 4-1 Introduction

This chapter presents and defines the minimum computational standards for the types of hydrologic analyses required to design the various stormwater best management practices (BMPs) described in detail in Chapters 5 and 6. It also provides an explanation of the methods to be used for the modeling of stormwater facilities and the supporting data and assumptions that will be needed to complete the design. The computational standards, methods of analysis, and necessary supporting data and assumptions for designs in western Washington are different than those in eastern Washington. As a result, Section 4-3 includes design criteria and guidelines for western Washington, and Section 4-4 includes design criteria and guidelines for eastern Washington. The hydrologic analysis tools and methodologies presented in this chapter support the following tasks:

- Designing stormwater runoff treatment and flow control facilities
- Designing infiltration facilities
- Closed Depression Analyses
- Analyzing wetland hydroperiod effects

This manual makes numerous references to the *Hydraulics Manual*, where additional design guidelines can be found, including the minimum computational standards, methods of analysis, and necessary supporting data and assumptions for analysis and design of the following:

- General hydrology
- Culverts and other fish passage structures
- Open channel flow
- Storm sewer design
- Drainage from highway pavement (inlet spacing and curb and gutter)
- Hydraulics issues associated with bridge structure design
- Downstream analysis
- Pipe classification and materials

## 4-2 Project Considerations

Prior to conducting any detailed stormwater runoff calculations, the overall relationship between the proposed project site and the runoff it will create must be considered. This section provides guidelines regarding what parameters should be reviewed to adequately evaluate the project.

The general hydrologic characteristics of the project site dictate the amount of runoff that will occur and where stormwater facilities can be placed. Several sources of information will be useful in determining the information necessary for preliminary runoff analyses. Drainage patterns and contributing areas can be determined by consulting topographic contour maps generated from preliminary surveys of the area for the proposed project or by using contour maps from a previous project in the same area. For some projects, adequate information on soil characteristics can be found in soils surveys published by the Natural Resource Conservation Service (NRCS).

## 4-2.1 Estimating Stormwater Management Areas

Estimates of the area that will be required for stormwater management must be developed when the project layout is first being determined. These estimates of stormwater BMP sizes and areas may dictate changes to the roadway or other infrastructure design and support decisions to purchase additional right of way for the project. The following information is required to successfully estimate the approximate area required for stormwater treatment and flow control facilities:

- The basic requirements for the stormwater facility design
- The general hydrologic characteristics of the project site
- The basic footprint of the proposed roadway or other infrastructure improvement project

## 4-2.2 Local and State Requirements

In most cases, the basic requirements for stormwater facilities described in the *Highway Runoff Manual* (HRM) will be adequate to meet other state agency and local jurisdiction requirements. Section 1-1.5 explains to what extent a local jurisdiction's stormwater requirements apply to Washington State Department of Transportation (WSDOT) projects. The first part of any hydrologic analysis involves research to determine whether the project is located in an area where additional requirements prevail. This can typically be accomplished by consulting with region hydraulics or environmental staff. When stricter standards do apply, they are usually related to unique runoff treatment concerns: a need for flow control under more extreme storm conditions than is required by the HRM or a need for lower site discharge rates than are required by this manual. Either case is easily applied to the methods of analysis outlined in this chapter.

## 4-2.3 Soils

Quite often, additional sources of information are needed to adequately characterize on-site soils, particularly within existing highway rights of way and in other urban areas. The WSDOT Materials Lab can provide detailed information on soils and shallow groundwater characteristics in conjunction with geotechnical field data collection efforts. Typically, the Materials Lab must be informed of the need for gathering additional data for drainage analysis purposes early in the project design phase. This is very important for determining infiltration rates.

## 4-2.4 Determining Existing Conditions

Information on existing drainage facilities and conveyance system locations can be found in Hydraulic Reports from previous projects in the same vicinity or in as-built plans for the existing roadway. The local jurisdiction may have mapping and/or as-built information for storm drainage facilities near the WSDOT right of way and may know of other projects in the vicinity that documented drainage conditions. A site visit will help determine the basic hydrological characteristics of the proposed project site. Observations made during a field visit will serve to verify the information obtained through research and will show where that information may have been deficient. In nearly every instance, the information gained by visiting the site prior to designing the stormwater facilities will benefit the ensuing design effort.

## 4-2.5 Mapping Threshold Discharge Areas

The final part of determining the site's hydrologic characteristics is mapping the threshold discharge areas (TDAs). A TDA is defined as an on-site area draining to a single natural or constructed discharge location or multiple natural or constructed discharge locations that combine within ¼ mile downstream—as determined by the shortest flowpath. A TDA delineation begins at the first discharge location that exits WSDOT right of way and is based on preproject conditions. The limits of a TDA generally are right of way line to right of way line and begin project mile post to end project mile post. The limits of a TDA should be large enough to catalog all of the development by the project. If the project were acquiring right of way, the TDA limits would extend to the proposed right of way limits. The purpose of this definition is to provide more flexibility in meeting the minimum requirements while still providing sufficient protection for the receiving water bodies. Note: All TDAs must be verified in the field.

To map a TDA, the designer must have an understanding of drainage basin delineation. A drainage basin includes all of the area that will contribute runoff to the point of interest. For example, in Figure 4-1, the designer must quantify off-site flow that discharges to the ditch, which is the point of interest. To determine the off-site area of land that contributes runoff to the ditch, topographic contours are needed. Where a contour forms a chevron (or the letter "V") pointing in the direction of increasing elevation, that contour depicts a valley. Where the chevron points in the direction of decreasing elevation, that contour depicts a ridge. Ridges are the limits of a drainage basin, since precipitation falling on a ridge or peak will flow either to or away from the point of interest. Connecting the ridges and peaks on the contour map will form the boundary of the drainage basin. In pavement drainage, artificial ridges and peaks are formed by cross slopes and vertical curves.

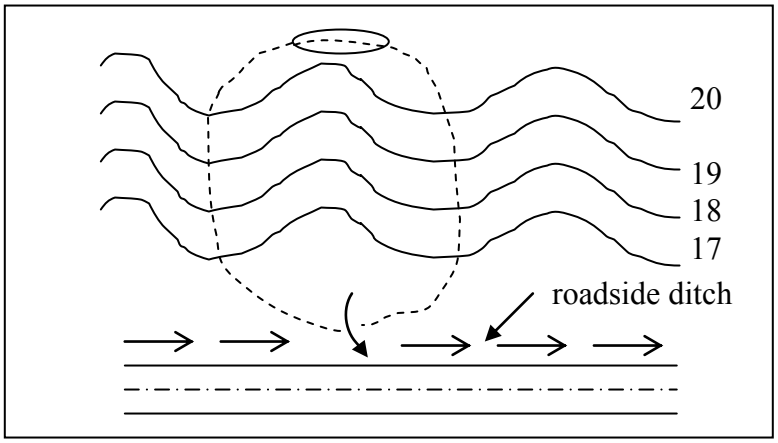



**Figure 4-1 Drainage basin delineation example.**

In Figure 4-2a, each drainage area (A1 – A4) is delineated by the crown of the roadway to the top of the ditch backslope (right of way limit) and between each vertical curve crest. Figure 4-3 shows the roadway profile and cross section. In drainage area A1, roadway runoff sheet flows off of the pavement into the ditch that eventually flows into the culvert. Flows from drainage area A1 combine with flows from drainage area A2 and leave WDSOT right of way using flow path A2. The same conditions occur with drainage areas A3 and A4, which leave the right of way using flow path A4. If flow paths A2 and A4 join within ¼ mile downstream from the right of way, all four drainage areas would combine to make one TDA (as indicated in Figure 4-2a). If the discharges remain separate for at least ¼ mile downstream of the project site right of way, drainage areas A1 and A2 combine to make one TDA and drainage areas A3 and A4 combine to make a second TDA.

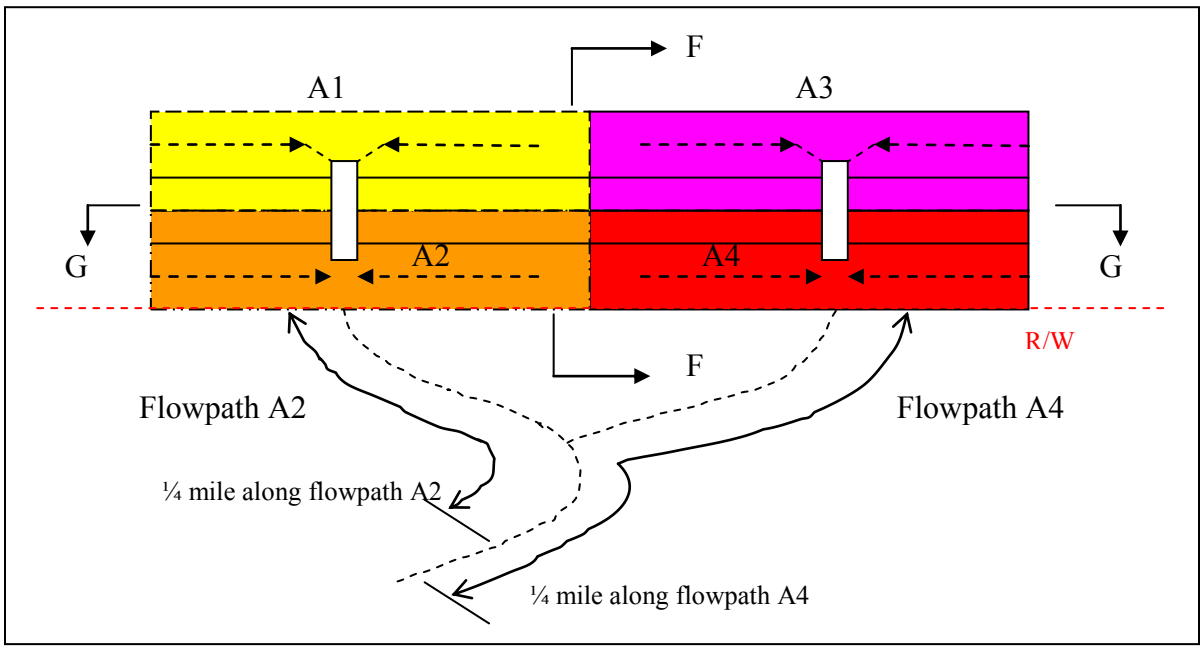



**Figure 4-2a Threshold discharge areas (plan – not to scale).**

Figure 4-2b illustrates the situation where the flow paths do not combine within ¼ mile and result in two separate TDAs (assuming drainage areas A1, A2, A3, and A4 are within one TDA and are represented by Flowpath A2). Measure ¼ mile along Flowpath A6. If Flowpath A2 (the most upstream flow path) and Flowpath A6 join within the shortest measured ¼ mile flow path, all areas are considered one TDA. Figure 4-2b shows Flowpath A2 and Flowpath A6 do not combine within the ¼ mile measured along the shortest flow path, so areas A1, A2, A3, and A4 combine to form one TDA, while areas A5 and A6 combine to form a separate TDA. Flow path A6 would be used to measure against any other additional flowpaths for combining areas to form the next TDA.

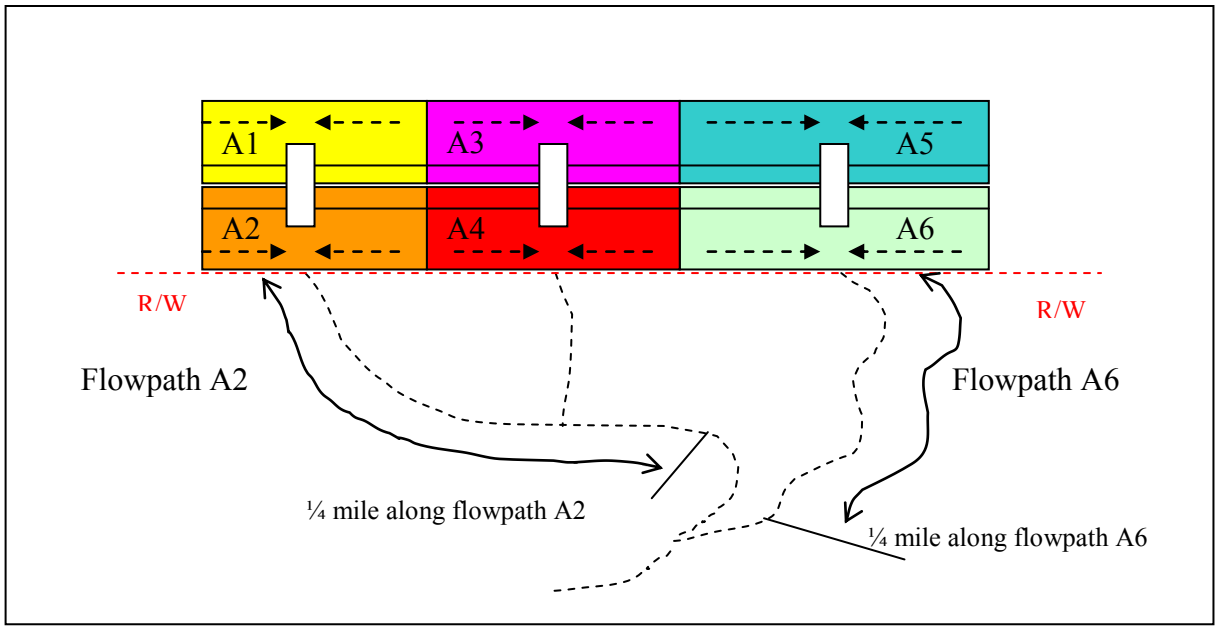



**Figure 4-2b Threshold discharge areas (plan – not to scale).**

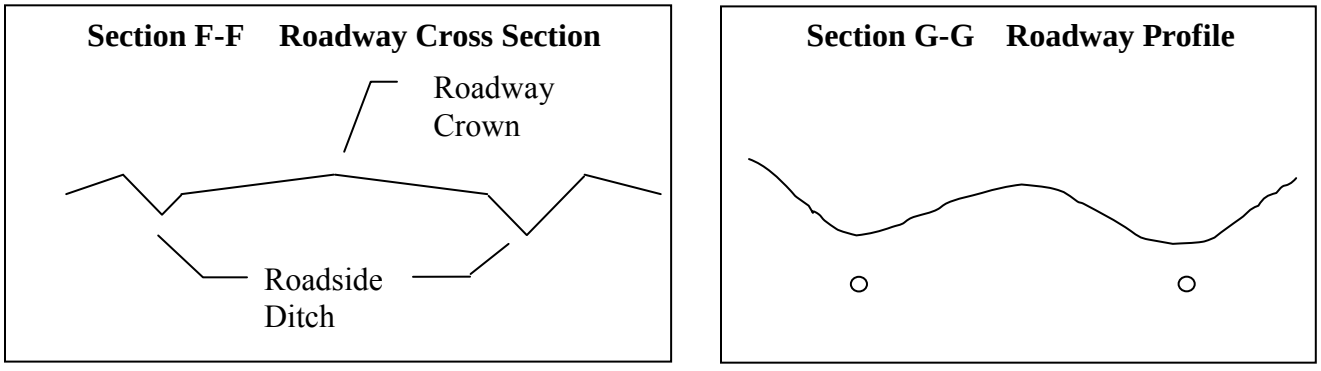



**Figure 4-3 Threshold discharge areas (section and profile).**

The above TDA delineation guidance is not all-inclusive. Direct project-specific questions regarding TDA delineations to the Region Hydraulics Office or the HQ Hydraulics staff. Once TDA delineations have been completed, the quantities of new, replaced, and existing impervious areas (and PGIS) can be tallied for each TDA. Apply minimum requirement thresholds to each TDA based on tallied quantities. (See Chapter 3 for minimum requirement applicability.)

## 4-2.6 Conclusions

Once the basic stormwater requirements are understood and the general hydrologic characteristics of the site are known, the size of the area necessary for stormwater facilities can be estimated. This is done by examining the proposed project layout and determining the most suitable locations to place stormwater management facilities. With one or more such locations identified, the computation methods described later in this chapter can be applied using site data and an estimate of the required stormwater facility area(s) can be calculated. If this preliminary facility sizing is done early enough in the project design schedule, slight alterations can be made to the project alignment/footprint and adequate right of way can be purchased without causing undue cost or delay to the project. A final design of the stormwater facilities will have to be performed when the project layout is finalized.

The locations of new stormwater outfalls from WSDOT right of way should be provided to local agencies and added to WSDOT's outfall inventory to facilitate compliance with NPDES and Highway Runoff Rule requirements (WAC 173-270). For details on how to relay the outfall inventory information, contact a region hydraulics or water quality section representative.

Flow charts are presented in Figures 4-4 and 4-5 to help the designer navigate through the requirements of Chapter 4 and hydrologic analyses for typical projects.

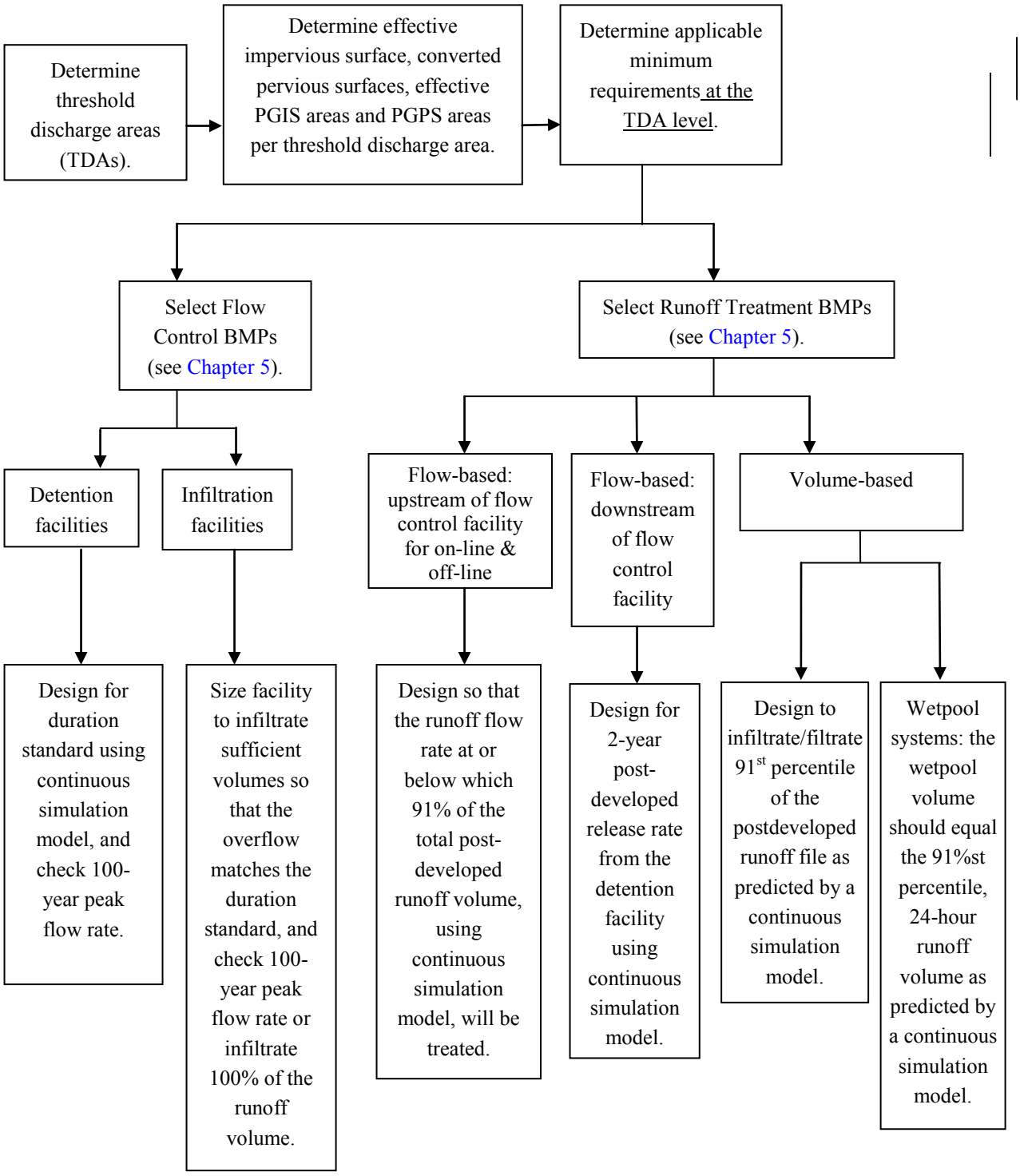



**Figure 4-4 Hydrologic analysis flowchart for western Washington.**

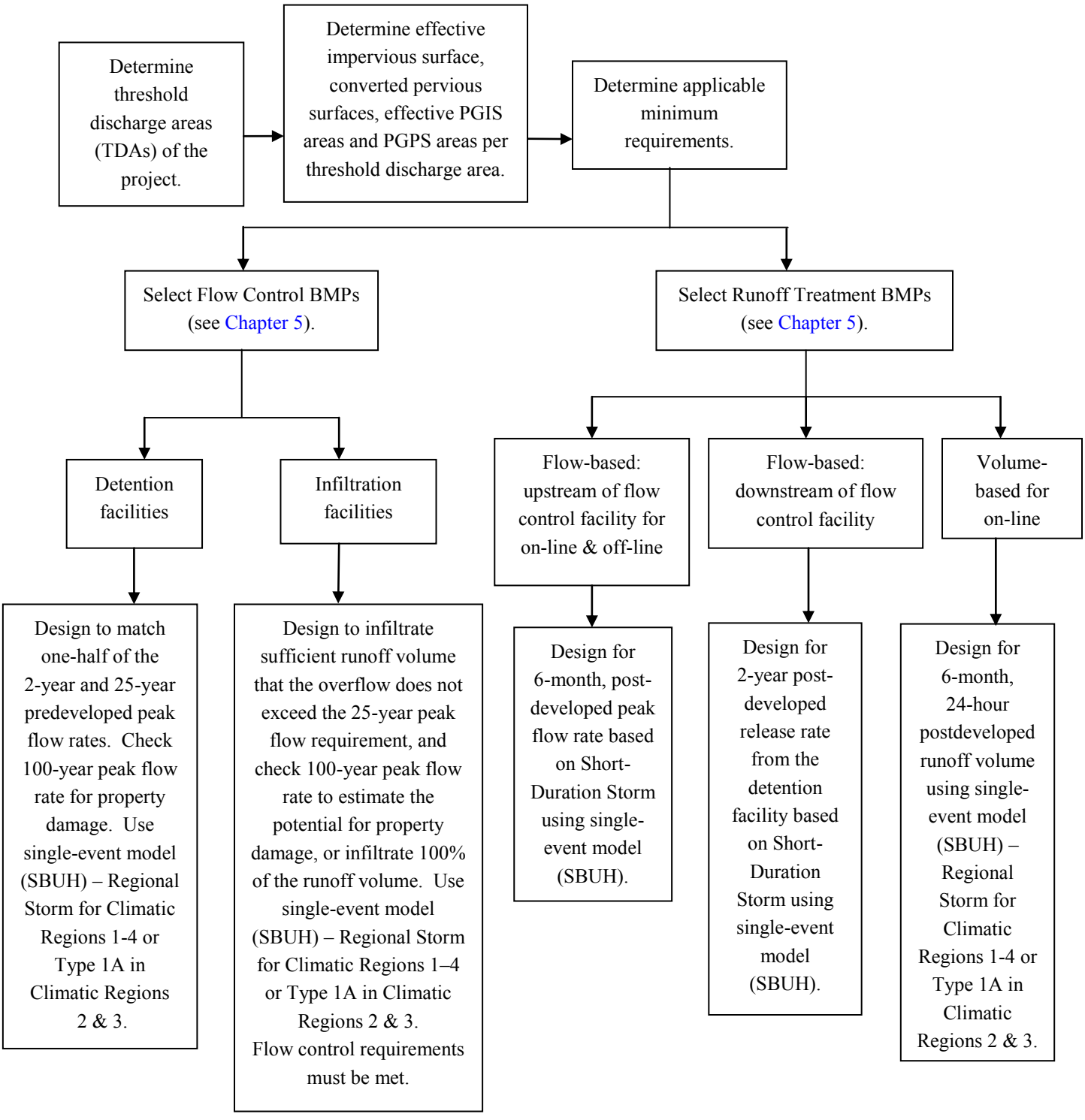



**Figure 4-5 Hydrologic analysis flowchart for eastern Washington.**

# 4-3 Western Washington Design Criteria

## 4-3.1 Runoff Treatment Flow-Based and Volume-Based BMPs

### 4-3.1.1 Flow-Based Runoff Treatment

An approved continuous simulation hydrologic model based on the U.S. Environmental Protection Agency's (U.S. EPA's) Hydrologic Simulation Program – Fortran (HSPF) is used when designing runoff treatment BMPs based on flow rate, in accordance with WSDOT Minimum Requirement 5 in Section 3-3.5). WSDOT prefers that the program **MGSFlood** be used for designing flow-based runoff treatment BMPs in WSDOT right of way. The design flow rate for these types of facilities is dependent on whether the treatment facility is located upstream or downstream of a flow control facility and whether it is an *on-line* or *off-line* facility (see Figure 4-6).

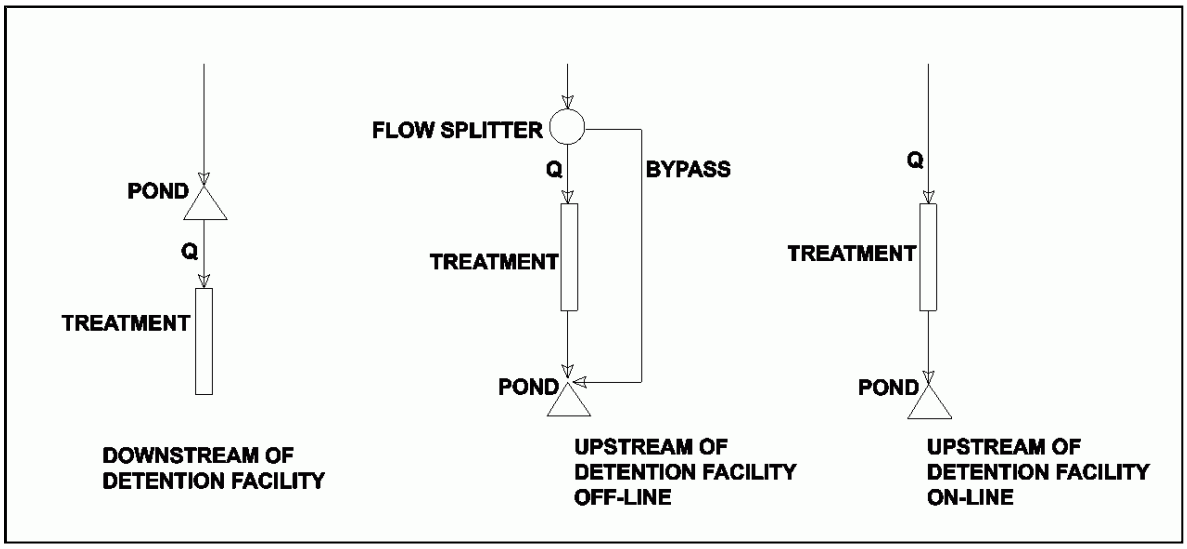



**Figure 4-6 Typical on-line and off-line facility configurations.**

#### *Downstream of Flow Control Facilities*

If the runoff treatment facility is located downstream of a stormwater flow control facility, the full 2-year recurrence interval release rate from the flow control facility, as estimated by an approved continuous simulation model**,** is used to design the treatment facility.

#### *Upstream of Flow Control Facilities: Off-Line*

The design flow rate for an off-line treatment facility located upstream of a flow control facility is the flow rate at or below which 91% of the runoff volume for the developed TDA will be treated, based on a 15-minute time step, as estimated by an approved continuous simulation model (see Figure 4-7). A high-flow bypass (flow splitter) is used to route the incremental flow in excess of the treatment design flow rate around the treatment facility. (See Section 5-4.3, for more details on flow splitters.) It is assumed that flows from the bypass enter the conveyance system downstream of the treatment facility but upstream of

the flow control facility. The bold horizontal line in Figure 4-7 is an example that shows the 91% runoff volume flow rate. All flows below that line will be treated, and the incremental portion of flow above that line will bypass the runoff treatment facility.

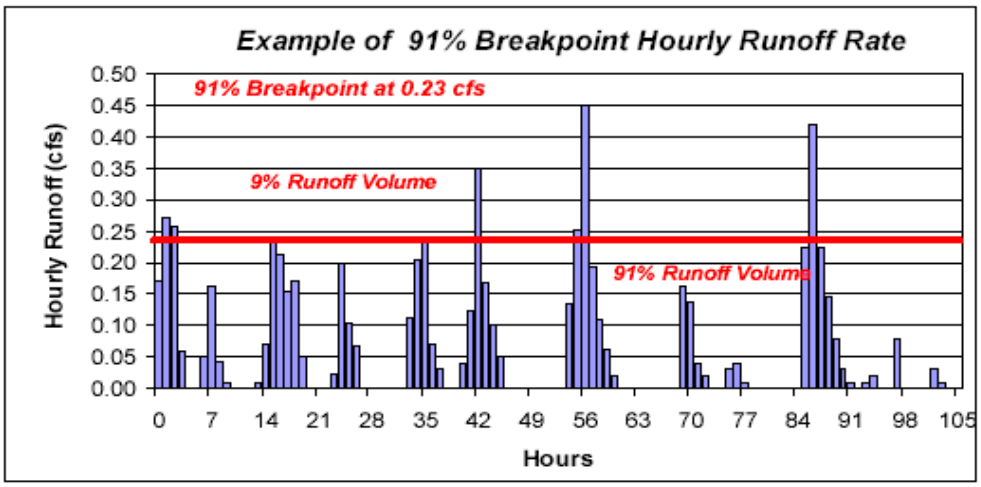



**Figure 4-7 Example showing calculation of runoff treatment discharge for off-line treatment facilities—computed as 0.23cfs.**

### *Upstream of Flow Control Facilities: On-Line*

On-line runoff treatment facilities do not include a high-flow bypass for flows in excess of the runoff treatment design flow rate, and all runoff is routed through the facility. The design flow rate for these types of on-line treatment facilities is the flow rate at or below which 91% of the runoff volume occurs, based on a 15-minute time step, as estimated by an approved continuous simulation model, to be in compliance with Minimum Requirement 5 (see Section 3-3.5). MGSFlood will determine the hourly runoff treatment design flow rate as the rate corresponding to the runoff volume that is greater than or equal to 91% of the hourly runoff volume entering the treatment facility. The simulation model automatically generates 15-minute time step flows based on hourly flows. Because on-line treatment facilities receive greater volumes of inflow than off-line facilities, the design flow rate corresponding to the 91% breakpoint is higher than for off-line facilities. The higher design flow rate will result in a slightly larger treatment facility. Figure 4-8 indicates that the facility will receive all the flow, but will be sized for only 91% runoff volume flow rates, minus the red bars in its calculations for the developed TDA.

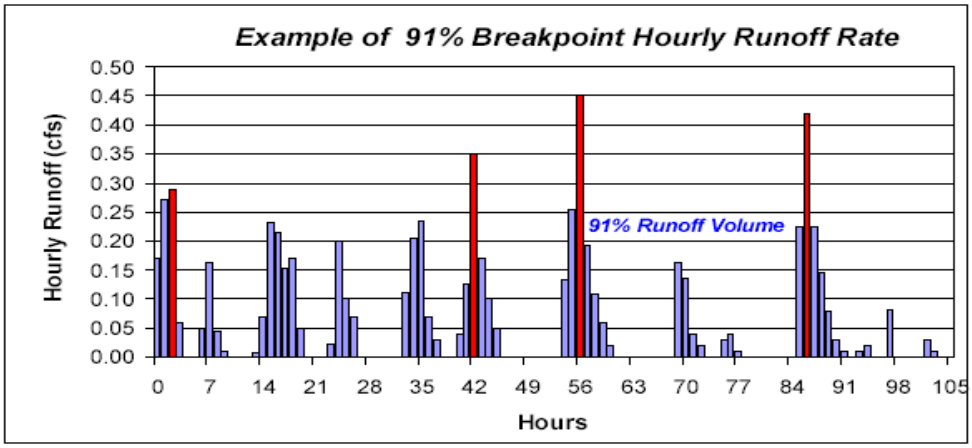



**Figure 4-8 Example showing calculation of runoff treatment discharge for on-line treatment facilities—computed as 0.28cfs.**

### 4-3.1.2 Volume-Based Runoff Treatment

Volume-based runoff treatment BMPs must be designed as on-line facilities. In accordance with Minimum Requirement 5 (see Section 3-3.5), the following methods can be used to derive the minimum required storage volume:

- Wetpool: An approved continuous simulation hydrologic model based on the U.S. EPA's HSPF can be used. WSDOT prefers that the program MGSFlood be used. For wetpools, the required total wetpool volume is the 91st percentile, 24-hour runoff volume (no credit is given for infiltration losses) based on the long-term runoff record generated in the TDA of concern—as predicted based on a 1-hour time step.
- For other volume based systems such as infiltration and filtration BMPs, the minimum treatment needed is the storage volume that is necessary to achieve treatment of 91% of the influent runoff file as predicted using a continuous runoff model and a design infiltration/filtration rate.

If runoff from the new impervious surfaces and converted pervious surfaces is not separated from runoff from other surfaces on the project site and/or is combined with run-on from areas outside the right of way, volume-based runoff treatment facilities must be sized based on runoff from the entire drainage area. This is because runoff treatment effectiveness can be greatly reduced if inflows to the facility are greater than the design flows that the facility was designed to handle. For infiltration facilities, the 91$^{st}$ percentile, 24 hour runoff volume must be infiltrated within 36 hours. Under this premise, the storm/runoff ends 12 hours after the runoff period midpoint and combines with the 24-hour drain criteria. Therefore, the actual drawdown time is 36 hours. (See "Pond Design Using Routing Table" in Section 4-3.6.1, Continuous Simulation Method.)

For a summary of the flow rates and volumes needed for sizing runoff treatment facilities for various situations, see Table 3-3.

## 4-3.2 Flow Control Volume and Flow Duration-Based BMPs

An approved continuous simulation hydrologic model, based on HSPF, is used for designing flow control BMPs in accordance with Minimum Requirement 6 (see Section 3-3.6). WSDOT prefers that the program MGSFlood be used for designing flow control BMPs in WSDOT right of way. Stormwater discharges must match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. The 100-year peak flow must also be checked for flood control and prevention of property damage using the continuous simulation model.

Infiltration facilities for flow control must either infiltrate the entire runoff file, or provide sufficient infiltration so that the predicted overflows match the predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50-year peak Table 3-6 summarizes the volumes needed for sizing flow control facilities for various situations.

## 4-3.3 Temporary Construction Site Erosion and Sediment Control

Interceptor dikes and swales, grass-lined channels, and pipe slope drains should be designed to be stable for the velocity generated by the 10-year, 15-minute flow rate predicted by MGSFlood. Sediment traps and temporary sediment ponds should be designed for the 2-year 15-minute flow rate predicted by MGSFlood for the developed site condition without flow control. The designer should consult the Headquarters Environmental Services Office or region hydraulics staff to determine if downstream conditions warrant that temporary erosion and sediment control (TESC) BMPs be designed to a higher level of protection beyond the 2-year, 15-minute event. The 10-year, 15-minute flow rate should be used if the project is expected to last several construction seasons. (See Appendix 6A for additional TESC BMP design criteria.)

## 4-3.4 Exemptions for Flow Control

WSDOT has developed a standardized process to help the designer produce an acceptable hydraulic analysis for determining flow control exemptions. The process helps the designer determine how extensive an analysis needs to be for a particular project. (See Chapter 3 for a process that has been established for lakes and some river systems.) For further details on exemptions, flow dispersion, and flow control thresholds, see Minimum Requirement 6 in Section 3-3.6.

## 4-3.5 Hydrologic Analysis Methods for Designing BMPs in Western Washington: HSPF versus SBUH

This section provides a brief description and in-depth discussion of the methodologies used for calculating stormwater runoff from a project site. It includes a discussion on estimating stormwater runoff with continuous simulation models versus single-event models such as Santa Barbara Urban Hydrograph (SBUH).

The Hydrologic Simulation Program – Fortran (HSPF) model is a U.S. EPA program for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. The HSPF model uses information such as the time history of rainfall, temperature, and solar radiation, and land surface characteristics such as land use patterns and land management practices to simulate the hydrologic processes that occur in a watershed. The result of this simulation is a time history of the quantity and quality of runoff from an urban, forested, or agricultural watershed. Flow rate and sediment load, as well as nutrient and pesticide concentrations, can be predicted.

Unlike intensity-duration models, which are sensitive to the peak rainfall intensity, the SBUH method models runoff by analyzing a given time period of rainfall to generate a hydrograph sensitive to variations in the rainfall preceding and following the peak. It was specifically developed to model runoff from urbanized areas that have mostly impervious land usage.

### 4-3.5.1 Hydrologic Analysis for Runoff Treatment

A calibrated, approved continuous simulation hydrologic model based on HSPF is used when designing a flow rate-based runoff treatment BMP. This is because single-event models, such as SBUH, tend to underestimate the time of concentration, and the peak flow rate occurs too early. This affects treatment BMPs that are designed to achieve a specified flow residence time (the resulting designs are more conservative). Calculation of the flow residence time is sensitive to the shape of the inflow hydrograph. The inflow hydrograph is also of fundamental importance when designing an infiltration or filtration BMP, as these BMPs are sized based on a routing of the inflow hydrograph through the BMP.

When designing a volume-based runoff treatment BMP, a calibrated, approved continuous simulation hydrologic model based on HSPF such as MGSFlood or the Washington State Department of Ecology's (Ecology's) Western Washington Hydrology Model (WWHM) should be used.

### 4-3.5.2 Hydrologic Analysis for Flow Control

Because of single-event hydrologic model limitations, an approved continuous simulation model, rather than a single-event model such as SBUH, should be used to design flow control BMPs for WSDOT projects in western Washington. While SBUH may give acceptable estimates of total runoff volumes, it tends to overestimate peak flow rates from pervious areas, because it cannot adequately model subsurface flow (which is a dominant flow regime for predevelopment conditions in western Washington basins). One reason SBUH overestimates the peak flow rate for a pervious area is that the actual time of concentration is typically greater than what is assumed. Better flow estimates could be made if a longer time of concentration was used. This would change both the peak flow rate (it would be lower) and the shape of the hydrograph (peak occurs somewhat later,) and the hydrograph would better reflect actual predeveloped conditions.

Another reason that SBUH overestimates the peak rates of runoff from undeveloped land is the curve numbers (CN) presented for single-event modeling in the 1995 *Highway Runoff Manual*. These curve numbers were developed by the U.S. Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), and published as the

Western Washington Supplemental Curve Numbers. These CN values are typically higher than the standard CN values published in NRCS Technical Release 55 (1986). In 1995, the NRCS recalled the use of the western Washington CNs for floodplain management and found that the standard CNs better describe the hydrologic conditions for rainfall events in western Washington. However, based on runoff comparisons with the King County Runoff Time Series (KCRTS), which is a continuous simulation model, better estimates of runoff are obtained when using the western Washington CNs for developed pervious areas such as parks, lawns, and other landscaped areas. Consequently, the CNs in this manual are changed to those in NRCS Technical Release 55, except for the open spaces category for the developed areas, which include lawns, parks, golf courses, cemeteries, and landscaped areas. For these areas, the western Washington CNs are used. Note: These changes are intended to provide better runoff estimates using the SBUH method. For CN values, see Appendix 4B.

When the SBUH is used to estimate runoff rates in a 24-hour storm event, it is not capable of simulating soil moisture characteristics that have a significant impact on generation of runoff. Sizing of stormwater BMPs based on 24-hour storms does not reflect the effects of longer-term storms in western Washington. The use of a longer-term (such as 3- or 7-day) storm is perhaps better suited for western Washington and could better capture the hydrologic effect of back-to-back storm events.

HSPF is a continuous simulation model capable of simulating a wider range of hydrologic responses than the single-event models like SBUH. For use in western Washington, WSDOT has developed the continuous simulation hydrologic model MGSFlood, based on HSPF. MGSFlood uses multiyear inputs of hourly precipitation and evaporation to compute a multiyear timeseries of runoff from the site. Use of precipitation input that is representative of the site under consideration is critical for the accurate computation of runoff and the design of stormwater facilities. Precipitation and evaporation timeseries have been assembled for most areas of western Washington and are stored in a database file accessed by the program.

Default HSPF model parameters that define rainfall interception, infiltration, and movement of moisture through the soil are based on work by the USGS and King County and have been included in MGSFlood. Pervious areas have been grouped into three land cover categories: forest, pasture, and lawn; and three soil/geologic categories: till, outwash, and saturated/ wetland soil—for a total of seven land cover/soil type combinations (as shown in Table 4-1). The combinations of soil type and land cover are called pervious land segments, or PERLNDS, in HSPF. Default runoff parameters for PERLNDS are loaded automatically by the program for each project and should not be changed. If the user changes these values, the changed values are noted in the project documentation report. If a basin or watershed has been calibrated, those PERLNDS values can be used, since they are site specific.

**Table 4-1 Pervious land cover/soil type combinations used with HSPF model parameters.**

| Pervious Land Cover/Soil Type Combinations |
|---|
| 1. Till/Forest |
| 2. Till/Pasture |
| 3. Till/Lawn |
| 4. Outwash/Forest |
| 5. Outwash/Pasture |
| 6. Outwash/Lawn |
| 7. Saturated Soil/All Cover Groups |

## 4-3.6 Hydrologic Analysis Methods for Flow Control and Runoff Treatment Facility Design

This section presents a detailed discussion for some of the parameters necessary to design a stormwater flow control facility using an approved continuous simulation model. A basic overview of the continuous simulation method can be found in Chapter 2 of the WSDOT *Hydraulics Manual*.

### 4-3.6.1 Continuous Simulation Method

WSDOT's continuous simulation hydrologic model MGSFlood (see Section 4-3.5.2) uses the HSPF routines for computing runoff from rainfall on pervious and impervious land areas. Specifically, the program is intended to size stormwater detention and infiltration ponds, as well as calculate runoff treatment flow rates and volumes, to meet the requirements of Ecology's *Stormwater Management Manual for Western Washington* (SMMWW). It should not be used for conveyance design unless the conveyance system is downstream of a stormwater pond. (See Appendix 4A for a web link to a detailed example of this modeling approach and for information on how to obtain a copy of the public domain program.)

MGSFlood does not include routines for simulating the accumulation and melt of snow, and its use should be limited to lowland areas where snowmelt is typically not a major contributor to floods or to the annual runoff volume. In general, these conditions correspond to an elevation below approximately 1500 feet. MGSFlood can be used to model TDAs up to 320 acres (about one-half square mile). If a TDA falls outside the modeling guidelines above, contact region or HQ hydraulics staff for assistance.

Several factors must be considered in the design of a stormwater flow control facility. Based on the proposed project improvements, watershed and TDA can be determined and precipitation and runoff parameters can be applied to them. The continuous simulation model uses this information to simulate the hydrologic conditions at the site and estimate runoff. The flow control facility is then sized to detain the runoff in a way that closely mimics the runoff from the predeveloped site conditions. The designer must then verify that the flow control performance is in accordance with Minimum Requirement 6 in Section 3-3.6. Key elements of continuous simulation modeling are presented below.

## Predevelopment Land Cover

The first consideration when modeling project site runoff for flow control BMP sizing is the amount of pervious cover versus impervious surface in the overall basin. The hydrologic analysis for flow control to protect a receiving water is based on mitigating floods and erosion. The predeveloped land cover assumptions for modeling effective impervious surfaces for both eastern and western Washington can be found in Chapter 3, Minimum Requirement 6. Predeveloped condition information for stormwater retrofits can be found in Figure 3-4 and Section 3-4.

## Reversion of Existing Impervious Surface Areas

Opportunities may emerge to remove an existing impervious surface due to roadway realignment, roadway abandonment, or other project condition rendering the existing impervious surface obsolete. Under these circumstances, reverting an impervious surface to a pervious surface may improve the hydrological functions of an area, thereby providing a proportional reduction in the amount of runoff generated. Note: At this time, when determining minimum requirement applicability, the concept of reversion of existing impervious surfaces only applies to flow control thresholds; it does not apply to runoff treatment thresholds.

The following *two-step approach* (Full Reversion and Partial Reversion) must be followed to analyze reversion of existing impervious surface areas in lieu of conventional surface water flow control. Only one of these two steps can be applied, and they **cannot** be combined if a flow control facility is required.

### Step 1: Full Reversion (minimum requirement benefits and flow modeling benefits)

The first step involves evaluating the potential for stormwater impacts based on the concept and application of *net-new impervious surface*. Applying the net-new impervious surface concept requires removing existing impervious surface, incorporating soil amendments into the subsurface layers, and revegetating the area with evergreen trees—unless the predeveloped condition was prairie, which may be the case in some parts of eastern Washington. In this case, the net-new impervious surface concept is applied at the threshold discharge area (TDA) level when determining if triggers for flow control (see Minimum Requirement 6) have been exceeded, as specified in Section 3-3.6, and then only if the following criteria can be met:

- Existing impervious areas removed must be replaced with soils meeting the soil quality and depth requirements of the soil amendment criteria in Chapter 5.
- The new pervious area must be planted with native vegetation, including evergreen trees. For further guidelines, see the *Roadside Classification Plan* and the *Roadside Manual*.
- The new pervious area must be designated as a stormwater management area in the stormwater database (see Chapter 2), whether or not it receives runoff from adjacent areas.

- The new pervious area must be permanently protected from development. If the area is sited off state right of way, it must be protected with a conservation easement or some other legal covenant that allows it to remain in native vegetation.
- The outfall to which the new impervious surfaces—that are not provided with flow control as a result of being exempted by using a net approach—drain must be entered into the stormwater database (see Chapter 2) as a deficiency.

**Step 2: Partial Reversion (flow modeling benefits only)**

If it is concluded that triggers for that particular TDA have been exceeded and any of the above criteria cannot be fully implemented (only low-lying native vegetation can be planted due to clear-zone restrictions), then application of the net-new impervious surface concept is not applicable and the reversion area must be evaluated strictly as a land use modification when modeling for flow control. In this case, if it is feasible and there is an opportunity within any TDA to rehabilitate an impervious area to a pervious area, it should be done, and techniques for flow control (as explained below in Modeling Best Management Practices) should be applied.

## Flow Control Modeling Scenarios, Off-Site Flow, and Flow Through Areas

The following guidelines primarily apply to meeting flow control requirements and do not generally apply to meeting runoff treatment requirements unless otherwise noted. These guidelines deal with how to generally set up a stormwater modeling scenario, what areas need to be shown in the model, and how to represent the land cover of those areas in the model. On-site flow generally refers to flows generated from areas within WSDOT right of way that are also in the project limits. Off-site flow generally refers to flows that are generated outside of WSDOT right of way and pass through WSDOT right of way. To minimize stormwater BMP sizes, WSDOT does not allow, or significantly restricts, off-site flows from entering into stormwater BMPs.

The "50 Percent Rule" allows areas to flow undetained through a flow control facility, up to a certain limit. The undetained *flow through* area (on-site and/or off-site) is allowed to pass through the flow control facility if the 100-year peak flow rate from the undetained *flow through* area is less than 50% of the 100-year peak flow rate from the area receiving flow control. Otherwise, the undetained *flow through* area would have to be reduced until the limit is not exceeded.

Stormwater modeling generally falls under one of three scenarios presented below.

1. **Equivalent area option.** When the situation arises where an area that needs to be treated for stormwater flow control and/or runoff treatment cannot physically be captured, the *equivalent area* option usually provides a workable solution. The *equivalent area* option allows the designer to find an equivalent area that can be treated to provide the same amount of required runoff treatment and flow control. *Equivalent* means equal in area, located within the same TDA, and having similar use characteristics (for example, similar ADT) to the impervious surface area being traded. The equivalent area should be upgradient of or in close proximity to the discharge from

the new area. The drawing on the left side of Figure 4-9 shows that the flow control facility needs to be sized for 10 acres of new impervious surface. Using the equivalent area option, runoff from the existing impervious areas and new impervious areas would be routed to the facility so that 10 acres within the same TDA drains to the facility. This concept can also be applied to meeting the minimum requirement for runoff treatment. Note that the 50 Percent Rule applies for any *flow through* areas.

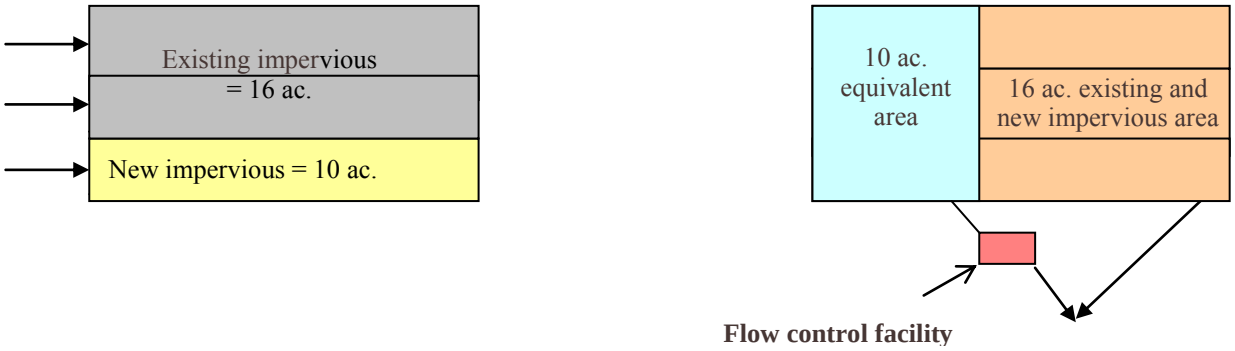



**Figure 4-9 Equivalent area option.**

2. **On-site, full area option.** The second option deals with the situation where on-site and off-site flows cannot be separated before going into a flow control facility. Note that the 50 Percent Rule does not apply for this option. **The designer must get prior approval from the Region Hydraulics Office before using this option.**

   The intent of this option is to size the detention facility for just the required amount of area (effective impervious and converted pervious surfaces) per HRM minimum requirements, but additionally have both unmitigated on-site and off-site areas flow to the facility (see Figure 4-10). This will require two separate model runs as follows:

   Model Run #1 – The detention facility and the outlet release structure initially should be sized using the drainage area (mitigated) for which flow control is required.

   Model Run #2 – A second modeling exercise is then conducted that routes flow from unmitigated on-site and off-site areas through the previously designed pond and outlet structure in Model Run #1. If the flow can pass through the outlet structure without overtopping the pond (engaging the emergency overflow structure), it is a successful design. If the pond does overtop, then the design is inadequate. There are two options the designer should consider for a successful design:

   1. Increase the distance between the design water surface elevation and the emergency overflow structure by raising the elevation of the emergency overflow structure and the pond embankment (note that a minimum of 1 foot of freeboard is required above the pond design water surface elevation).

2. Redesign the outlet structure. Increase the diameter of the riser while keeping the orifices the same so that the higher flows can be discharged. However, the designer has to demonstrate that the new outlet structure design could meet the flow control duration requirement if the pond were only serving the mitigated area (the initial design condition). This option would provide flow control for all of the impervious surface draining to the stormwater facility, but the duration standards would be applied only to the mitigated area, even though there will be higher flows passing through the facility.

The on-site, full area option does not meet a retrofit standard and is applicable for flow control facilities only. If the pond also provides runoff treatment, the dead storage volume would be sized for the entire area flowing to the pond. Once Model Run #2 is complete, the designer should verify that the pond still meets the flow control standards for the mitigated area by rerunning Model Run #1 analysis with the updated pond structure and geometry.

Figure 4-10 shows a detention pond that is initially sized for 10 acres as required by HRM Minimum Requirements. After, the full 10 acres plus 22 acres (nonmitigated area) areas are modeled to show that the pond does not go into emergency overflow.

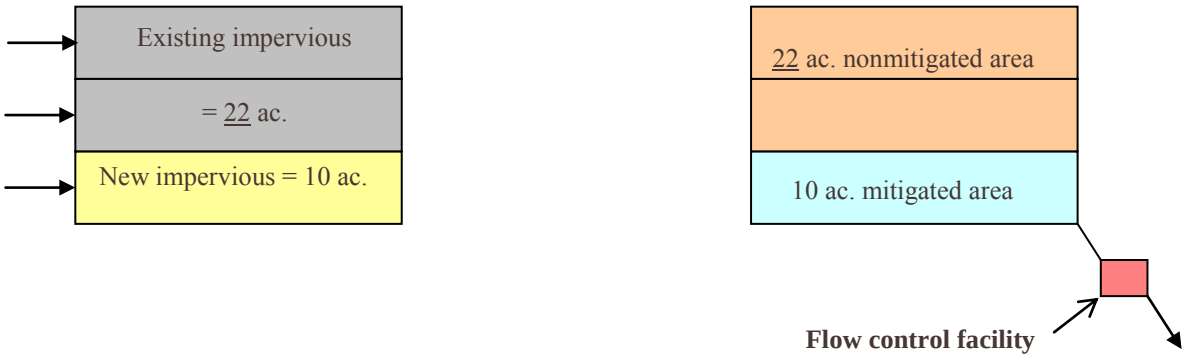



**Figure 4-10 Full area option.**

3. **Point of Compliance option.** There may be instances when some of the area that must be captured to meet the flow control requirement cannot be captured and not enough equivalent area can be captured to make up the difference. The following option, as depicted in Figure 4-11, provides a way to meet the overall intent of the flow control requirement for the total area that must be mitigated while allowing some of the required area to bypass the flow control facility. The analysis focuses on a point of compliance downstream where flows from the flow control facility and the bypass area combine.

   - To use this scenario, **all** of the following conditions must be met. These criteria apply only to that portion of the area that must be mitigated and for the area that is bypassed. (See Appendix 4A for a web link to an example that explains how a point of compliance analysis can be modeled using MGSFlood.)

- Runoff from both the bypass area and the flow control facility converges within ¼ mile downstream of the project site discharge point.
- If the bypass area flows to the point of compliance via overland flow, the 100-year developed peak flow rate from the bypass area will not exceed 0.4 cfs. If the bypass area flows through a manmade conveyance channel or pipe, then the 0.4 cfs criteria does not apply.
- Runoff from the bypass area will not create a significant adverse impact to downstream drainage systems or properties.
- Runoff treatment requirements applicable to the bypass area are met.

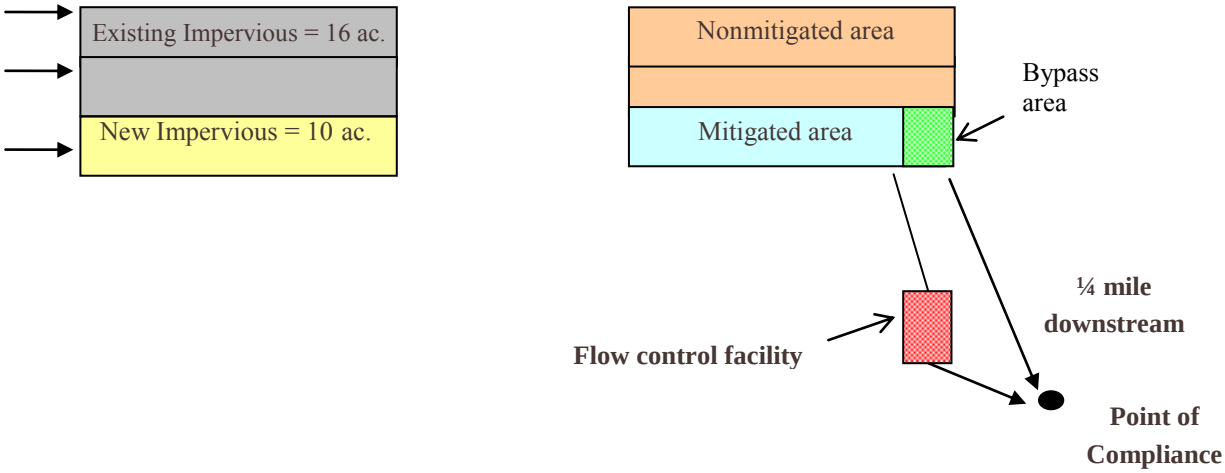



**Figure 4-11 Point of Compliance option.**

**Existing flow control ponds** that were designed using the 1995 HRM method can now be modified to accept additional runoff from roadways that require widening. Please contact the HQ Hydraulics Office for current modeling guidance.

## Modeling Best Management Practices (BMPs)

Flow control BMP design focuses on infiltrating, dispersing, and, as a last resort, detaining and discharging stormwater. In contrast to conventional BMPs that receive runoff at one location on the site, low-impact development (LID) BMP applications manage stormwater in small-scale, dispersed facilities located as close to the source of the runoff as possible. Due to the many different factors affecting both stormwater runoff treatment and flow control, there is no one technique that will work in all situations. The following is a list of modeling strategies that must be considered when modeling BMPs:

1. **General modeling guidelines:** In determining the appropriate modeling approach, it is important to understand how stormwater infiltration, dispersion, and runoff occurred historically on the site. The site analysis (see Section 4-2) provides information on how the site and the surrounding areas currently process stormwater and how they processed stormwater before any land use changes had altered them. This information should aid the designer

in determining the best site layout and deciding on appropriate BMPs that will either maintain or restore the natural predeveloped stormwater process. Use the following items from the site analysis to determine appropriate site layouts and BMPs:

- Location and quantity of off-site drainage entering and on-site drainage leaving the site, if any.
- Slopes throughout the site.
- Locations of existing mature vegetation (trees and shrubs) that retain intact upper soil profiles for stormwater processing.
- Small depressions on-site that retain stormwater runoff.
- Depths and conditions of the upper soil profile (the A and B horizons), along with the identification of the lower soils.

2. **Modeling and sizing in western Washington:** Modeling and sizing of multiple BMPs with a readily available continuous simulation model is possible with MGSFlood. In order to incorporate low impact development (LID) BMPs into the MGSFlood model, Table 4-2 and Table 4-3 have been created to show what land covers to assume for each BMP. Table 4-2 lists the assumed land covers broken down by outwash or till soils. Outwash soils would represent soils in Hydrologic Soil Group A and some uncompacted soils in Hydrologic Soil Group B. Till soils would represent some compacted soils in Hydrologic Soil Group B, as well as soils in Hydrologic Soil Groups C and D.

**Table 4-2 Flow control modeling techniques based on land use.**

| BMP Type: Land Use | Assume the TDA is Composed of the Following: Outwash Soil | Till Soil |
|---|---|---|
| Reversion of impervious surface[1] | 100% Pasture | 100% Grass |
| Landscaped with amended soils[2] | 25% Impervious, 75% Pasture, or Apply FC.02, Engineered Dispersion Criteria | 50% Impervious, 50% Pasture, or Apply FC.02, Engineered Dispersion Criteria |
| Permeable pavement without perforated drain pipe[3] | Represented in MGSFlood internally as its own land use | Represented in MGSFlood internally as its own land use |
| Permeable pavement with perforated drain pipe[3] | 100% Impervious | 100% Impervious |

[1] See Step 2 in preceding section titled "Reversion of Existing Impervious Surface Areas" and Section 5-4.3.2, Soil Amendments.

[2] See Section 5-4.3.2, Soil Amendments.

[3] See BMP IN.06, Permeable Pavement Surfaces, in Chapter 5.

Table 4-3 lists modeling technique procedures for specific LID systems in the form of modifications to model input parameters for pond and infiltration characteristics. Adjusting the pond and infiltration characteristics takes into account the water loss

and avoids over-designing the flow control facility. MGSFlood has the routine for multiple structures BMP systems.

For sites with multiple types of BMPs, soil types, and/or land covers, modeling must incorporate multiple TDAs. Alternatively, a weighted average of the modeling techniques can be calculated for the combination of BMPs. The designer should note that these techniques are for flow control only, and must model the postproject conditions in order to determine the appropriate runoff treatment volume. Once this is complete, the designer can then apply these modeling techniques to land use to determine the appropriate flow control volume.

**Table 4-3 Flow control modeling techniques for the interim.**

| BMP Type: Structural | Assume the Following Process for the Interim: Outwash Soil | Till Soil |
|---|---|---|
| Drywells* | See Section 4-5.4.2. | See Section 4-5.4.2 |
| Bioretention (Linear & Cell)* | Pond with a steady-state saturated hydraulic conductivity rate. | Pond with a steady-state saturated hydraulic conductivity rate. |
| Compost-Amended Soils* | Apply BMP FC.02, Engineered Dispersion Criteria, or Model as Pasture. | See Section 4-5.3.3. |

* These BMPs can be modeled using MGSFlood. Please contact the Region Hydraulics Office first to obtain procedures, or see the web link: www.wsdot.wa.gov/design/hydraulics/training.htm

### *Flow Control Facility Design*

Flow control facility design can be completed in one of two ways: by defining the pond hydraulics in the *Pond Hydraulics Excel Spreadsheet* (http://www.wsdot.wa.gov/design/hydraulics/programdownloads.htm) or by using an optimization routine available in a proprietary version of MGSFlood.

The flow control analysis for detention pond design should include the detention pond surface area as impervious surface. Regardless of the method used for sizing a flow control facility, detention pond design must take into account the effect that the actual pond will have as a land use change in the postdeveloped condition. Therefore, the flow control analysis should also include the pond surface area in the postdeveloped condition as an impervious surface since the precipitation falling on the detention pond surface will result in a runoff volume that will contribute directly to the flow control facility. In the predeveloped condition, the detention pond top surface area should be represented by its existing land cover condition. This will require at least two iterations using MGSFlood to properly size the facility. The water quality flow rates determined from this analysis should be used to size runoff treatment BMPs that are downstream of the flow control facility. A separate model without the pond area should be used for sizing runoff treatment BMPs that are upstream of the flow control facility, since the runoff volume from this pond area will not contribute to the runoff treatment BMP.

## Pond Design Using Routing Table

Routing is performed using the information entered in the *Pond Hydraulics Excel Spreadsheet*. Information can be keyed into and copied from the spreadsheet and pasted into the hydrology program (MGSFlood or WHAM) using the Windows clipboard function. *Elevation* is the water surface elevation in the pond; *Area* is the pond surface area (acres); *Volume* is the pond volume (acre-feet); *Discharge* is the pond discharge (cfs); and *Infilt* is the infiltration rate (cfs) through the pond bottom. Water infiltrated through the pond bottom does not contribute to the computed pond outflow. (See Appendix 4A for a web link to example problems that will provide suggestions for manipulating the design to achieve matching predeveloped and postdeveloped durations.)

## Pond Design Using Optimization

The proprietary version of MGSFlood includes routines for computing pond hydraulics and automatically sizing detention pond and outlet works to meet the duration-based flow control standard (see Table 3-6). Designing stormwater ponds to this standard is a laborious, iterative process, whereby the runoff timeseries (typically 40 years or more) is routed through the pond, and flow-duration statistics are computed and compared with predeveloped flow-duration statistics. The automatic pond-sizing routine in MGSFlood performs this pond design procedure.

The automatic pond-sizing optimization routine in the MGSFlood Hydraulic Structures add-in module will determine the pond size and outlet configuration for three pond types: (1) a detention pond with no infiltration, (2) a detention pond with minor infiltration, and (3) an infiltration pond. The characteristics of these pond types are listed in Table 4-4.

MGSFlood also has the following features:

1. Option for simulating multiple structures to allow the designer to account for infiltration that occurs upstream of a detention facility and to analyze sites with multiple treatment facilities.
2. Determines whether the runoff treatment volumes can be infiltrated in 36 hours. Under this premise, the storm/runoff ends 12 hours after the runoff period midpoint and combines with the 24-hour drain criteria; therefore, it would take 36 hours to drain the pond.
3. Subroutine that provides water surface elevation magnitude-frequency statistics and reports these in the project report.
4. Subroutine that computes varying infiltration rates as a function of pond depth using the Detailed Approach Method (Massmann's) equations.
5. Subroutine to compute the volume of stormwater treated by a sand filter.
6. Subroutine that states the percentage of runoff that infiltrates through the pond bottom relative to the total pond inflow.
7. Predevelopment, 100-year line on pond performance flow duration graph.

8. Subroutine for infiltration trench design on the embankment or in the ditch line.
9. Subroutines for compost-amended vegetated filter strips (CAVFS), filter strips, and flow splitters.

**Table 4-4 Characteristics of detention and infiltration ponds sized using MGSFlood optimization routine.**

| Characteristic | Detention Pond | Infiltration Pond |
|---|---|---|
| Pond Configuration | Riser Structure With Low-Level Circular Orifice and Vertical Rectangular Upper Orifice | Overflow Riser Only |
| Valid Infiltration Rates | 0.00–0.10 inches/hour | 0.05–50 inches/hour |
| Optimization Levels | Quick or Full | Quick Only |

Two levels of optimization are available for detention pond sizing: Quick Optimization and Full Optimization. Quick Optimization determines a "ballpark" solution in a relatively short time (usually less than one minute). Full Optimization does an exhaustive search of potential solutions, seeking a configuration for the minimum pond size required to meet the flow duration standard. The Full Optimization routine usually converges on a solution in less than ten minutes, depending on the speed and memory of the computer.

The pond-sizing optimization routine uses general input about the pond geometry, including:

- Pond length-to-width ratio
- Pond side slope
- Pond floor elevation
- Riser crest elevation
- Pond infiltration rate

The pond-sizing routine uses this information to establish the geometric relationships for the pond configuration. The program establishes a parameter space of possible solutions by varying the pond bottom area and the sizes and elevations of hydraulic devices for the outlet structure. The program then routes the developed runoff timeseries through the pond and seeks to find a solution that provides the minimum pond size to meet the discharge flow duration requirements.

Once the optimization has determined a pond size, it is still possible to go back to the first tab under Pond/Vault Geometry and manually manipulate the pond size under the Prismatic Pond Geometry or the Elevation Volume Table for irregularly shaped ponds.

The standard outlet configuration used for detention ponds consists of a circular low-level orifice and a vertical rectangular orifice (slot). If a different outlet configuration is desired, the volume-discharge characteristics of the desired configuration can be set to match the volume-discharge characteristics returned by the program for the orifice/slot weir configuration. The low-level circular orifice is assumed to be free of tailwater effects. If tailwater conditions are present, first use the optimization routine to determine the

pond configuration without consideration of tailwater. Then, include the tailwater rating table and manually adjust the pond configuration to meet the flow duration design criteria.

There is a wide variety of combinations of hydraulic devices, device sizes and invert heights, and pond configurations that can be used to match the flow duration standard. However, it is difficult to find a pond configuration that minimizes the pond volume and meets the duration standard using a manual trial and error approach. The automatic pond-sizing routine searches the parameter space of possible solutions and seeks to find the minimum pond size to meet the flow duration standard.

In some situations, usually when there are "outliers" in the precipitation data or precipitation data of poor quality are used, the pond design may not meet all design criteria. In these cases, the pond design determined by the MGSFlood program is returned to the Hydraulic Structures and Pond/Vault Geometry tabs for manual refinement. The user can make modifications to the design, and flows can be routed through the pond using manual mode.

### *Flow Frequency and Duration Statistics Check*

To analyze a stormwater pond's effectiveness at reducing postdevelopment flows to pre-developed levels, flows are first routed through the pond. Statistics can be computed and graphs created to show the performance graphically. Pond performance can be assessed by comparing the flow frequency and duration statistics for the pond outflow with the statistics computed for the predeveloped condition. The designer must also check the 100-year peak flow for flood control and property damage. The designer should review the history file and verify that the postdeveloped 100-year peak is less than the predeveloped 100-year peak flow. If the postdeveloped peak flow is not less than the predeveloped 100-year peak flow, the designer should field verify that property damage will be prevented.

## 4-4 Eastern Washington Design Criteria

This section provides a discussion of the methodologies used for calculating stormwater runoff from project sites in eastern Washington. The hydrologic analysis method for most WSDOT project sites in eastern Washington is either the SCS or SBUH method. The input required for a single-event hydrograph method includes pervious and impervious TDAs; times of concentration; pervious and impervious curve numbers; design storm precipitation; and a design storm hyetograph. An approved single-event model, such as StormShed, should be used for calculating runoff characteristics. Single-event models are explained in more detail in Section 4-4.6.

Note: The threshold discharge area concept must also be applied to projects in eastern Washington (see Section 4-2.5).

After the existing and postdeveloped hydrographs are computed for the project site, the results are routed through a level pool reservoir. The level pool reservoir is a model of either a detention or an infiltration facility. If a detention facility is proposed, the design includes a flow control structure consisting of one or more orifices in a riser or baffle wall that slowly releases the outflows. If an infiltration facility is proposed, the model input includes the

infiltration pond/trench area, design infiltration rate, and outlet control facility parameters—if only a portion of the design storm hydrographs will infiltrate and some flow will be released to a surface conveyance system. The level pool routing method is used to optimize the size of the facility with the space and depth available and meet the design criteria from Minimum Requirement 6 (see Section 3-3.6).

## 4-4.1 Runoff Treatment Flow-Based and Volume-Based BMPs

Runoff treatment BMPs are used to treat the stormwater runoff from pollutant-generating surfaces and should be designed in accordance with Minimum Requirement 5 (see Section 3-3.5). Some treatment BMPs are sized based on flow rate, while others are sized based on volume of runoff. For example, a bioswale or proprietary filtration BMP is sized based on flow rate, whereas an infiltration pond is sized based on runoff volume. Sizing is dependent on flow rates or volumes, as detailed in the following sections. The criteria for sizing runoff treatment facilities in eastern Washington are summarized in Table 3-4.

### 4-4.1.1 Flow-Based Runoff Treatment

The design flow rate for these types of facilities is dependent on whether the treatment facility is located upstream of a flow control facility and whether it is an *on-line* or *off-line* facility (see Section 4-3.1.1 for examples). Most treatment facilities can be designed as on-line systems, with flows greater than the runoff treatment design flow rate simply passing through the facility as overflow, with lesser or no pollutant removal. However, it is sometimes desirable to restrict flows to treatment facilities and bypass the remaining higher flows around them. These are called off-line systems.

### 4-4.1.2 Volume-Based Runoff Treatment

Runoff treatment facilities are designed based on volumes and must be sized for the entire flow volume that is directed to them. The following method can be used to derive the storage volume.

- **Wetpool and Infiltration:** The NRCS curve number equations (see *Hydraulics Manual*, Section 2.6.3) can be used to determine the runoff treatment design storm runoff volume. This is the volume of runoff from the storm noted in Table 3-4. WSDOT prefers that StormShed, an SBUH-based program, be used for this method to size volume-based runoff treatment BMPs. The size of the wetpool or infiltration storage volume is the same whether it is located upstream or downstream of a flow control facility or coupled with the flow control facility.

If the runoff from the new impervious surfaces and converted pervious surfaces is not separated from runoff from other surfaces on the project site, and/or is combined with run-on from areas outside the right of way, the runoff treatment facilities must be sized for the entire flow volume that is directed to them. Infiltration facilities must infiltrate 6-month, 24-hour total runoff volume within 72 hours after precipitation has ended.

## 4-4.2 Flow Control BMPs

An approved single-event model must be used when designing flow control BMPs, in accordance with Minimum Requirement 6 (see Section 3-3.6). WSDOT prefers that StormShed be used for designing flow control BMPs in WSDOT right of way. Stormwater discharges must match developed peak flows to predeveloped peak flows for the range of predeveloped discharge rates noted in Table 3-7.

## 4-4.3 Temporary Construction Site Erosion and Sediment Control

Interceptor dikes and swales, grass-lined channels, pipe slope drains, sediment traps, and temporary sediment ponds should be designed for peak flows or volumes from the 6-month, 3-hour storm using a single-event model. The designer should consult the HQ Environmental Services Office (ESO) or region hydraulics staff to determine whether a higher level of protection is needed beyond the 6-month, 3-hour storm due to the time of year for construction (freezing conditions and snowmelt); the downstream conditions; or the project is expected to last several construction seasons. (See Appendix 6A for additional TESC BMP design criteria.)

## 4-4.4 Exemptions for Flow Control

WSDOT has developed a standardized process to aid the designer in producing an acceptable hydraulic analysis for determining flow control exemptions. The process will help the designer determine how extensive an analysis must be for a particular project. (See Chapter 3 for a process that has been established for lakes and some river systems.) Please refer to Minimum Requirement 6 (see Section 3-3.6) for further details on exemptions, flow dispersion, and flow control thresholds.

## 4-4.5 Hydrologic Analysis Methods for Flow Control and Runoff Treatment Facility Design

This section presents the general process involved in conducting a hydrologic analysis using single-event hydrograph methods to (1) design retention/detention flow control facilities and (2) determine runoff treatment volumes. The exact step-by-step method for entering data into a computer model varies with the different models and is not described here (see the Documentation or Help modules of the computer program). Predeveloped and postdeveloped site runoff conditions must be determined and documented in the Hydraulic Report.

The process for designing retention/detention flow control facilities in eastern Washington is presented below. Review Minimum Requirement 6 (see Section 3-3.6) to determine all the requirements that will apply to the proposed project.

1. Determine rainfall depths for the site (see Appendix 4A).
   - 2-year – 24-hour
   - 25-year – 24-hour
   - 100-year – 24-hour
2. Determine predeveloped soils type and hydrologic group (A, B, C, or D) from SCS maps.
3. Determine predeveloped and postdeveloped TDAs and the subsequent pervious and impervious area (in acres) for each condition (see Section 4-2.5 for more details).
4. Determine curve numbers for pervious and impervious area using hydrologic soil groups for both the predeveloped and postdeveloped conditions (see Section 3-3.6.4, Appendix 4B, and Equations 4-10 and 4-11).
5. Determine predeveloped and postdeveloped time of concentration. StormShed will do this calculation if the designer enters length, slope, roughness, and flow type.
6. Select storm hyetograph and analysis time interval. Check that the analysis time interval is appropriate for use with storm hyetograph time increment (see Appendix 4C).
7. For each TDA, input the data obtained above into the computer model for each predeveloped and postdeveloped storm event.
8. Have the computer model compute the hydrographs.
9. Review the peak flow rate for the predeveloped conditions in the 2-year and 25-year storm events. The allowable release rate is listed in Table 3-7. Note: In some cases, the predeveloped 2-year peak flow rate may be 0 cfs, which means there is no discharge from the site. The 2-year postdeveloped flows in this situation must be retained as dead storage that will ultimately infiltrate or evaporate.
10. Review the peak flow rate for postdeveloped conditions in the 2-year and 25-year storms. Compare the increases in peak flow rates for 2-year and 25-year design storms to determine whether the project qualifies for an exemption.
11. Assume the size of the detention facility and input the data into the computer model. Refer to the volume of the design storm hydrograph computed in Step 8 for a good assumption of the detention volume required.
12. Assume the size of the orifice structure and input the data into the computer model. A single orifice at the bottom of the riser may suffice in some cases. In other projects, multiple orifices may result in decreased pond sizes. A good approximation would be to assume a 1-inch-diameter orifice per 0.05 cfs outflow for a typical pond.

13. Use the computer model to route the postdeveloped hydrographs through the detention facility and orifice structure. Compare the postdeveloped peak outflow rates to allowable release rates from Step 9.

14. If the postdeveloped peak outflow rates exceed the allowable release rates, adjust detention volume, orifice size, orifice height, or number of orifices. Keep running the computer model and adjusting the parameters until the post-developed outflow rates are less than or equal to the allowable release rates.

15. The flow control analysis for detention pond design should include the detention pond surface area as impervious surface. The detention pond design must take into account the effect that the actual pond will have as a land use change in the postdeveloped condition. Therefore, the flow control analysis should also include the pond surface area in the postdeveloped condition as an impervious surface since the precipitation falling on the detention pond surface will result in a runoff volume that will contribute directly to the flow control facility. In the predeveloped condition, the pond top surface area should be represented by its existing land cover condition. This will require at least two iterations using StormShed to properly size the detention facility. The water quality flow rates determined from this analysis should be used to size runoff treatment BMPs that are downstream of the flow control facility. A separate model without the pond area should be used for sizing runoff treatment BMPs that are upstream of the flow control facility since the runoff volume from this pond area will not contribute to the runoff treatment BMP.

16. Check the 100-year release rate and compare to predeveloped conditions, and check for potential property damage.

17. Calculations are complete.

Examples can be found through the web links, which are provided in Appendix 4A.

The following is the process for calculating runoff treatment design volumes or flow rates. Note that the data for many of the initial steps matches the data used in designing retention/detention flow control facilities described above.

1. Review Minimum Requirement 5 (see Section 3-3.5) to determine all requirements that will apply to the proposed project.

2. Determine the climatic region and Mean Annual Precipitation (MAP) (see Appendix 4A).

3. Determine the rainfall for the site depending on the treatment BMP (see Appendix 4A and Section 4-4.1).

4. Multiply the rainfall by the appropriate coefficient to determine the 6-month precipitation (see Appendix 4C).

5. Determine the existing soils type and hydrologic group (A, B, C, or D) from SCS maps (see *Hydraulics Manual*, Section 2-6.2).

6. Determine postdeveloped TDAs and the subsequent pervious and impervious area (in acres) requiring treatment that contributes flow to the treatment BMP.
7. Determine curve numbers for pervious and impervious area using the hydrologic soil group for the postdeveloped condition (see Appendix 4B).
8. Determine postdeveloped time of concentration; StormShed computes this when the designer inputs length, slope, roughness, and flow type (see *Hydraulics Manual*, Section 2-6.2).
9. If modeling the short-duration storm hyetographs, select the short-duration rainfall type in StormShed. Determine that the analysis time interval is appropriate for use with the storm hyetograph time increment (see Appendix 4C).
10. Input data obtained from above into StormShed for the postdeveloped storm event.
11. Have the model compute the hydrograph.
12. For the design of flow-based treatment BMPs, the computed peak flow from the 6-month, 3-hour hydrograph is the design flow.
13. For the design of volume-based treatment BMPs, the computed volume from the 6-month, 24-hour storm is the design volume.

Examples can be found through the web links, which are provided in Appendix 4A.

## 4-4.6 Single-Event Hydrograph Method

In eastern Washington, a single-event hydrograph method is typically used for calculation of runoff, with an integrated set of hydrology design tools developed to address the needs of conventional engineering practice. There are many single-event models based on the SCS (Soil Conservation Service) and SBUH methodologies that include level pool routing, pipe and ditch conveyance system analysis, and backwater computation. Appendix 4A provides a link to the approved WSDOT single-event model. Single-event models are described in more detail in Chapter 2 of the WSDOT *Hydraulics Manual*. Runoff curve numbers and the precipitation data differ considerably in eastern and western Washington (see Appendix 4B). Refer to Appendix C for a discussion on the eastern Washington design storm events.

## 4-4.7 Eastern Washington Design Storm Events

When rainfall patterns during storms were analyzed in eastern Washington, it was concluded that the SCS Type II rainfall does not match the historical records. Two types of storms were found to be prominent on the east side of the state: short-duration thunder storms (later spring through early fall seasons) and long-duration winter storms (any time of year, but most common in the late fall through winter period and the late spring and early summer period). The short-duration storm generates the greatest peak discharges and should be used to design flow-based BMPs. The long duration storm occurs over several days, generating the greatest volume, and should be used to design volume-based BMPs.

When using the long-duration storm, it should be noted that the state has been divided into the following four climatic regions:

1. East Slope Cascades
2. Central Basin
3. Okanogan, Spokane, Palouse
4. NE and Blue Mountains

The long-duration storms in Regions 2 and 3 are similar to the SCS Type 1A storm. Designers in those regions can choose to use either the long-duration storm or the SCS Type 1A storm. Eastern Washington design storm events are further discussed in Appendix 4C.

## 4-4.8 Modeling Using Low-Impact Development Techniques in Eastern Washington

Low-impact development (LID) is a BMP application that manages stormwater on a small scale and disperses it into a facility as close as possible to the source of runoff. This is in contrast to conventional BMP applications that manage stormwater at one location on the project site.

Design of low-impact development BMP drainage features in eastern Washington requires a different approach than in western Washington, since the sizing of these systems is based on a single-event hydrologic model. Adjustments to site runoff parameters are based on the SCS Curve Numbers (CNs) applicable to the site ground cover and soil conditions. Appendix 4B presents the adjusted runoff CNs for selected soil and ground cover combinations, reflecting the reduced values for situations where pervious areas drain to low-impact BMPs. (See *Hydraulics Manual*, Section 2-6.2 for soil type definitions and more discussion on CN values.) Note: The analysis described in this section generally uses StormShed.

Composite custom CN values are calculated using a weighted approach based on individual land covers, without considering disconnectivity of the site's impervious surfaces. This approach is appropriate because it places increased emphasis on minimal disturbance to, and retention of, site areas that have potential for runoff storage and infiltration. This approach also provides an incentive to save more trees and shrubs and maximize the use of Type A and B soils for recharge.

If the impervious surface coverage on the site is less than 30% of the site area, the percentage of unconnected impervious areas within the watershed influences the calculation of the CN value. For linear transportation systems, the percentage of impervious surface should be evaluated based on a "unit length" method, such as a drainage area 30 feet wide that is bound by the crown of the roadway centerline to the right of way limit.

Use Equation 4-10 when disconnectivity of impervious areas is not considered.

$$CN_c = \frac{CN_1A_1 + CN_2A_2 \ldots + CN_jA_j}{A_1 + A_2 \ldots + A_j} \quad \textbf{(4-10)}$$

where: $CN_c$ = Composite Curve Number
$A_j$ = Area of each land cover in $ft^2$
$CN_j$ = Curve number for each land cover

Use Equation 4-11 for sites with less than 30% impervious surface coverage where those impervious surfaces are disconnected.

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right) x \left(98 - CN_p\right) x \left(1 - 0.5R\right) \quad \textbf{(4-11)}$$

where: $CN_c$ = Composite Curve Number
$CN_p$ = Composite pervious Curve Number
$P_{imp}$ = Percentage impervious site area
$R$ = Ratio of unconnected impervious area to total impervious area

Unconnected impervious areas are impervious areas without any direct connection to a drainage system or other impervious surface.

After calculation of the $CN_c$ is complete, use the SBUH method to determine stormwater runoff volumes and rates from the unit length of roadway basin (for example, 30-foot width for continuous roadway prisms with consistent soils/vegetation) for the applicable runoff treatment and flow control design storms. This method can also be applied to specific roadway lengths (noncontinuous width) where soils and roadway character vary.

It is extremely important to verify soil infiltration capacity and vegetative cover in all areas where the SBUH method is to be applied. Determine the natural infiltration capacity of the roadside area where runoff will be distributed. The WSDOT Materials Lab should provide the infiltration rates, although initial estimates based on published NRCS data can be used for rough sizing estimates (see Section 4-5.3). If the resultant infiltration rate ($Q$) of the receiving area is greater than the peak 25-year design flow rate of the contributing drainage basin, all stormwater will be infiltrated along the roadside and no further analysis is needed. Calculation of the infiltrative flow rate, $Q_i$, can be performed as follows:

**Calculation of Infiltrative Flow Rate**

$$Q_i = \frac{F \times A}{43200 \frac{in/hr}{ft/s}}$$

where: $Q_i$ = Flow rate in cfs

$A$ = Area available for infiltration in $ft^2$

$F$ = Saturated (long-term) infiltration rate in inches/hour

Should peak flow rates of the contributing drainage basin exceed the infiltrative flow rate of the receiving roadside area, further analysis is required and some storage of stormwater will be necessary. In semiarid nonurban areas, formalized detention ponds are usually not the best solution. Storage of minor to moderate amounts of stormwater runoff can be accomplished by using natural depression storage. This includes depressions in the roadside topography, swales, and even roadway ditches. Each of these features can accommodate stormwater storage and allow for releasing runoff through infiltration over a longer time scale.

To determine the needed runoff retention volume, subtract the continuous saturated infiltration rate from the 25-year storm hydrograph produced from the SBUH method. The resulting quantity represents the runoff volume that needs to be detained until infiltration can "catch up" with the runoff. Check to see if this volume can be accommodated in the existing roadside landscape or roadway ditches. If roadside hydraulic conveyance capacity allows, *check dams* may be placed in ditches to detain stormwater in noncentralized locations. This method for small-scale flow detention will require a site-specific analysis; a continuous linear approach may not be valid.

## 4-5 Infiltration Design Criteria

An infiltration facility provides stormwater flow control by containing excess runoff in a storage facility, then percolating that runoff into the surrounding soil. Infiltration facilities can provide runoff treatment and flow control, but to do so requires certain soil characteristics. Section 4-5.1, Site Suitability Criteria, provides a detailed discussion of soil characteristics needed to determine which type of infiltration facility is most appropriate for the site.

There are many types of infiltration BMPs listed in Chapter 5. Some of these facilities include ponds, vaults, trenches, and drywells, along with partial infiltration facilities such as natural and engineered dispersion and compost-amended vegetated filter strips (CAVFS). This section provides design criteria on the various ways to determine infiltration rates and facility size, dependent on the facility and whether infiltration occurs at the surface or below the surface (subsurface).

Surface infiltration BMP designs and subsurface infiltration BMP designs follow different criteria. Infiltration ponds, infiltration vaults, infiltration trenches (designed to intercept sheet flow), dispersion, and CAVFS are considered surface infiltration BMPs and are based on infiltration rates. In order to compute these infiltration rates, determination of the soil saturated hydraulic conductivity must be completed. Infiltration trenches designed as an end-of-pipe application (with underdrain pipe) and drywells are considered subsurface infiltration BMPs and regulated by the Underground Injection Control (UIC) Rule, which is intended to protect underground sources of drinking water. As a result, subsurface infiltration BMPs are

known as underground injection facilities and designed dependent on the treatment capacity of the subsurface soil conditions.

The sections that follow provide detailed information on site suitability criteria, saturated hydraulic conductivity determination, determination of infiltration rates, and underground injection facilities.

## 4-5.1 Site Suitability Criteria (SSC)

This section specifies the site suitability criteria that must be considered for siting infiltration treatment systems. When a site investigation reveals that any of the following eight applicable criteria cannot be met, appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to safety, health, or the environment.

For infiltration treatment, site selection, and design decisions, a qualified engineer with geotechnical and hydrogeologic experience should prepare a geotechnical and hydrogeologic report. A comparable professional may also conduct the work if it is under the seal of a registered Professional Engineer (PE). The design engineer may use a team of certified or registered professionals in soil science, hydrogeology, geology, and other related fields.

To design infiltration facilities, the following SSC must be followed when applicable, in addition to those described in the BMP descriptions.

### *SSC 1 – Setback Requirements*

Setback requirements for infiltration facilities are generally provided in local regulations, Uniform Building Code requirements, or other state regulations. The following setback criteria are used unless otherwise required by Critical Area Ordinance or other jurisdictional authorities.

- In general, infiltration facilities should be located 20 feet downslope and 100 feet upslope from building foundations and 50 feet or more behind the top of slopes steeper than 15%. The designer should request a geotechnical report for the project that would evaluate structural site stability impacts due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties (especially on hills with known side-hill seeps). The report should address the adequacy of the proposed BMP locations and recommend any adjustments to the setback distances provided above, either greater or smaller, based on the results of this evaluation.
- Infiltration facilities should be set back at least 100 feet from drinking water wells, septic tanks or drain fields, and springs used for public drinking water supplies. Infiltration facilities upgradient of drinking water supplies and within 1-, 5-, and 10-year time of travel zones must comply with health department requirements (Washington Wellhead Protection Program, WAC 246-290-135).
- Additional setbacks must be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system.

- Infiltration facilities must be located at least 20 feet from a native growth protection easement (NGPE).
- Infiltration facilities must be a minimum of 5 feet from any property line and vegetative buffer. This distance may be increased based on permit conditions required by the local government.

### *SSC 2 – Seepage Analysis and Control*

Determine whether there would be any adverse effects caused by seepage zones near building foundations, roads, parking lots, or sloping sites. Infiltration of stormwater is not recommended on or upgradient of a contaminated site where infiltration of even clean water can cause contaminants to mobilize.

Sidewall seepage is not usually a concern if seepage occurs through the same stratum as the bottom of the facility. However, for engineered soils or soils with very low permeability, the potential to bypass the treatment soil through the sidewalls may be significant. In those cases, the sidewalls must be lined, either with an impervious liner or with at least 18 inches of treatment soil, to prevent seepage of untreated flows through the sidewalls.

### *SSC 3 – Groundwater Protection Areas*

A site is not suitable if the infiltrated stormwater will cause a violation of the Ecology water quality standards for ground waters (WAC 173-200). Local jurisdictions should be consulted to determine applicable pretreatment requirements and whether the site is located in an aquifer-sensitive area, a sole-source aquifer, or a wellhead protection zone.

### *SSC 4 – Depth to Bedrock, Water Table, or Impermeable Layer*

The base of all infiltration basins or trench systems must be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan), or other low-permeability layer. A separation down to 3-feet may be considered if the design of the overflow and/or bypass structures is judged by the site professional to be adequate to prevent overtopping and meet the SSC specified in this section.

### *SSC 5 – Soil Infiltration Rate*

For runoff treatment infiltration facilities, the short-term soil infiltration rate is 2.4 inches per hour or less, calculated as described in Section 4-5.3.1 using the "Detailed Approach," but using a value of 1.0 for $CF_{silt/bio}$. The "Simplified Approach" (see Section 4-5.3.2) should not be used for this determination in western Washington, as it is set up to only produce long-term infiltration rates. The infiltration rate calculated in this manner should not be used to size the facility, but only to determine whether the treatment criterion is met. This infiltration rate is typical for soil textures that possess sufficient physical and chemical properties for adequate treatment, particularly for soluble pollutant removal (see below). It is comparable to the textures represented by Hydrologic Soil Groups B and C (see hydrologic soil groups in *Hydraulics Manual*, Section 2-6.2).

Long-term infiltration rates up to 3.0 inches per hour can also be considered if the infiltration receptor is not a sole-source aquifer and if, in the judgment of the site professional, the

treatment soil has characteristics comparable to those specified in SSC 7 to adequately control the target pollutants.

Bioretention areas may have a greater maximum allowable infiltration rate. (See Appendix III-C in Ecology's SMMWW, Volume III.)

### *SSC 6 – Drawdown Time*

For western Washington, the 91% percentile, 24 hour runoff volume must be infiltrated within 36 hours. Under this premise, the storm/runoff ends 12 hours after the runoff period midpoint and combines with the 24-hour drain criteria. Therefore, the actual drawdown time is 36 hours. Flow control and runoff treatment in eastern Washington is designed to completely drain ponded runoff within 72 hours in order to meet the following objectives:

- Restore hydraulic capacity to receive runoff from a new storm (applicable for single-event modeling, but not applicable for continuous hydrograph modeling).
- Aerate vegetation and soil to keep the vegetation healthy, prevent anoxic conditions in the treatment soil, and enhance the biodegradation of pollutants and organics (if the infiltration facility is to provide treatment).

In general, this drawdown requirement is applicable only if it is intended for the infiltration facility to provide treatment and for addressing storage capacity if a single-event hydrograph model is used. Drawdown time criteria are not applicable for infiltration facilities designed for flow control in western Washington.

### *SSC 7 – Soil Physical and Chemical Suitability for Treatment*

Soil texture and design infiltration rates should be considered, along with the physical and chemical characteristics specified below, to determine whether the soil is adequate for removing the target pollutants. The following soil properties must be carefully considered in making such a determination:

- Cation exchange capacity (CEC) of the treatment soil must be ≥5 milliequivalents CEC/100 g dry soil (U.S. EPA Method 9081). Consider empirical testing of soil sorption capacity, if practicable. Ensure soil CEC is sufficient for expected pollutant loadings, particularly heavy metals. CEC values of >5 meq/100g are expected in loamy sands, according to Rawls et al. (1982). Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is accepted by the local jurisdiction.
- The sodium adsorption ratio (SAR) can have a dramatic effect on the long-term performance of an infiltration facility. Soils with an excess of sodium ions, compared to calcium and magnesium ions, remain in a dispersed condition, almost impermeable to water. A dispersed soil is extremely sticky when wet, tends to crust, and becomes very hard and cloddy when dry. An SAR value of 15 or greater indicates that an excess of sodium will be adsorbed by the soil clay particles and severely restrict infiltration. Montmorillionite, vermiculite, illite, and mica-derived clays are more sensitive to sodium than other clays and could

develop problems if the SAR is greater than 5. If runoff contains high levels of sodium in relation to calcium and magnesium, it may also present problems in the future. The addition of gypsum (calcium sulfate) to the soil can be used to free the sodium and allow it to be leached from the soil.

- Depth of soil used for infiltration treatment must be a minimum of 18 inches, except for designed, vegetated infiltration facilities with an active root zone, such as bioinfiltration swales.
- The organic content of the treatment soil (ASTM D 2974); organic matter can increase the sorptive capacity of the soil for some pollutants. The site professional should evaluate whether the organic matter content is sufficient for control of the target pollutant(s).
- Waste fill materials should not be used as infiltration soil media, nor should such media be placed over uncontrolled or nonengineered fill soils.
- Engineered soils may be used to meet the design criteria in this chapter and the runoff treatment targets in Table 3-1. Field performance evaluation(s), using acceptable protocols, would be needed to determine feasibility and acceptability by the local jurisdiction. (See Soil Amendments in Chapter 5.)

### *SSC 8 – Cold Climate and Impacts of Roadway Deicers*

- For cold climate design criteria (snowmelt/ice impacts), refer to the D. Caraco and R. Claytor document, Stormwater BMP Design Supplement for Cold Climates, U.S. EPA, December 1997.
- The potential impact of roadway deicers on potable water wells must be considered in the siting determination. Mitigation measures must be implemented if infiltration of roadway deicers can cause a violation of groundwater quality standards. For assistance, contact region or HQ hydraulics staff.

## 4-5.2 Saturated Hydraulic Conductivity

Once a site is determined suitable for infiltration, the infiltration design can begin. The sizing of an infiltration BMP is dependent on the infiltration rate of the soils over which the BMP is located. Section 4-5.3 discusses the various ways to determine an infiltration rate. Infiltration rates are based on two components: the soil's saturated hydraulic conductivity and the hydraulic gradient. This section explains how to determine saturated hydraulic conductivity, which is based on the porosity of the underlying soil saturated.

There are two ways to determine saturated hydraulic conductivity. The first methodology, called the Detailed Approach, was developed from research conducted by Massmann (2003). The second methodology is the use of the Guelph Permeameter and is only allowable in eastern Washington.

### 4-5.2.1 Detailed Approach to Determine Saturated Hydraulic Conductivity

The geotechnical investigation will typically provide a computation of the saturated hydraulic conductivity ($K_{sat}$) for the area proposed for infiltration. In those cases where the $K_{sat}$ is not provided, the designer can use the gradation information from the geotechnical investigation and the following equations to compute the $K_{sat}$ value.

The $K_{sat}$ derived using the Detailed Approach can then be used to design the following:

- Infiltration pond (BMP IN.02)
- Infiltration trench (BMP IN.03)
- Infiltration vault (BMP IN.04)
- Underlying soils of CAVFS (BMP RT.02)
- Drywell (BMP IN.05)
- Natural dispersion (BMP FC.01)

For each defined layer below the facility to a depth below the facility bottom of 2.5 times the maximum depth of water in the facility, but not less than 6 feet, estimate the $K_{sat}$ (cm/sec) using the following relationship (see Massmann, 2003, and Massmann et al., 2003):

$$\log_{10}(K_{sat}) = -1.57 + 1.90 D_{10} + 0.015 D_{60} - 0.013 D_{90} - 2.08 f_{fines} \quad \textbf{(4-12)}$$

where: $K_{sat}$ = the saturated hydraulic conductivity in cm/s
$D_{10}$, $D_{60}$ and $D_{90}$ = grain sizes in mm for which 10%, 60%, and 90% of the sample is more fine
$f_{fines}$ = grain sizes in mm for the fraction of the soil (by weight) that passes the number-200 sieve

Use the following equation to convert $K_{sat}$ from cm/s to ft/day:

$$K_{sat}\,(\text{ft/day}) = K_{sat}\,(\text{cm/s}) \times 2{,}834.65$$

If the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the facility, soil layers at greater depths must be considered when assessing the site's saturated hydraulic conductivity characteristics. Massmann (2003) indicates that where the water table is deep, soil or rock strata up to 100 feet below an infiltration facility can influence the rate of infiltration. Note that only the layers near and above the water table or low permeability zone (such as a clay, dense glacial till, or rock layer) need to be considered, as the layers below the groundwater table or low permeability zone do not significantly influence the rate of infiltration. Also, note that this equation for estimating saturated hydraulic conductivity assumes minimal compaction consistent with the use of tracked (low-to-moderate ground pressure) excavation equipment, as described in the Site Design Elements of Section 5-4.2.1.

If the soil layer being characterized has been exposed to heavy compaction, or is heavily overconsolidated due to its geologic history (for example, overridden by continental glaciers), the saturated hydraulic conductivity for the layer could be approximately an order of magnitude less than what would be estimated based on grain size characteristics alone (Pitt, 2003). In such cases, compaction effects must be taken into account when estimating saturated hydraulic conductivity. For clean, uniformly graded sands and gravels, the reduction in $K_{sat}$ due to compaction will be much less than an order of magnitude. For well-graded sands and gravels with moderate-to-high silt content, the reduction in $K_{sat}$ will be close to an order of magnitude. For soils that contain clay, the reduction in $K_{sat}$ could be greater than an order of magnitude.

There are field tests that can estimate specific soil layer $K_{sat}$ values. These tests include the packer permeability test (above or below the water table), the piezocone (below the water table), an air conductivity test (above the water table), and a pilot infiltration test (PIT), as described in Ecology's SMMWW. Note that these field tests generally provide a saturated hydraulic conductivity combined with a hydraulic gradient (see Darcy's Law, Equation 4-18). In some of these field tests, the hydraulic gradient may be close to 1.0. For this condition, Darcy's Law would show that the $K_{sat}$ would be nearly equal to the infiltration rate of that soil layer. It is important to recognize that the gradient in theses field tests may not be the same as the gradient likely to occur in the full-scale infiltration facility in the long term (when groundwater mounding is fully developed). This issue will need to be evaluated on a case-by-case basis when interpreting the results of field tests.

For Infiltration Pond, Infiltration Trench, Infiltration Vault, and the underlying soils for CAVFS, once the saturated hydraulic conductivity for each layer has been identified, determine the effective average saturated hydraulic conductivity below the BMP. Saturated hydraulic conductivity estimates from different layers can be combined using the harmonic mean:

$$K_{equiv} = \frac{d}{\sum \frac{d_n}{K_{sat\_n}}} \qquad \textbf{(4-13)}$$

where: $K_{equiv}$ = the average saturated hydraulic conductivity in ft/day
$d$ = the total depth of the soil column in feet
$d_n$ = the thickness of layer "$n$" in the soil column in feet
$K_{sat\_n}$ = the saturated hydraulic conductivity of layer "$n$" in the soil column in ft/day

The depth of the soil column, $d$, typically would include all layers between the BMP bottom and the water table. However, for sites with very deep water tables (>100 feet) where groundwater mounding to the base of the BMP is not likely to occur, it is recommended that the total depth of the soil column in Equation 4-13 be limited to approximately 20 times the depth of BMP. This is to ensure the most important and relevant layers are included in the saturated hydraulic conductivity calculations. Deep layers that are not likely to affect the infiltration rate near the BMP bottom should not be included in Equation 4-13. Equation 4-13 may overestimate the effective saturated hydraulic conductivity value at sites with low

conductivity layers immediately beneath the infiltration BMP. For sites where the lowest conductivity layer is within 5 feet of the base of the BMP, it is suggested that this lowest saturated hydraulic conductivity value be used as the equivalent saturated hydraulic conductivity rather than the value from Equation 4-13. The harmonic mean given by Equation 4-13 is the appropriate effective saturated hydraulic conductivity for flow that is perpendicular to stratigraphic layers and will produce conservative results when flow has a significant horizontal component (such as could occur with groundwater mounding).

For the soils underlying a CAVFS, a correction factor should be applied to the saturated hydraulic conductivity to account for compaction in the embankment. A correction factor of 10 ($1/10^{th}$ of the estimated $K_{sat}$ determined by Equation 4-12) should be used for "well-graded sands and gravels with moderate-to-high silt content." For clean, uniformly graded sands and gravels, a correction factor of 5 should be used, and a correction factor of 15 should be applied to $K_{sat}$ for soils that contain clay. The designer should verify that this compaction factor is applied to $K_{sat}$ before using these rates in any continuous simulation model.

- **Alternate method of determining the saturated hydraulic conductivity ($K_{sat}$) for CAVFS**

  Refer to Ecology's SMMWW, Volume III, Appendix III-D, Procedure for Conducting a Pilot Infiltration Test. A correction factor of 1.5 to 6 should be applied to the measured infiltration rate ($f$) determined by this method. A correction factor on the lower end of the range should be applied to the infiltration rate if the designer can verify that the underlying fill material being tested is relatively consistent for the length of proposed CAVFS. Otherwise, a reduction factor toward the higher end of the range should be used. $K_{sat}$ can be determined by using Equation 4-12. The hydraulic gradient will need to be established for the CAVFS area.

For drywells, once the saturated hydraulic conductivity for each layer has been identified, the designer must convert the saturated hydraulic conductivity to (ft/min) and then calculate the geometric mean of the multiple saturated hydraulic conductivity values.

The geometric mean for saturated hydraulic conductivity value is given by the following expressions:

$$K_{geometric} = e^{Yaverage} \quad \textbf{(4-14)}$$

where: $K_{geometric}$ = the average saturated hydraulic conductivity in ft/min
$Y_{average}$ = the average of the natural logarithms of the hydraulic conductivity values:

$$Y_{average} = \frac{1}{n}\sum Y_i = \frac{1}{n}\sum \ln(K_i) \quad \textbf{(4-15)}$$

where: $K_i$ = the saturated hydraulic conductivity of soil layer $i$ in ft/min
$Y_i$ = the natural logarithms of the saturated hydraulic conductivity values

### 4-5.2.2 Determining Saturated Hydraulic Conductivity Using the Guelph Permeameter

The $K_{sat}$ derived using the Geulph Permeameter can then be used to design:

- Natural dispersion for eastern Washington only (FC.01)

The determination of an appropriate $K_{sat}$ measurement protocol is essential for the proper implementation of the *natural dispersion* BMP on the embankment. Equally, accurate $K_{sat}$ measurements are one of the most challenging aspects in hydrologic modeling, particularly for surface infiltration methods. The following method can be used in eastern Washington only.

In cases when the existing embankments will, for the most part, remain in place with little disturbance or additional embankment construction (minor shoulder widening), the Guelph Permeameter (GP) method should be used to determine the in situ $K_{sat}$ values. Once a value has been established, a correction factor of 2 should be applied to $K_{sat}$ for the natural dispersion design.

- The recommended testing frequency should be 5 tests per 2500 linear feet of roadway, with the average value of all tests representing the design $K_{sat}$ value. This recommendation is based on the premise that existing roadway embankments were constructed with imported fill material hauled from off-site borrow sites. If the designer wants to limit the number of test holes needed, it would be necessary to conduct a review of all as-built information and any other relevant design records to determine where placement of borrow material has occurred. If it is determined that consecutive segments of the subject highway were constructed from the same materials source, then no additional testing outside the recommended frequency would be necessary.
- The GP method provides simultaneous in situ measurements in the vadose zone of field-saturated hydraulic conductivity sorptivity and the hydraulic conductivity pressure head relationship. The method involves measuring the steady-state rate of water recharge from a small cylindrical hole in which a constant depth of water is maintained. A simple "in-hole" bottle device is used to establish and maintain the depth to measure the corresponding discharge rate.

## 4-5.3 Determination of Infiltration Rates

An overview of the design procedure is provided in Figures 4-14 through 4-16. The focus of these design procedures is to size the facility. For other geotechnical aspects of the facility design, including geotechnical stability of the facility and constructibility requirements, see Chapter 5 and the *Design Manual*. A multidisciplinary approach is required to design infiltration facilities, as described in Chapter 2. This section describes the three methods for determining infiltration rates.

1. **Detailed Approach for determining infiltration fates**. A detailed analysis that allows the designer to consider the type of hydrograph used (continuous or single-event); the depth to the groundwater table; the site-specific hydraulic gradient for the facility; and the facility geometry.

2. **Simplified Approach for determining infiltration rates**. This method generally follows Ecology's SMMWW and commonly produces a more conservative facility size.

3. **Determining Infiltration Rates for Soil Amendments**. This method follows a standard ASTM and has been accepted by Ecology.

### 4-5.3.1 Detailed Approach for Determining Infiltration Rates

This Detailed Approach was obtained from Massmann (2003) and should be used for infiltration pond, infiltration vault, and the underlying soils of a CAVFS design. Procedures for the Detailed Approach are as follows (see Figures 4-14 and 4-15 for a process flowchart):

1. **Select a location.**

   This will be based on the ability to convey flow to the location and the expected soil conditions. The minimum setback distances must also be met. (See Section 4-5.1 for Site Suitability Criteria and setback distances.)

2. **Estimate volume of stormwater, $V_{design}$.**

   For eastern Washington, a single-event hydrograph or value for the volume can be used, allowing a modeling approach such as StormShed to be conducted. For western Washington, a continuous hydrograph should generally be used, requiring a model such as MGSFlood to perform the calculations. (See Section 4-3 for western Washington and Section 4-4 for eastern Washington methodologies.)

3. **Develop a trial infiltration facility geometry based on length, width, and depth.**

   To accomplish this, either assume an infiltration rate based on previously available data or use a default infiltration rate of 0.5 inches/hour. This trial geometry should be used to help locate the facility and for planning purposes in developing the geotechnical subsurface investigation plan.

4. **Conduct a geotechnical investigation.**

   A geotechnical investigation must be conducted to evaluate the site's suitability for infiltration; to establish the infiltration rate for design; and to evaluate slope stability, foundation capacity, and other geotechnical design information needed to design and assess the constructibility of the facility. Geotechnical investigation requirements are provided below.

The depth, number of test holes or test pits, and sampling described below should be increased if a licensed engineer with geotechnical expertise (P.E.), or other licensed professional acceptable to WSDOT, judges that conditions are highly variable and make it necessary to increase the depth or the number of explorations to accurately estimate the infiltration system's performance. The exploration program described below may be decreased if a licensed engineer with geotechnical expertise (P.E.), or other licensed professional acceptable to WSDOT, judges that conditions are relatively uniform; design parameters are known to be conservative based on site-specific data or experience; and the borings/test pits omitted will not influence the design or successful operation of the facility.

- For infiltration ponds, at least one test pit or test hole per 5,000 $ft^2$ of basin infiltrating bottom surface area.
- For infiltration trenches, infiltration vaults, and CAVFS, at least one test pit or test hole per 100 to 300 feet of length.
- For drywells, samples should be collected from each layer beneath the facility to the depth of groundwater or to approximately 40 feet below the ground surface (approximately 30 feet below the base of the drywell). Subsurface explorations (test holes or test pits) to a depth below the base of the infiltration facility of at least 5 times the maximum design depth of water proposed for the infiltration facility, or at least 2 feet into the saturated zone.
- Continuous sampling to a depth below the base of the infiltration facility of 2.5 times the maximum design depth of water proposed for the infiltration facility, or at least 2 feet into the saturated zone, but not less than 6 feet. Samples obtained must be adequate for the purpose of soil gradation/classification testing.
- Groundwater monitoring wells installed to locate the groundwater table and establish its gradient, direction of flow, and seasonal variations, considering both confined and unconfined aquifers. (Monitoring through at least one wet season is required unless site historical data regarding groundwater levels are available.) In general, a minimum of three wells per infiltration facility, or three hydraulically connected surface or groundwater features, are needed to determine the direction of flow and gradient. If gradient and flow direction are not required and there is low risk of downgradient impacts, one monitoring well is sufficient. Alternative means of establishing the groundwater levels may be considered. If the groundwater in the area is known to be greater than 50 feet below the proposed facility, detailed investigation of the groundwater regime is not necessary.

- Laboratory testing as necessary to establish the soil gradation characteristics and other properties to complete the infiltration facility design. At a minimum, one grain-size analysis per soil stratum in each test hole must be conducted within 2.5 times the maximum design water depth, but not less than 6 feet. When assessing the saturated hydraulic conductivity characteristics of the site, soil layers at greater depths must be considered if the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the facility, requiring soil gradation/classification testing for layers deeper than indicated above.

5. **From the geotechnical investigation, determine the following, as applicable:**

   - The stratification of the soil/rock below the infiltration facility, including the soil gradation (and plasticity, if any) characteristics of each stratum.
   - The depth to the groundwater table and to any bedrock/impermeable layers.
   - Seasonal variation of the groundwater table.
   - The existing groundwater flow direction and gradient.
   - The saturated hydraulic conductivity or the infiltration rate for the soil/rock at the infiltration facility.
   - The porosity of the soil below the infiltration facility, but above the water table.
   - The lateral extent of the infiltration receptor.
   - The impact of the infiltration rate and volume on flow direction and water table at the project site and the potential discharge point or area of the infiltrating water.

   For other aspects of the geotechnical design of infiltration facilities, see Chapters 2 and 5.

6. **Determine the saturated hydraulic conductivity as noted in Section 4-5.2.**

7. **For unusually complex, critical design cases, develop input data for a simulation model.**

   Use **MODFLOW**, including trial geometry, continuous hydrograph data, soil stratigraphy, groundwater data, saturated hydraulic conductivity data, and reduction in saturated hydraulic conductivity due to siltation or biofouling on the surface of the facility. Use of this approach will generally be fairly rare. If necessary, the design office should contact consulting services for help in locating an appropriate resource to complete a MODFLOW analysis. Otherwise, skip this step and develop the data needed to estimate the hydraulic gradient, as shown in the following steps.

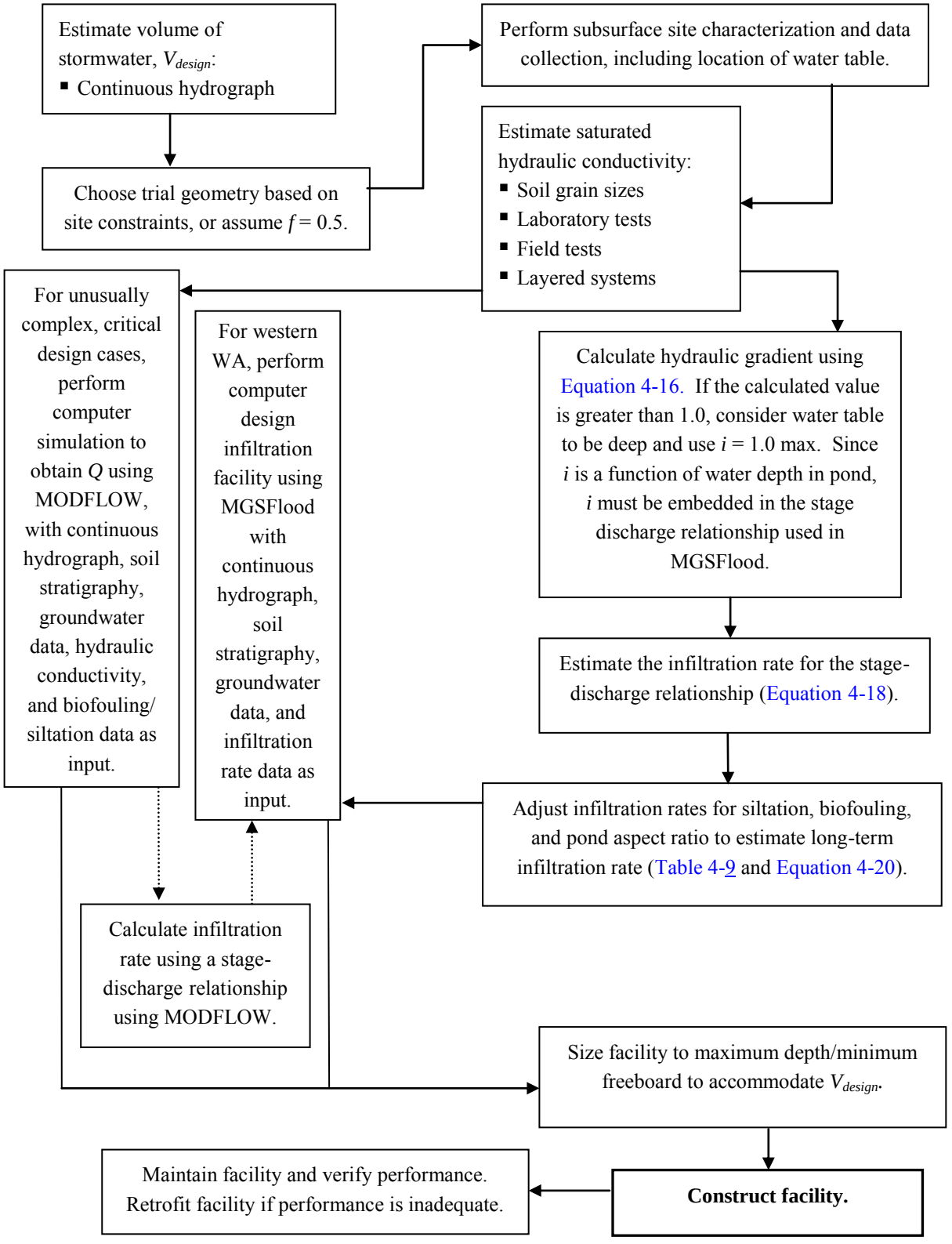



**Figure 4-12 Engineering design steps for final design of infiltration facilities using the continuous hydrograph method (western Washington).**

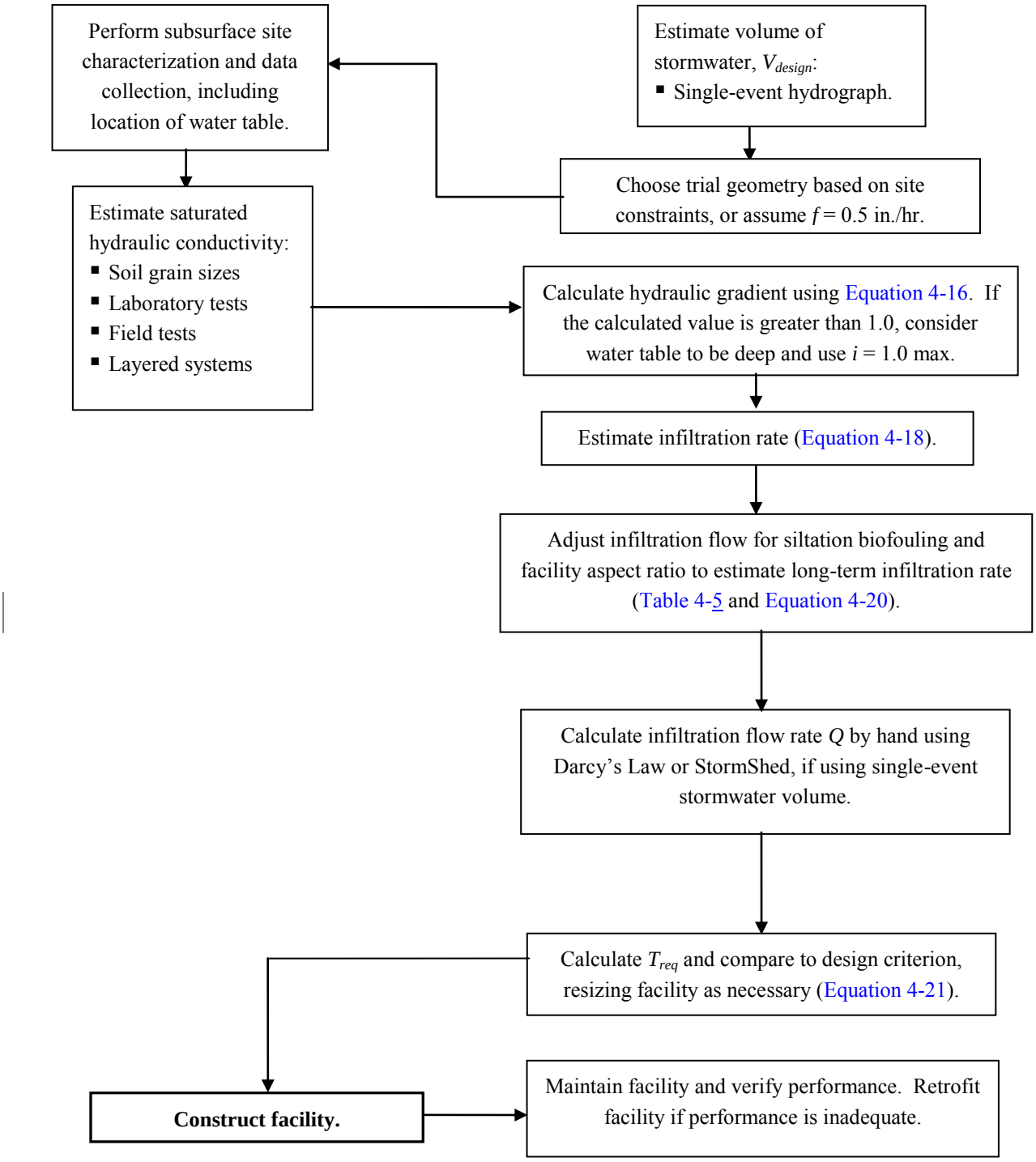



**Figure 4-13 Engineering design steps for final design of infiltration facilities using the single-event hydrograph method (eastern Washington).**

8. **Calculate the hydraulic gradient.**

The steady state hydraulic gradient is calculated as follows:

$$\text{gradient} = i \approx \frac{D_{wt} + D_{pond}}{138.62(K_{equiv}^{0.1})} CF_{size} \quad \textbf{(4-16)}$$

where: i = steady state hydraulic gradient
$D_{wt}$ = the depth from the base of the infiltration facility to the water table in feet
$K_{equiv}$ = the average saturated hydraulic conductivity in feet/day
$D_{pond}$ = the depth of water in the facility in feet (see Massmann et al., 2003, for the development of this equation)
$CF_{size}$ = the correction for pond size

The correction factor was developed for ponds with bottom areas between 0.6 and 6 acres in size. For small ponds (ponds with area equal to 2/3 acre), the correction factor is equal to 1.0. For large ponds (ponds with area equal to 6 acres), the correction factor is 0.2, as shown in Equation 4-17.

$$CF_{size} = 0.73(A_{pond})^{-0.76} \quad \textbf{(4-17)}$$

where: $A_{pond}$ = the area of pond bottom in acres

This equation will generally result in a calculated gradient of less than 1.0 for moderate-to-shallow groundwater depths (or to a low permeability layer) below the facility and conservatively accounts for the development of a groundwater mound. A more detailed groundwater mounding analysis, using a program such as MODFLOW, will usually result in a gradient that is equal to or greater than the gradient calculated using Equation 4-16. If the calculated gradient is greater than 1.0, the water table is considered to be deep and a maximum gradient of 1.0 must be used.

Typically, a depth to groundwater of 100 feet or more is required to obtain a gradient of 1.0 or more using this equation. Since the gradient is a function of depth of water in the facility, the gradient will vary as the pond fills during the season. Therefore, the gradient must be calculated as part of the stage-discharge calculation used in MGSFlood for the continuous hydrograph method. For designs using the single-event hydrograph, it is sufficiently accurate to calculate the hydraulic gradient based on one-half the maximum depth of water in the pond.

For the underlying soils of a CAVFS, use Equation 4-16 (pond gradient equation) to determine the hydraulic gradient if the CAVFS length is less than 30 times the width. A correction factor is not needed for CAVFS design. The designer can assume $CF_{size}$ = 1.0 for CAVFS design. If the CAVFS length is greater than or equal to 30 times the width, use Equation 4-22 (trench gradient equation) to determine the hydraulic gradient for the underlying soils of a CAVFS. No correction factors for biofouling or siltation are needed for underlying soils of CAVFS since those soils are under the CAVFS layer.

9. **Calculate the infiltration rate using Darcy's Law as follows:**

$$f = 0.5K_{equiv}\left(\frac{dh}{dz}\right) = 0.5K_{equiv}(i) \quad \textbf{(4-18)}$$

where: $f$ = the infiltration rate of water through a unit cross section of the infiltration facility (in/hr)
$K_{equiv}$ = the average saturated hydraulic conductivity (ft/day)
$dh/dz$ = the steady state hydraulic gradient
$i$ = the steady state hydraulic gradient
0.5 = converts ft/day to in/hr

10. **Adjust the infiltration rate or infiltration stage-discharge relationship obtained in Steps 8 and 9.**

This is done to account for reductions in the rate resulting from long-term siltation and biofouling, taking into consideration the degree of long-term maintenance and performance monitoring anticipated; the degree of influent control (such as presettling ponds or biofiltration swales); and the potential for (among others) siltation, litterfall, or moss buildup based on the surrounding environment. It should be assumed that an average-to-high degree of maintenance will be performed on these facilities. A low degree of maintenance should be considered only when there is no other option (such as with access problems). The infiltration rates estimated in Steps 8 and 9 are multiplied by the reduction factors summarized in Table 4-5.

**Table 4-5 Infiltration rate reduction factors to account for biofouling and siltation effects for ponds (Massmann, 2003).**

| Potential for Biofouling | Degree of Long-Term Maintenance/Performance Monitoring | Infiltration Rate Reduction Factor, $CF_{silt/bio}$ |
|---|---|---|
| Low | Average to High | 0.9 |
| Low | Low | 0.6 |
| High | Average to High | 0.5 |
| High | Low | 0.2 |

The values in this table assume that final excavation of the facility to the finished grade is deferred until all disturbed areas in the upgradient drainage area have been stabilized or protected (for example, construction runoff is not allowed into the facility after final excavation of the facility) as required in Section 5-4.2.1.

An example of a situation with a high potential for biofouling would be a pond located in a shady area where moss and litterfall from adjacent vegetation can build up on the pond bottom and sides, the upgradient drainage area will remain in a long-term disturbed condition, and no pretreatment (such as presettling ponds or biofiltration swales) is provided. Situations with a low degree of long-term maintenance include locations where access to the facility for maintenance is very difficult or limited or where there is minimal control of the party responsible for enforcing the required maintenance. A low degree of maintenance should be considered only when there is no other option.

Adjust this infiltration rate for the effect of pond aspect ratio by multiplying the infiltration rate determined in Step 9 (Equation 4-18) by the aspect ratio correction factor $CF_{aspect}$, as shown in the following equation. In no case shall $CF_{aspect}$ be greater than 1.4.

$$CF_{aspect} = 0.02A_r + 0.98 \quad \textbf{(4-19)}$$

where: $CF_{aspect}$ = the aspect ratio correction factor
$A_r$ = the aspect ratio for the pond (length/width)

The final infiltration rate will therefore be as follows:

$$f = (0.5K_{equiv})(i)(CF_{aspect})(CF_{silt/bio}) \quad \textbf{(4-20)}$$

The infiltration rates calculated based on Equations 4-18 and 4-20 are long-term design rates. No additional reduction factor or factor of safety is needed.

11. **Determine the infiltration flow rate *Q*.**

    If the infiltration facility is located in eastern Washington, determine the infiltration flow rate *Q* using the Infiltration Pond Design Spreadsheet at: www.wsdot.wa.gov/design/hydraulics/training.htm. If located in western Washington, determine the infiltration flow rate *Q* using MGSFlood.

12. **Size the facility.**

    Size the facility to ensure the pond depths are between 2 and 6 feet, with 1-foot-minimum required freeboard. Use one of the following two approaches, depending on the type of hydrograph used:

    - If using a continuous hydrograph for runoff treatment design, refer to Appendix 4A for a "Time-to-Drain" spreadsheet web link.

- If using a single-event hydrograph, calculate $T_{req}$ using StormShed to determine the time it takes the pond to empty or from the value of $Q$ determined from Step 11 and $V_{design}$ from Step 2, as follows:

$$T_{req} = \frac{V_{design}}{Q} \quad \textbf{(4-21)}$$

where: $T_{req}$ = the time required to infiltrate the design stormwater volume
$V_{design}$ = volume of stormwater in cubic feet
$Q$ = infiltration flow rate in cfs

This value of $T_{req}$ must be less than or equal to the maximum allowed infiltration time specified in the Site Suitability Criteria in Section 4-5.1.

13. **Construct the facility.**

Maintain and monitor the facility for performance in accordance with the *Maintenance Manual*.

### 4-5.3.2 Simplified Approach to Determining Infiltration Rates

The Simplified Approach was derived from high groundwater and shallow pond sites in western Washington and, in general, will produce conservative designs. Applying this method to eastern Washington will produce even more conservative designs. The Simplified Approach can be used when determining the trial geometry of the infiltration facility for small or low-impact facilities or for facilities where a more conservative design is acceptable. The simplified method must not be used for determining short-term soil infiltration rates for runoff treatment infiltration facilities in western Washington, as referenced in SSC 5. The Simplified Approach is applicable to ponds, vaults, and trenches and includes the following steps (see Figure 4-14 for a flowchart of this process):

1. **Select a location.**

   This will be based on the ability to convey flow to the location and the expected soil conditions of the location. The minimum setback distances must also be met.

2. **Estimate volume of stormwater, Vdesign.**

   For eastern Washington, a single-event hydrograph for the volume can be used, allowing for a simplified modeling approach such as StormShed. For western Washington, a continuous hydrograph should be used, requiring MGSFlood for the calculations.

3. **Develop trial infiltration facility geometry.**

   To accomplish this, assume an infiltration rate based on previously available data, or a default infiltration rate of 0.5 inches/hour can be used. This trial facility geometry should be used to help locate the facility and for planning purposes in developing the geotechnical subsurface investigation plan.

4. **Conduct a geotechnical investigation.**

   The geotechnical investigation evaluates the suitability of the site for infiltration; establishes the infiltration rate for design; and evaluates slope stability, foundation capacity, and other geotechnical design information needed to design and assess constructibility of the facility. The geotechnical investigation is described in Section 4-5.3.1, Steps 4 and 5 (Figures 4-14 and 4-15).

5. **Determine the infiltration rate.**

   Ecology's SMMWW provides a correlation between the $D_{10}$ size of the soils **below the infiltration facility and the infiltration rate, as shown in Table 4-6,** which can be used to estimate the infiltration rate.

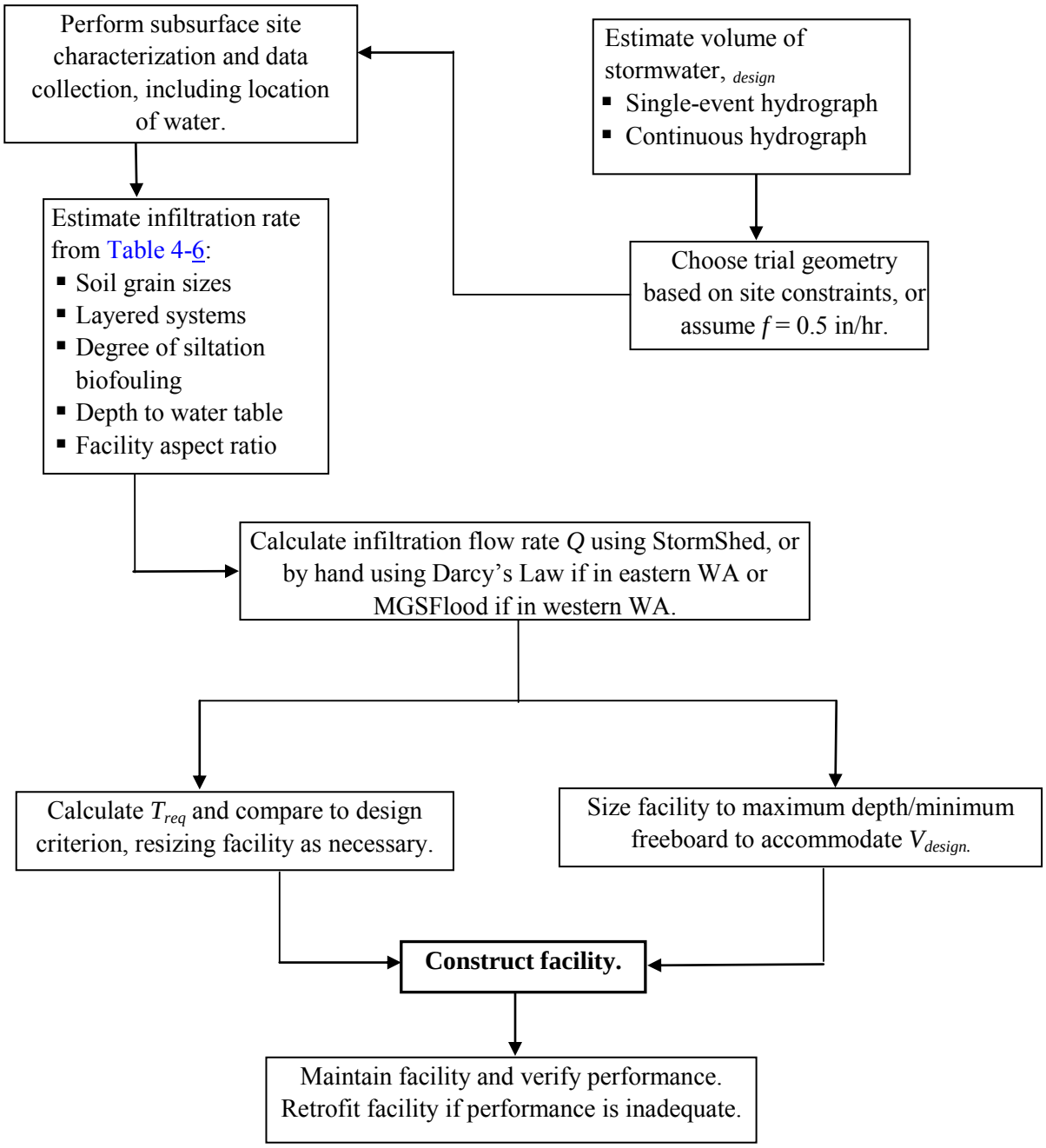
   The data that form the basis for Table 4-6 were from soils that would be classified as sands or sandy gravels. No data were available for finer soils at the time the table was developed. However, additional data based on recent research (Massmann et al., 2003) for these finer soils are now available and are shown in Figure 4-15.

   Figure 4-15 provides a plot of this relationship between the infiltration rate and the $D_{10}$ of the soil, showing the empirical data upon which it is based. The figure provides an upper and lower bound range for this relationship, based on the empirical data. These upper and lower bound ranges can be used to adjust the design infiltration rate to account for site-specific issues and conditions.

   The long-term rates provided in Table 4-6 represent average conditions regarding site variability, the degree of long-term maintenance, and pretreatment for TSS control. They also represent a moderate depth to groundwater below the pond.

**Table 4-6 Recommended infiltration rates based on ASTM Gradation Testing.**

| $D_{10}$ Size from ASTM D422 Soil Gradation Test (mm) | Estimated Long-Term (Design) Infiltration Rate (inch/hour) |
|---|---|
| ≥ 0.4 | 9 |
| 0.3 | 6.5 |
| 0.2 | 3.5 |
| **0.1** | **2.0** |
| 0.05 | 0.8 |




(Note: Use for trial geometry, small or low-impact facilities, or for facilities where a more conservative design is acceptable.)

**Figure 4-14 Engineering design steps for design of infiltration facilities: Simplified infiltration rate procedure.**

The long-term infiltration rates in Table 4-6 may need to be decreased (toward the lower bound in Figure 4-15) if the site is highly variable; the groundwater table is shallow; there is fine layering present that would not be captured by the soil gradation testing; or maintenance and influent characteristics are not well controlled. However, if influent control is good (for example, water entering the pond is pretreated through a biofiltration swale or presettling basin); if a good, long-term maintenance plan will be implemented; and if the water table is moderate in depth, then an infiltration rate toward the upper bound in the figure could be used.

The infiltration rates provided in Figure 4-15 represent rates for homogeneous soil conditions. If more than one soil unit is located within 2.5 times the maximum design depth of water proposed for the infiltration facility, or at least 2 feet into the saturated zone but no less than 6 feet below the base of the infiltration facility, use the lowest infiltration rate determined from each of the soil units as the representative site infiltration rate.

The rates shown in Table 4-6 and Figure 4-15 are long-term design rates. No additional reduction factor or factor of safety is needed.

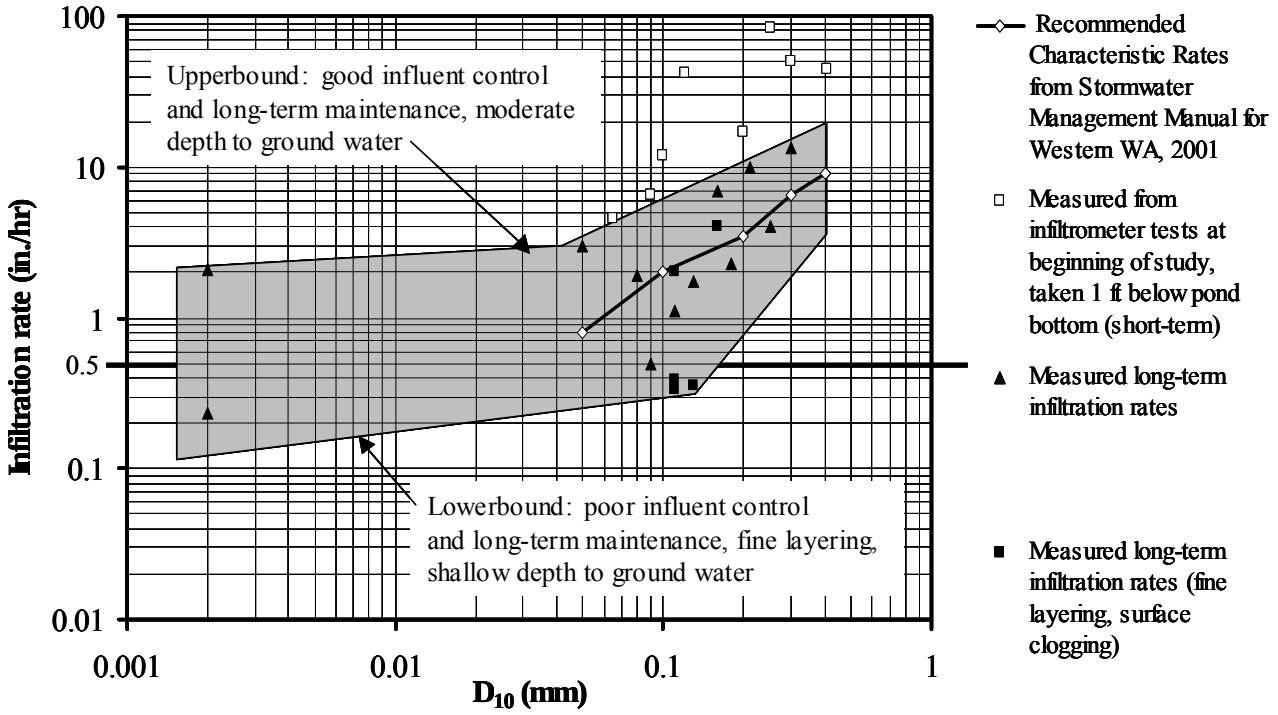
Note that Table 4-6 provides an infiltration rate, not a saturated hydraulic conductivity that must be multiplied by a hydraulic gradient or other factors, as provided in Equation 4-20. The infiltration rates provided in this table assume a fully developed groundwater mound and very low hydraulic gradients. Hence, if the water table is relatively deep, the infiltration rate calculated from Equation 4-20 will likely be more accurate, but less conservative, than the infiltration rates provided in Table 4-6. For shallow water table situations, Equation 4-20 will produce infiltration rates similar to those provided in Table 4-6 and shown in Figure 4-15.

The minimum infiltration rate at which infiltration would be considered the primary function of the facility is 0.5 inches/hour. Infiltration can still be taken into account if the infiltration rate is lower, but it should be considered a secondary design parameter for the facility.

6. **Determine the infiltration flow rate Q.**

   If the infiltration facility is located in eastern Washington, determine the infiltration flow rate *Q* using the Infiltration Pond Design Spreadsheet at:
   www.wsdot.wa.gov/design/hydraulics/training.htm

   If the infiltration facility is located in western Washington, determine the infiltration flow rate *Q* using MGSFlood.




(Note: The mean values represent low-gradient conditions and relatively shallow ponds.)

**Figure 4-15 Infiltration rate as a function of the $D_{10}$ size of the soil for ponds in western Washington.**

7. **Size the facility.**

   Size the facility to ensure the pond depths are between 2 and 6 feet, with 1-foot-minimum required freeboard. Use one of the following two approaches, depending on the type of hydrograph used:

   - If using a continuous hydrograph for runoff treatment design, refer to Appendix 4A for a "Time-to-Drain" spreadsheet web link.
   - If using a single-event hydrograph, calculate $T_{req}$ using Equation 4-21 from the Detailed Approach in Section 4-5.3.1, using the value of $Q$ determined from Step 11 and $V_{design}$ from Step 2 of that approach. The value of $T_{req}$ calculated must be less than or equal to the maximum allowed infiltration time specified in the Site Suitability Criteria in Section 4-5.1.

8. **Construct the facility.**

   Maintain and monitor the facility for performance in accordance with the *Maintenance Manual*.

### 4-5.3.3 Determining Infiltration Rates for Soil Amendment BMPs

It is necessary to establish the long-term infiltration rate of an amended soil or engineered soil mix when used as a BMP design component to achieve treatment or flow control requirements. These guidelines are applicable to CAVFS and engineered dispersion. The assumed design infiltration rate should be the lower of the following two rates: (1) the estimated long-term rate of the engineered soil mix (see Figure 4-16), or (2) the initial (short-term or measured) infiltration rate of the underlying soil profile. The underlying native soil can be tested using either the Detailed Approach in Section 4-5.3.1 or the Simplified Approach in Section 4-5.3.2.

Use the long-term infiltration rate of the engineered soil mix as the assumed infiltration rate of the overlying soil mix if it is lower than the underlying native soil. If the underlying native soil is lower than the engineered soil mix, use either the underlying native soil infiltration rate or a varied infiltration rate that includes both the engineered soil mix infiltration rate and the native soil infiltration according to Section 4-5.3.1, Step 6. Also, refer to Table 4-3 for flow control modeling guidelines to determine flow reduction benefits using MGSFlood.

#### Soil Specification

Proper soil specification, preparation, and installation are the most critical factors for LID BMP performance. Soil specifications can vary according to the design objectives and the in situ soil. For more information, see Section 5-4.3.2.

#### 4-5.3.3.1 Design Procedure for Compost-Amended Vegetated Filter Strips (CAVFS) for Western Washington

The design for CAVFS is an iterative process in MGSFlood to adequately address the infiltrative capacity of both the compost amended layer and the underlying soils to achieve the 91% volume treatment criteria.

Flow through CAVFS is simulated using Darcy's Equation (as shown in Figure 4-17), where $K_c$ is the saturated hydraulic conductivity. Note that the width dimension corresponds to the CAVFS width along the slope. Infiltration is accounted for using a constant infiltration rate into the underlying soils. During large storms, the voids in the CAVFS may become full (the CAVFS is saturated) in which case runoff is simulated as overflow down the surface of the CAVFS. The runoff volume filtered by the CAVFS, the volume infiltrated, and the volume flowing over the CAVFS surface are listed in the project report.

Precipitation and evapotranspiration may (optionally) be applied to the CAVFS. If precipitation and evapotranspiration are applied in the CAVFS link, do not include the area of the CAVFS in the Subbasin Area input.

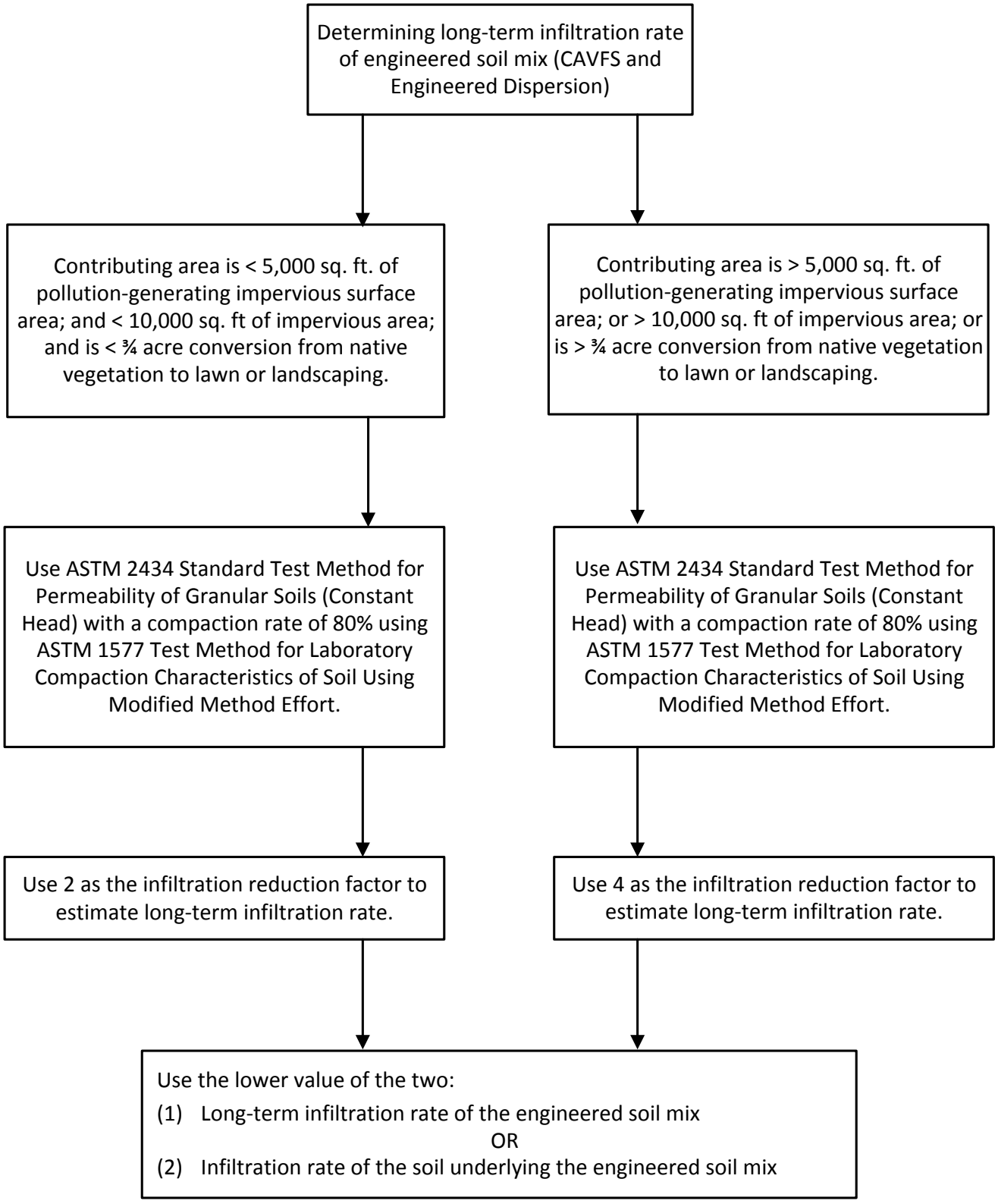



**Figure 4-16. Determining infiltration rate of soil amendments.**

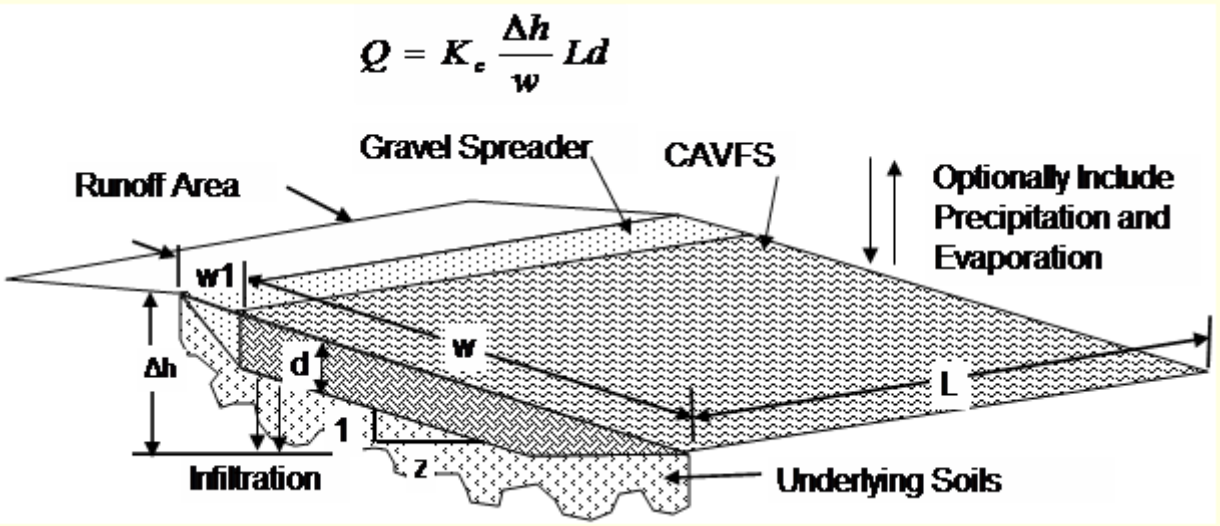



**Figure 4-17 CAVFS Detail.**

1. **Follow Steps 1 through 11 in the Detailed Approach for Determining Infiltration Rates for the underlying soils of a CAVFS (see Section 4-5.3.1).**

2. **Follow Section 4-5.3.3 for CAVFS hydraulic conductivity.**

   - Note: The ASTM method described in Section 4-5.3.3 provides an infiltration rate. Assuming a hydraulic gradient of one, the infiltration rate is the same as the hydraulic conductivity.

3. **Modeling steps for CAVFS.**

   Using MGSFlood, the dimensions of the CAVFS will be set as follows under the Network Tab:

   - Select the Link type: CAVFS

     ***CAVFS Depth d(ft):*** This is a constant depth of 1 foot for all CAVFS designs unless other recommendations have been given based on the organic content percentage by the HQ Roadside and Site Development Section.

     ***CAVFS Porosity (% by Volume):*** The default value is 20%, but must be verified or reestablished by the WSDOT Materials Lab or a licensed geotechnical engineer for the particular site and particular installation.

     ***CAVFS Hydraulic Conductivity (ft/day):*** The default value is 2 ft/day and must be verified or reestablished by the WSDOT Materials Lab or a licensed geotechnical engineer for the particular site and particular installation.

     ***CAVFS Length (ft):*** The length parallel to the roadway.

     ***CAVFS Width (ft):*** The width perpendicular to the roadway. This is usually the parameter being solved for.

     ***Underlying Soil Infiltration Rate:*** Refer to Step 1.

     ***CAVFS Slope Z:*** The horizontal slope of the roadway embankment—it cannot be steeper than 3:1.

***Gravel Spreader Width (ft):*** The width perpendicular to the roadway.
***Gravel Porosity (% by Volume):*** Typical value for gravel porosity is 30.
***Gravel Hydraulic Conductivity (ft/day):*** The default value is 4 ft/day and must be verified or reestablished by the WSDOT Materials Lab or a licensed geotechnical engineer for the particular site and particular installation.

4. **Determine that the volume of runoff infiltrated and filtered is 91% or greater than the total runoff volume.**

   MGSFlood will output Postdeveloped CAVFS Treatment Statistics in the MGSFlood Project Report file. The report file will give the percent treated for the structure defined in Step 3. The designer should verify that this number is equal to or greater than 91%.

5. **Flow Control Compliance.**

   After a successful runoff treatment design (Steps 1–4 above), the designer may be able to widen the CAVFS to try to meet the flow duration standard if the particular TDA is required to provide flow control. Otherwise, a flow control structure should be linked downstream of the CAVFS to attenuate the resultant runoff and meet the flow duration standard. Contact the Region Hydraulics Office for questions regarding flow control modeling. For an example problem, refer to Appendix 4A.

## 4-5.4 Underground Injection Facilities

Infiltration is one of the preferred methods for disposing of excess stormwater in order to preserve natural drainage systems in Washington. Subsurface infiltration is regulated by the Underground Injection Control (UIC) Rule, which is intended to protect underground sources of drinking water (www.ecy.wa.gov/programs/wq/grndwtr/uic/index.html). By definition, a UIC facility includes a constructed subsurface fluid distribution system or a dug hole that is deeper than the largest surface dimension. For the purposes of this section, infiltration systems include drywells (BMP IN.05) and infiltration trenches with perforated underdrain pipes (BMP IN.03) designed to discharge stormwater directly into the ground. The following are not regulated as stormwater underground injection facilities:

- Infiltration trenches that do not include perforated underdrain pipes
- Infiltration vaults (BMP IN.04)
- Buried pipe and/or tile networks that serve to collect water and discharge that water to a conveyance system or a surface water
- Any facilities that are designed to receive fluids other than stormwater

For additional guidance and design criteria for protection of groundwater see "Guidance for UIC Wells that Manage Stormwater Activities" published by Ecology:
www.ecy.wa.gov/programs/wq/grndwtr/uic/index.html

Vadose zones, the area between the bottom of a facility and the top of the groundwater table, vary widely in their ability to remove stormwater pollutants based on their thickness and soil

texture. This section provides instructions on how to identify the conditions under which the vadose zone may be presumed to provide sufficient treatment for a given pollutant loading surface. This section also identifies the types of pretreatment that are required to meet Minimum Requirement 5 when the vadose zone alone cannot be presumed to adequately treat runoff. Following the requirements of this section will ensure a facility meets the nonendangerment standards in the UIC Rule and Minimum Requirement 5, Runoff Treatment, in Section 3-3.5, under the *presumptive approach*. The demonstrative approach in Section 1-1.3 may be used if WSDOT can document that alternative methods will protect water quality. Data requirements for using the *demonstrative approach* in association with underground injection facilities are also described in Ecology's "Guidance for UIC Wells that Manage Stormwater Activities" (see website above).

All new underground injection facilities must meet the requirements of this section under the presumptive approach. If an existing facility is within the limits of an improvement project, it shall be brought into compliance with the requirements or replaced with a different BMP type unless an Engineering and Economic Feasibility (see Section 2-7.4) assessment shows it is not feasible. No additional flows shall be allowed to enter existing underground injection facilities that do not meet the requirements of this section.

### Registering Underground Injection (UIC) Facilities

The UIC Rule requires WSDOT to assess and register all underground injection facilities. Region Hydraulics offices are primarily responsible for the registration and assessment of existing facilities. Contact the appropriate office whenever existing facilities are encountered in the field to determine whether they have already been registered and assessed. If any UIC facilities (such as drywells and infiltration trenches with perforated underdrain pipes) within the limits of a project have not been registered, the Project Engineer's Office, in coordination with the Region Hydraulics Office, shall complete the registration and assessment forms.

Coordinate with the Region Hydraulics Office for technical support when collecting data to register proposed underground injection control facilities and to establish pretreatment requirements. Information that must be collected includes physical location, pollutant-generating properties of the drainage area, and the depth and texture of vadose zone soils.

Physical location information, including latitude, longitude, and state route, must be collected in accordance with the Roadside Features Inventory Program's *Field Procedures Manual* (http://wwwi.wsdot.wa.gov/gis/roadwaydata/pdf/rfip_field_procedures_manual.pdf). This manual contains specific instructions regarding drywells and vaults, but not infiltration trenches; however, infiltration trenches must be inventoried in the same manner described for drywells using the manhole lid or other identifiable surface feature as the point from which to identify its location. Observe the surrounding landscape characteristics like topography and presence of nearby water bodies when performing field work. Such observations can help confirm the accuracy of geotechnical data about the depth of the vadose zone.

Download the Underground Injection Control Registration Spreadsheet at the HQ Environmental Services Office (ESO), Stormwater & Watersheds Program's website: www.wsdot.wa.gov/environment/waterquality/#facilities. Provide information for each well as shown on the *Example* row of the Excel file. The Region Hydraulics Office

is the primary resource if assistance is needed to complete the spreadsheet. E-mail the completed table to the Region Hydraulics Office and the HQ ESO Stormwater & Watersheds Program. Submitted spreadsheet information will be forwarded to Ecology; project offices do not need to directly register the UIC facilities. The UIC registration information should also be included in the design justification section of the Hydraulic Report. Contact the Water Quality Team Leader (360-570-6648) at the HQ ESO Stormwater & Watersheds Program for questions about UIC registration.

### Establishing Treatment Capacity Class

Vadose zone properties must be characterized to establish the treatment capacity class of the vadose zone using Table 4-7. Existing WSDOT data may provide sufficient information about the depth to groundwater and the vadose zone soil texture. UIC wells shall not directly discharge into groundwater. The minimum vertical separation is 5 feet between the bottom of the UIC well and the seasonal high water table. If the minimum separation cannot be met the demonstrative approach may be used for rule authorization. (See the "Guidance for UIC Wells That Manage Stormwater" document from Ecology for additional information on minimum separation and the demonstrative approach.) Contact the Regional Materials Engineer (RME) for assistance locating and evaluating WSDOT's geotechnical data in the vicinity of the proposed facility. If WSDOT does not have data regarding depth to groundwater and vadose zone soil texture, the following sources should be considered:

- Washington State Department of Ecology drinking well log database containing water table levels: apps.ecy.wa.gov/welllog/index.asp
- Washington State Department of Health Source Water Assessment Program: http://www.doh.wa.gov/ehp/dw/sw/assessment.htm
- USGS groundwater reports: wa.water.usgs.gov/pubs/
- Local health departments
- Local municipalities

The RME may consider the available data to be adequate for establishing vadose zone treatment capacity class. If not, vadose zone soils will have to be tested. (See Step 4 in Section 4-5.3.1 for geotechnical testing requirements.)

Use Table 4-7 to determine the level of treatment that will be provided by the underground injection facility given the thickness and texture of vadose zone materials.

**Table 4-7 Treatment capacity class based on vadose zone properties.**

| Treatment Capacity Class and Minimum Thickness* | Description of Vadose Zone Layer |
|---|---|
| HIGH<br>Minimum thickness of 5 feet | ▪ Average grain size <0.125mm<br>▪ Sand to silt/clay ratio of 1:1 and sand plus gravel < than 50%<br>▪ Lean, fat, or elastic clay<br>▪ Sandy or silty clay<br>▪ Silt<br>▪ Clayey or sandy silt<br>▪ Sandy loam or loamy sand<br>▪ Silt/clay with interbedded sand<br>▪ Well-compacted, poorly sorted materials<br>▪ Includes till, hardpan, caliche, and loess |
| MEDIUM<br>Minimum thickness of 10 feet | ▪ Average grain size 0.125mm to 4mm<br>▪ Sand to silt/clay ratio from 1:1 to 9:1 and percent sand > percent gravel<br>▪ Fine, medium, or coarse sand<br>▪ Sand with interbedded clay and/or silt<br>▪ Poorly compacted, poorly sorted materials<br>▪ Includes some alluvium and outwash deposits |
| LOW<br>Minimum thickness of 25 feet | ▪ Average grain size 4mm to 64mm<br>▪ Sand to silt/clay ratio > 9:1 and percent sand < percent gravel<br>▪ Sandy gravel, gravelly sand, or sand and gravel<br>▪ Poorly-sorted, silty, or muddy gravel<br>▪ Includes some alluvium and outwash deposits |
| NONE<br>Minimum thickness not applicable | ▪ Average grain size > 64mm<br>▪ Total fines (sand and mud) < 5%<br>▪ Well-sorted or clean gravel<br>▪ Boulders and/or cobbles<br>▪ Fractured rock<br>▪ Includes fractured basalt, other fractured bedrock, and cavernous limestone |

* Assume NONE for treatment class if minimum thickness is not met.

## *Determine Pollutant Loading Class*

Runoff is categorized into pollutant loading classes based on ADT. Criteria for establishing pollutant loading classes are included in Table 4-8. ADT data are available in WSDOT's Annual Traffic Reports: www.wsdot.wa.gov/mapsdata/travel/annualtrafficreport.htm. The GIS Workbench also contains a data layer showing where the different ADT thresholds are met. The Statewide Travel & Collision Data Office (STCDO) must be contacted for intersection ADT data (www.wsdot.wa.gov/mapsdata/stcdo_home.htm). Parking area use levels and their relationship to building size are not tracked by WSDOT. Contact maintenance staff for an estimate of parking area use levels at maintenance and park-and-ride facilities.

**Table 4-8 Stormwater pollutant loading classifications for UIC facilities receiving stormwater runoff.**

| Pollutant Loading Classification | Proposed Land Use or Site Characteristics* |
|---|---|
| INSIGNIFICANT | ▪ Impervious surfaces not subject to motorized vehicle traffic, deicing sand, or deicing compounds<br>▪ Unmaintained open space |
| LOW | ▪ Parking areas with < 40 trip ends* per 1,000 s.f. of gross building area or < 100 trip ends<br>▪ **Highways Inside Urban Growth Management Areas (UGMA)**<br>□ Fully or partially controlled limited access highways with < 15,000 ADT*<br>□ Other highways with < 7,500 ADT<br>▪ **Highways Outside UGMA**<br>† All highways with < 15,000 ADT |
| MEDIUM | ▪ Parking areas with 40–100 trip ends per 1,000 s.f. of gross building area or 100–300 total trip ends<br>▪ Intersections controlled by traffic signals where the main highway is not > 25,000 ADT and there is not > 15,000 ADT on the intersecting highway<br>▪ Transit center bus stops<br>▪ **Highways Inside UGMA**<br>† Fully or partially controlled limited access highways between 15,000 and 30,000 ADT<br>† Other highways with 7,500–30,000 ADT<br>▪ **Highways Outside of UGMA**<br>† All highways between 15,000 and 30,000 ADT |
| HIGH | ▪ Eastern Washington highways with > 30,000 ADT<br>▪ Intersections controlled by traffic signals where the main highway has > 25,000 ADTand the intersecting highway has > 15,000 ADT<br>▪ Parking areas with > 100 trip ends per 1,000 s.f. of gross building area or > 300 total trip ends<br>▪ Highway rest areas |

* Average daily traffic (ADT) count and trip ends must be calculated for an assumed 20-year project design life. Contact the Statewide Travel & Collision Data Office, Traffic Data and Analysis Branch, for assistance:
www.wsdot.wa.gov/mapsdata/stcdo_home.htm

## Determine Treatment Requirements

Use Table 4-9 to determine the required level of treatment based on the treatment capacity and pollutant loading classes associated with each facility. All new facilities must provide the appropriate level of treatment as defined in Table 4-9.

**Table 4-9 Matrix for determining pretreatment requirements.**

| Treatment Capacity / Pollutant Loading | HIGH | MEDIUM | LOW | NONE |
|---|---|---|---|---|
| **INSIGNIFICANT** | None | None | None | None |
| **LOW** | None | None | None | Basic treatment[2] |
| **MEDIUM** | Two-stage drywell[1] | Two-stage drywell[1] | Basic treatment | Basic treatment |
| **HIGH** | Oil control[3] | Oil control[3] | Basic treatment and oil control[3] | Basic treatment and oil control[3] |

[1] A two-stage drywell includes a catch basin or spill control structure that traps small quantities of oils and solids; the spill control device may be a turned-down pipe elbow or other passive device. This pretreatment requirement applies to all UIC facilities, not just drywells. Catch basins or other presettling spill control devices must be inspected and cleaned regularly.

[2] For low-pollutant loading sites, implementation of appropriate source control BMPs may be employed in lieu of structural treatment BMPs.

[3] At high-density intersections and at commercial or industrial sites subject to an expected average daily traffic count (ADT) of 100 vehicles/1000 ft² gross building area, sufficient quantities of oil will be generated to justify operation of a separator BMP.

At other high-use sites, designers may select a basic runoff treatment BMP that also provides adsorptive capacity, such as a biofiltration swale, bioinfiltration pond, a filter strip, or a compost-amended vegetated filter strip (CAVFS), or other adsorptive technology, in lieu of a separator BMP.

The requirement to remove oil for all highways with ADT > 30,000 applies only in eastern Washington. For those highways in eastern Washington, an oil control facility is not required; instead a basic treatment facility with adsorptive characteristics (listed above) is required.

This requirement to apply a basic treatment facility with adsorptive characteristics also applies to commercial parking and to highways with ADT > 7500; alternatively a simple passive oil control device such as a turned-down elbow may be used.

To preserve infiltration rates and provide some solid removal and spill protection, all UIC facilities should be preceded by a catch basin with a turned-down elbow or tee and/or a pre-settling basin. Presettling basins should be as large as site constraints allow. They do not have to meet the requirements of BMP RT.24, but should provide 4–6 inches of storage prior to overflow into the UIC facility.

Existing underground injection facilities that meet the treatment requirements in Table 4-9 are presumed to provide adequate groundwater protection. Existing wells that do not meet the treatment requirements in Table 4-9 are considered deficient. The treatment requirements in Table 4-9 identify the retrofit requirements for deficient facilities.

### *Application and Limitations*

For UIC facilities, an evaluation of the infiltration capacity is necessary to determine whether the facility will be able to accommodate the necessary volume of water. Infiltration rates lessen over time due to clogging, so the long-term infiltration rate under the worst-case scenario should be accommodated by the design. The amount of time it takes for water to drain out of a UIC facility depends on how fast the soil allows water to infiltrate and how much water the UIC facility holds. For eastern Washington, facilities are designed to completely drain ponded runoff from the flow control design storm within 48 to 72 hours after flow to the UIC facility has stopped.

### Siting Criteria and Treatment Requirements

Prior to evaluating runoff treatment considerations, the designer should be certain that the site meets the criteria for infiltration found in Chapters 4 and 5 and the requirements of this section.

- **Subsurface Geologic Data**

  Geologic information may be available from regional subsurface geology maps in publications from the Department of Natural Resources (DNR) or the U.S. Geological Survey; from a well borehole log(s) in the same quarter section on Ecology's web site; or from local governments. Surface soils maps generally do *not* provide adequate information, although the parent material information provided may be helpful in some locations. Well borehole log locations should be verified because electronic databases contain many errors of this type.

  When using borehole logs, a "nearby" site is generally within ¼ mile. Subsurface geology can vary considerably in a very short horizontal distance in many areas of the state, so professional judgment should be used to determine whether the available data are adequate or site exploration is necessary.

  Where reliable regional information or nearby borehole logs are not readily available, it will be necessary to obtain data through site exploration. Alternatively, for small projects where site exploration is not cost-effective, a design professional might apply a conservative design approach, subject to the approval of region or HQ hydraulics staff and/or the WSDOT Materials Lab.

For treatment capacity and pollutant loading definitions, see Tables 4-9 and 4-10. All project proponents should read Section 4-5.1 for exceptions or other requirements that apply in certain situations. Appropriate pretreatment and presettling requirements must be determined using the information provided in Chapter 5, BMP Selection Process.

## 4-5.4.1 Design Procedure for Infiltration Trenches

The Detailed Approach for infiltration trenches was obtained from Massmann (2003) and is applicable for trenches with flat or shallow slopes—not to be used for slopes greater than 0.5%. Procedures for the Detailed Approach for both sheet flow and end of pipe applications are as follows:

1. **Follow Steps 1 through 7 in the Detailed Approach (see Section 4-5.3.1).**
2. **Calculate the hydraulic gradient.**

   If using a single-event hydrograph or continuous hydrograph, calculate the hydraulic gradient for trenches as follows:

$$gradient = i_t \approx \frac{D_{wt} + D_{trench}}{78(K_{equiv}{}^{0.05})} \qquad \textbf{(4-22)}$$

where: $i_t$ = steady state hydraulic gradient in the trench
$D_{wt}$ = the depth from the base of the infiltration facility to the water table, in feet
$K_{equiv}$ = the average saturated hydraulic conductivity, in feet/day
$D_{trench}$ = the depth of water in the trench, in feet

As is true of Equation 4-16, Equation 4-22 is applicable to conditions where a full groundwater mound develops.

If the calculated gradient is greater than 1.0, the water table is considered to be deep and a maximum gradient of 1.0 must be used. It is sufficiently accurate to calculate the hydraulic gradient assuming that $D_{trench}$ is equal to one-half the trench depth.

3. **Follow Step 9 in the Detailed Approach (see Section 4-5.3.1).**

4. **Adjust the infiltration rate or infiltration stage-discharge relationship obtained in Step 9.**

This accounts for reductions in the rate resulting from long-term siltation and biofouling, taking into consideration the degree of long-term maintenance and performance monitoring anticipated; the degree of influent control (such as presettling ponds or biofiltration swales); and the potential for siltation and bio-buildup based on the surrounding environment. It should be assumed that an average-to-high degree of maintenance will be performed on these facilities. A low degree of maintenance should be considered only when there is no other option (such as with access problems). The infiltration rate estimated in Step 9 is multiplied by the reduction factors summarized in Table 4-10. The final infiltration rate is therefore as follows:

$$f = (0.5K_{equiv})(i_t)(CF_{silt/bio}) \quad \textbf{(4-23)}$$

The infiltration rates, which were calculated based on Equation 4-23, are long-term design rates. No additional reduction factor or factor of safety is needed.

**Table 4-10 Infiltration rate reduction factors to account for biofouling and siltation effects for trenches (Massmann, 2003).**

| Potential for Biofouling | Degree of Long-Term Maintenance/Performance Monitoring | Infiltration Rate Reduction Factor, $CF_{silt/bio}$ |
|---|---|---|
| Low | Average to High | 0.9 |
| Low | Low | 0.8 |
| High | Average to High | 0.75 |
| High | Low | 0.6 |

Although siltation and biofouling may be less prevalent in infiltration trenches than in infiltration ponds, field data have not been collected that would allow correction factors to be estimated for trenches. However, the computer simulation results described in Massmann et al. (2003) suggest that reductions

in saturated hydraulic conductivity due to bottom clogging from siltation and biofouling may have relatively small effects on overall infiltration rates and gradients for trenches. This is because of the larger amounts of lateral flow that occur in trenches compared to ponds. Reductions in vertical flow from the bottom of the trench are offset by increases in lateral flow, particularly for trenches with deeper water levels.

5. **Follow Steps 11 through 13 in the Detailed Approach (see Section 4-5.3.1).**

### 4-5.4.2 Design Procedure for Drywells

This design procedure was obtained from a research project conducted by Massmann (2004) and developed for eastern Washington. The design procedure for drywells originated from a design based on soil types prevalent in Spokane County. This research helped to determine a more accurate drywell design based on soils typically found throughout eastern Washington and deep groundwater tables. Steps for this procedure are as follows:

1. **Estimate volume of stormwater, $V_{design}$.**

   For eastern Washington, a single-event hydrograph or value for the volume can be used, allowing a modeling approach such as StormShed to be conducted. For western Washington, a continuous hydrograph generally should be used, requiring a model such as MGSFlood to perform the calculations. (See Section 4-3 for western Washington methodology and Section 4-4 for eastern Washington methodology.)

2. **Follow Steps 4 through 5 in the Detailed Approach (see Section 4-5.3.1).**

3. **Determine the average saturated hydraulic conductivity as noted in Section 4-5.2.1.**

4. **Estimate the uncorrected steady-state infiltration rate for drywells.**

   The results of the computer simulations included in Massmann (2004) were used to develop regression equations relating steady-state flow rates with saturated hydraulic conductivity values and the depth to groundwater. The following two regression equations were derived from the results of these computer simulations:

   Double-barrel wells: $Q = K[3.55ln(D_{wt}) + 12.32]$ **(4-24)**

   Single-barrel wells: $Q = K[1.34ln(D_{wt}) + 8.81]$ **(4-25)**

   where: $Q$ = the infiltration rate in cfs
   $K$ = the average saturated hydraulic conductivity value in ft/minute
   $D_{wt}$ = the depth from the bottom of the drywell to groundwater in feet

   Uncorrected steady-state infiltration rates for single- and double-barrel configurations can be estimated using the regression equations given in Equations 4-24 and 4-25.

5. **Apply correction factor for siltation.**

   Siltation and plugging may reduce the equivalent saturated hydraulic conductivity values of the facilities by an order of magnitude or more. This will result in a corresponding reduction in infiltration rate. If pretreatment cannot be provided, the design infiltration rates calculated in Step 3 above should be reduced by a factor on the order of 0.5 or less.

6. **Size the facility.**

   Because this design procedure was based on eastern Washington conditions, the facility sizing and drawdown time requirement for eastern Washington must be applied even if designing a drywell in western Washington. Until further research can be completed for drywell design in western Washington, the more conservative drawdown time of eastern Washington must be used.

   Calculate $T_{req}$ using Equation 4-21 from the Detailed Approach (see Section 4-5.3.1), using the value of $Q$ determined from Step 11, and $V_{design}$ from Step 1 above. The value of $T_{req}$ calculated must be less than or equal to the maximum allowed infiltration time specified in the Site Suitability Criteria in Section 4-5.1.

7. **Construct the facility.**

   Maintain and monitor the facility for performance in accordance with the *Maintenance Manual*.

## 4-6 Wetland Hydroperiods

An important consideration in the stewardship of certain wetland functions is the protection and control of a wetland's *hydroperiod***.** The hydroperiod is the pattern of fluctuation of water depth and the frequency and duration of water levels on the site. This includes the duration and timing of drying in the summer. A hydrologic assessment is useful to measure or estimate elements of the hydroperiod under existing **preproject** and anticipated **post-project** conditions. This assessment involves reviewing and applying the best available science to assess potential impacts and deciding whether hydrological modeling is warranted.

Wetland hydroperiod analysis is of concern when proposing to discharge stormwater into or detract stormwater from a natural wetland (not constructed). The purpose of the analysis is to determine whether the stormwater will change the natural hydroperiod beyond the limits allowed. When this is an issue on a project, contact the region environmental staff for assistance. Refer to Minimum Requirement 7 (see Section 3-3.7.3) for the process, if applicable.

## 4-7 Closed Depression Analysis

Analysis of closed depressions requires careful assessment of the existing hydrologic performance in order to evaluate a proposed project's potential impacts. The applicable flow control requirements (see Minimum Requirement 6, Section 3-3.6) and the local

government's Sensitive Areas Ordinance and Rules (if applicable) should be thoroughly reviewed prior to proceeding with the analysis. A calibrated continuous simulation hydrologic model must be used for closed depression analysis and design of mitigation facilities. Where an adequately calibrated continuous simulation model is not available, the procedures listed below can be followed.

## 4-7.1 Analysis and Design Criteria

The infiltration rates used in the analysis of closed depressions must be determined according to the procedures in Section 4-5. For closed depressions containing standing water, soil texture tests must be performed on dry land adjacent to, and on opposite sides of, the standing water (as practicable). The elevation of the testing surface at the bottom of the test pit must be 1 foot above the standing water elevation. A minimum of four tests must be performed to estimate an average surface infiltration rate.

Projects proposing to modify or compensate for replacement storage in a closed depression must meet the design criteria for detention ponds as described in Chapter 5.

## 4-7.2 Western Washington Method of Analysis

Closed depressions are analyzed using hydrographs routed as described in Section 4-5. Infiltration must be addressed where appropriate. In assessing the impacts of a proposed project on the performance of a closed depression, there are three cases that dictate different approaches to meeting Minimum Requirement 6 (see Section 3-3.6) and applicable local requirements. Note: Where there is a flooding potential, concern about rising groundwater levels, or local sensitive area ordinances and rules, this analysis may not be sufficient and local governments may require more stringent analysis.

### *Case 1*

The 100-year recurrence interval storm runoff from an approved continuous simulation program, flowing from the TDA to the closed depression, is routed into the closed depression using only infiltration as outflow. If predevelopment runoff does not overflow the closed depression, then no runoff may leave the closed depression at the 100-year recurrence interval following development of a proposed project. This may be accomplished by excavating additional storage volume in the closed depression, subject to all applicable requirements (for example, providing a defined overflow system).

### *Case 2*

The 100-year recurrence interval storm runoff from an approved continuous simulation program, from the TDA to the closed depression, is routed into the closed depression using only infiltration as outflow. If runoff overflows the closed depression under existing conditions during the 100-year recurrence interval storm, the performance objective can be met by excavating additional storage volume in the closed depression, subject to all applicable requirements (for example, providing a defined overflow system).

### *Case 3*

The 100-year recurrence interval storm runoff from an approved continuous simulation program, from the TDA to the closed depression, is routed into the closed depression using only infiltration as outflow, and both cause overflow to occur. The closed depression must then be analyzed as a detention/infiltration pond. The required performance, therefore, is to meet the runoff duration standard specified in Minimum Requirement 6 (see Section 3-3.6), using an adequately calibrated continuous simulation model. This will require a control structure, emergency overflow spillway, access road, and other design criteria. Also, depending on who will maintain the system, it will require placing the closed depression in a tract dedicated to the responsible party.

## 4-7.3 Eastern Washington Methods of Analysis

*The Stormwater Management Manual for Eastern Washington (SMMEW) states that local jurisdiction guidelines should be followed. The Spokane County Guidelines are included below. Other eastern Washington regions are encouraged to provide comment on their local guidelines and compare them to those stated below.*

Depending upon soil characteristics, a closed depression may or may not accumulate surface water during periods of the year. Some closed depressions may be classified as wetlands. The design team must coordinate its stormwater design with consideration of any wetland area, as defined by applicable regulations that may govern wetland areas. If the proper authorities agree that none of these closed areas is a wetland, and the design team desires to fill these natural depressions, the designer evaluating the site and formulating a stormwater disposal concept will consider these natural depressions and replace any disturbed depressions. Normally, the natural storage volume lost due to the proposed earthwork must be replaced using a 1:1 ratio as a minimum. A higher ratio may be required if the new area infiltrates water at a lower rate than occurred in the natural depression. The road and drainage plans must include: (1) a grading plan of the closed depression area to be filled in, (2) both existing and finished grade contours, and (3) compaction and fill material requirements.

- For natural depressions that are capable of complete water disposal within 72 hours by infiltrating the runoff generated from a 100-year, 24-hour storm event, a properly designed grassed percolation area, or combination grassed percolation area/drywell that is equal or greater in volume and that will also completely infiltrate the runoff from a 100-year, 24-hour storm event within a 72-hour time period, could be an acceptable substitution.
- For natural depressions that do not drain within 72 hours, it is acceptable to consolidate all the volumes of the depressions from the subject site that are proposed for filling into one or more infiltration/evaporative ponds that will emulate the natural condition. If the site has a disposal area that will allow increased percolation from the natural condition, a Design Deviation may be granted for increased infiltration if it can be demonstrated that the groundwater levels in the area will not be adversely affected and runoff treatment problems will not increase.

- For sites with natural depressions, the designer must clearly identify the location of all depressions that could contain more than 50 cubic feet of stormwater. For these types of depressions, the designer must survey each depression and show the maximum volume that each could hold, as well as show the maximum storage capacity water elevation contour line on the predeveloped condition basin map. The basin map should show adequate survey data points to demonstrate that accurate volume calculations can be made from them. If the site contains many small depressions that will hold water, but are smaller than 50 cubic feet in size, the designer must adjust the runoff factors to allow for this retention of stormwater or make other adjustments to the runoff model that are approved in writing by region or HQ hydraulics staff. If the site had depression storage in its historic natural state, and grading and filling have been done to these natural features, the designer must reasonably estimate the depression storage that was on the site and comply with the provisions of this section.

If the total storage capacity of a closed depression exceeds the maximum volume used (as computed using the water budget method), both volumes must be clearly identified in the Hydraulic Report, and both of these water surface elevation contour lines are to be shown in the basin map.

If a closed depression is to remain or be replaced, the lowest floor elevation or road grade of any building or road adjacent to it must be at or above the maximum water elevation and outside the limits of the closed depression. The maximum water elevation must be computed using the water budget method as per the standards for an evaporative systems design unless the pond can naturally drain within 72 hours following a 100-year, 24-hour storm event. If the depression can drain within the 72-hour time period, the maximum water elevation is computed as being the elevation containing the runoff from a 100-year, 24-hour storm event. If the limits of the high water in the infiltration facility are considered in the design, a geotechnical report must be provided that shows site-specific infiltration testing results and verifies that each depression being used will drain within the 72-hour period unless waived by region or HQ hydraulics staff based on knowledge of approved soils under the site. The closed depression must be placed in a drainage easement or separate tract if the development is noncommercial. The easement must be granted to WSDOT and any other entity responsible for maintaining the closed depression.

# 4-8 References

Brater, E.F. and H.W. King. 1976. Handbook of Hydraulics. McGraw-Hill Company, New York.

Chow, V.T. 1959. Open Channel Hydraulics. McGraw-Hill Book Company.

Daughtery, R.L. and J.B. Franzini. 1977. Fluid Mechanics with Engineering Applications. McGraw-Hill, New York.

Ecology, Washington State Department of. *Stormwater Management Manual for Western Washington*. August 2005.

Ecology, Washington State Department of. *Stormwater Management Manual for Eastern Washington*. September 2004.

King County Surface Water Management Division. 1999. King County Runoff Timeseries (KCRTS), *Computer Software Reference Manual*, Version 4.4. January 1999.

King County. *Washington Surface Water Design Manual*. September 1998.

"Low-Impact Development Design Strategies, An Integrated Design Approach," prepared by Prince George's County Maryland, Department of Environmental Resources, Programs and Planning Divisions. June 1999.

Maryland *Stormwater Manual.*

Massmann, J.W. 2003. *A Design Manual for Sizing Infiltration Ponds*. WSDOT, WA-RD 578.2. 61 pp.

Massmann, J.W. April 2004. *An Approach For Estimating Infiltration Rates For Stormwater Infiltration Drywells*, WSDOT, Agreement Y-7717 Task Order AU.

Massman, Joel, Carolyn Butchart, and Stephanie Stolar. 2003. University of Washington, Final Research Report-T1803, Task 12, "Infiltration Characteristics, Performance, and Design of Stormwater Facilities."

Miller, J.F., R.H. Frederick, and R.S. Tracey. 1973. NOAA Atlas 2, Precipitation Frequency Atlas of the Western United States, Volume IX-Washington. U.S. Dept. of Commerce, NOAA, National Weather Service. Washington D.C.

Oregon Climate Service. 1997. Mean Annual Precipitation Maps for Western United States, prepared with PRISM Model for NRCS, Corvallis, Oregon.

Pierce County *Stormwater Manual*.

Pitt, R., S.E. Chen, S. Clark, J. Lantrip, C.K. Ong, and J. Voorhees. 2003. "Infiltration Through Compacted Urban Soils and Effects on Biofiltration Design," *Stormwater and Urban Water Systems Modeling, Models, and Applications to Urban Water Systems*, Ed. – W. James, CHI, Guelph, Ontario, Vol. 11. pp. 217-252.

Schaefer, M.G. 1981. "Shaft Spillways, Fundamental Hydraulics and Hydrology of Dam Design." University of Missouri Short Course, available through Dam Safety Section, Washington Department of Ecology. May 1981.

Schaefer, M.G. and B.L. Barker. 2002. "Extended Precipitation Time Series for continuous hydrological modeling in Western Washington," prepared for Washington State Department of Transportation by MGS Consulting Inc. April 2002.

Schaefer, M.G. and B.L. Barker. 2003. MGS Flood – *Proprietary Version User Manual*, prepared for Washington State Department of Transportation by MGS Consulting Inc., Version 2.2. March 2003.

U.S. Bureau of Reclamation. 1987. Design of Small Dams. U.S. Department of the Interior, U.S. Government Printing Office, 3rd edition.

USDA-SCS. 1986. Technical Release No. 55: Urban Hydrology for Small Watershed.

U.S. EPA. 1984. *Hydrological Simulation Program-Fortran HSPF User Manual* for Release 9. EPA 600/3-84-066. Environmental Research Laboratory, Athens, GA. June 1984.

## APPENDIX 4A

# Web Links

# Appendix 4A Web Links

**Washington 2-hour Isopluvial Map, January 2006**
www.wsdot.wa.gov/design/hydraulics/default.htm

Also available on the Environmental Workbench in ArcMap (internal WSDOT only).
http://wwwi.wsdot.wa.gov/GIS/supportteam/gis_workbench/GISWBQuickStart10.pdf

**Washington Mean Annual Precipitation Map**
www.wsdot.wa.gov/design/hydraulics/default.htm
Also available on the Environmental Workbench in ArcMap (internal WSDOT only).
http://wwwi.wsdot.wa.gov/GIS/supportteam/gis_workbench/GISWBQuickStart10.pdf

**Washington 24-hour Isopluvial Maps, January 2006**
www.wsdot.wa.gov/design/hydraulics/default.htm
www.wrcc.dri.edu/climatedata.html

**MGSFlood Users Manual**
www.wsdot.wa.gov/design/hydraulics/training.htm

**MGSFlood Training Example**
www.wsdot.wa.gov/design/hydraulics/training.htm

**StormShed**
www.wsdot.wa.gov/design/hydraulics/training.htm

**StormShed Training Example**
www.wsdot.wa.gov/design/hydraulics/training.htm

**Downstream Analysis**
Provided in the 2006 *Hydraulics Manual*, Chapter 4:
www.wsdot.wa.gov/design/hydraulics/default.htm

**Low-Impact Development (LID) Modeling**
Provides guidance on how to model LID.
www.wsdot.wa.gov/design/hydraulics/training.htm

**Time-to-Drain Infiltration Pond and Trench Spreadsheet**
www.wsdot.wa.gov/design/hydraulics/training.htm

**MGSFlood CAVFS Example**
www.wsdot.wa.gov/design/hydraulics/training.htm

**APPENDIX 4B**

# TR55 Curve Number Tables

# Appendix 4B List of Tables

## Table 4B-1 Hydrologic soil series for selected soils in Washington State.

| Soil Type | Hydrologic Soil Group | Soil Type | Hydrologic Soil Group |
|---|---|---|---|
| Agnew | C | Dimal | D |
| Ahl | B | Dragoon | C |
| Aits | C | Dupont | D |
| Alderwood | C | Earlmont | C |
| Arents, Alderwood | B | Edgewick | C |
| Arents, Everett | B | Eld | B |
| Ashoe | B | Eloika | B |
| Athena | B | Elwell | B |
| Baldhill | B | Emdent | D |
| Barneston | C | Esquatzel | B |
| Baumgard | B | Everett | A |
| Beausite | B | Everson | D |
| Belfast | C | Freeman | C |
| Bellingham | D | Galvin | D |
| Bellingham variant | C | Garfield | C |
| Bernhill | B | Garrison | B |
| Boistfort | B | Getchell | A |
| Bong | A | Giles | B |
| Bonner | B | Glenrose | B |
| Bow | D | Godfrey | D |
| Brickel | C | Green Bluff | B |
| Bridgeson | D | Greenwater | A |
| Briscot | D | Grove | C |
| Buckley | C | Hagen | B |
| Bunker | B | Hardesty | B |
| Cagey | C | Harstine | C |
| Caldwell | C | Hartnit | C |
| Carlsborg | A | Hesseltine | B |
| Casey | D | Hoh | B |
| Cassolary | C | Hoko | C |
| Cathcart | B | Hoodsport | C |
| Cedonia | B | Hoogdal | C |
| Centralia | B | Hoypus | A |
| Chehalis | B | Huel | A |
| Cheney | B | Indianola | A |
| Chesaw | A | Jonas | B |
| Cinebar | B | Jumpe | B |
| Clallam | C | Kalaloch | C |
| Clayton | B | Kapowsin | C/D |
| Coastal beaches | variable | Katula | C |
| Cocolalla | D | Kilchis | C |
| Colter | C | Kitsap | C |
| Custer | D | Klaus | C |
| Custer, Drained | C | Klone | B |
| Dabob | C | Konner | D |
| Dearyton | C | Lakesol | B |
| Delphi | D | Laketon | C |
| Dick | A | Lance | B |
| Larkin | B | Poulsbo | C |

## Table 4B-1. Hydrologic soil series for selected soils in Washington State (continued).

| Soil Type | Hydrologic Soil Group | Soil Type | Hydrologic Soil Group |
|---|---|---|---|
| Latah | D | Prather | C |
| Lates | C | Puget | D |
| Lebam | B | Puyallup | B |
| Lummi | D | Queets | B |
| Lynnwood | A | Quilcene | C |
| Lystair | B | Ragnar | B |
| Mal | C | Rainier | C |
| Manley | B | Raught | B |
| Marble | A | Reardan | C |
| Mashel | B | Reed | D |
| Maytown | C | Reed, Drained or Protected | C |
| McKenna | D | Renton | D |
| McMurray | D | Republic | B |
| Melbourne | B | Riverwash | variable |
| Menzel | B | Rober | C |
| Mixed Alluvial | variable | Salal | C |
| Molson | B | Salkum | B |
| Mondovi | B | Sammamish | D |
| Moscow | C | San Juan | A |
| Mukilteo | C/D | Scamman | D |
| Naff | B | Schneider | B |
| Narcisse | C | Schumacher | B |
| Nargar | A | Seattle | D |
| National | B | Sekiu | D |
| Neilton | A | Semiahmoo | D |
| Newberg | B | Shalcar | D |
| Nez Perce | C | Shano | B |
| Nisqually | B | Shelton | C |
| Nooksack | C | Si | C |
| Norma | C/D | Sinclair | C |
| Ogarty | C | Skipopa | D |
| Olete | C | Skykomish | B |
| Olomount | C | Snahopish | B |
| Olympic | B | Snohomish | D |
| Orcas | D | Snow | B |
| Oridia | D | Solduc | B |
| Orting | D | Solleks | C |
| Oso | C | Spana | D |
| Ovall | C | Spanaway | A/B |
| Palouse | B | Speigle | B |
| Pastik | C | Spokane | C |
| Peone | D | Springdale | A |
| Pheeney | C | Sulsavar | B |
| Phelan | D | Sultan | C |
| Phoebe | B | Sultan variant | B |
| Pilchuck | C | Sumas | C |
| Potchub | C | Swantown | D |
| Tacoma | D | Vailton | B |
| Tanwax | D | Vassar | B |

## Table 4B-1. Hydrologic soil series for selected soils in Washington State (continued).

| Soil Type | Hydrologic Soil Group | Soil Type | Hydrologic Soil Group |
|---|---|---|---|
| Tanwax, Drained | C | Verlot | C |
| Tealwhit | D | Wapato | D |
| Tekoa | C | Warden | B |
| Tenino | C | Wethey | C |
| Tisch | D | Whidbey | C |
| Tokul | C | Wilkeson | B |
| Townsend | C | Winston | A |
| Triton | D | Wolfeson | C |
| Tukwila | D | Woodinville | B |
| Tukey | C | Yelm | C |
| Uhlig | B | Zynbar | B |
| Urbana | C | | |

Hydrologic Soil Group Classifications, as defined by the Soil Conservation Service:

**A** = (Low runoff potential) Soils having low runoff potential and high infiltration rates, even when thoroughly wetted. They consist chiefly of deep, well- to excessively drained sands or gravels, and have a high rate of water transmission (greater than 0.30 in/hr).

**B** = (Moderately low runoff potential) Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well- to well-drained soils, with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15–0.3 in/hr).

**C** = (Moderately high runoff potential) Soils having low infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine textures. These soils have a low rate of water transmission (0.05–0.15 in/hr).

**D** = (High runoff potential) Soils having high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential; soils with a permanent high water table; soils with a hardpan or clay layer at or near the surface; and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0–0.05 in/hr).

* = From SCS, TR-55, Second Edition, June 1986, Exhibit A-1. Revisions made from SCS, Soil Interpretation Record, Form #5, September 1988 and various county soil surveys.

This information can also be found online at: websoilsurvey.nrcs.usda.gov/app/websoilsurvey.aspx

## Table 4B-2 Runoff curve numbers for selected agricultural, suburban, and rural areas (western Washington).

| Cover Type and Hydrologic Condition | CNs for hydrologic soil group A | B | C | D |
|---|---|---|---|---|
| **Curve Numbers for Predevelopment Conditions** | | | | |
| **Pasture, Grassland, or Range – Continuous Forage for Grazing:** | | | | |
| Fair condition (ground cover 50% to 75% and not heavily grazed) | 49 | 69 | 79 | 84 |
| Good condition (ground cover >75% and lightly or only occasionally grazed) | 39 | 61 | 74 | 80 |
| **Woods:** | | | | |
| Fair (woods are grazed but not burned, and some forest litter covers the soil) | 36 | 60 | 73 | 79 |
| Good (woods are protected from grazing, and litter and brush adequately cover the soil) | 30 | 55 | 70 | 77 |
| **Curve Numbers for Postdevelopment Conditions** | | | | |
| **Open Space (lawns, parks, golf courses, cemeteries, landscaping, etc.):**[1] | | | | |
| Fair condition (grass cover on 50% to 75% of the area) | 77 | 85 | 90 | 92 |
| Good condition (grass cover on >75% of the area) | 68 | 80 | 86 | 90 |
| **Impervious Areas:** | | | | |
| Open water bodies: lakes, wetlands, ponds, etc. | 100 | 100 | 100 | 100 |
| Paved parking lots, roofs,[2] driveways, etc. (excluding right of way) | 98 | 98 | 98 | 98 |
| **Porous Pavers and Permeable Interlocking Concrete (assumed as 85% impervious and 15% lawn):** | | | | |
| Fair lawn condition (weighted average CNs) | 95 | 96 | 97 | 97 |
| Good lawn condition (weighted average CNs) | 94 | 95 | 96 | 97 |
| Paved | 98 | 98 | 98 | 98 |
| Gravel (including right of way) | 76 | 85 | 89 | 91 |
| Dirt (including right of way) | 72 | 82 | 87 | 89 |
| **Pasture, Grassland, or Range – Continuous Forage for Grazing:** | | | | |
| Poor condition (ground cover <50% or heavily grazed with no mulch) | 68 | 79 | 86 | 89 |
| Fair condition (ground cover 50% to 75% and not heavily grazed) | 49 | 69 | 79 | 84 |
| Good condition (ground cover >75% and lightly or only occasionally grazed) | 39 | 61 | 74 | 80 |
| **Woods:** | | | | |
| Poor (forest litter, small trees, and brush are destroyed by heavy grazing or regular burning) | 45 | 66 | 77 | 83 |
| Fair (woods are grazed but not burned, and some forest litter covers the soil) | 36 | 60 | 73 | 79 |
| Good (woods are protected from grazing, and litter and brush adequately cover the soil) | 30 | 55 | 70 | 77 |

| **Single Family Residential:**[3] Dwelling Unit/Gross Acre | Should only be used for subdivisions >50 acres | Average percent impervious area[3,4] | |
|---|---|---|---|
| 1.0 DU/GA | | 15 | Separate curve number |
| 1.5 DU/GA | | 20 | must be selected for |
| 2.0 DU/GA | | 25 | pervious & impervious |
| 2.5 DU/GA | | 30 | portions of the site or |
| 3.0 DU/GA | | 34 | basin |
| 3.5 DU/GA | | 38 | |
| 4.0 DU/GA | | 42 | |
| 4.5 DU/GA | | 46 | |
| 5.0 DU/GA | | 48 | |
| 5.5 DU/GA | | 50 | |
| 6.0 DU/GA | | 52 | |
| 6.5 DU/GA | | 54 | |
| 7.0 DU/GA | | 56 | |
| 7.5 DU/GA | | 58 | |
| PUDs, condos, apartments, commercial businesses, industrial areas, and subdivisions <50 acres | % impervious must be computed | Separate curve numbers must be selected for pervious and impervious portions of the site | |

For a more detailed and complete description of land use curve numbers, refer to Chapter Two (2) of the Soil Conservation Service's Technical Release No. 55 (210-VI-TR-55, Second Ed., June 1986).

[1] Composite CNs may be computed for other combinations of open space cover type.

[2] Where roof runoff and driveway runoff are infiltrated or dispersed according to the requirements in Chapter 3, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for Roof Downspout Infiltration" and "Flow Credit for Roof Downspout Dispersion."

[3] Assumes roof and driveway runoff is directed into street/storm system.

[4] All remaining pervious area (lawn) is considered to be in good condition for these curve numbers.

## Table 4B-3 Runoff curve numbers for selected agricultural, suburban, and rural areas (eastern Washington).

| | CNs for hydrologic soil group | | | |
|---|---|---|---|---|
| **Cover Type and Hydrologic Condition** | **A** | **B** | **C** | **D** |
| **Open Space (lawns, parks, golf courses, cemeteries, landscaping, etc.):**[1] | | | | |
| Poor condition (grass cover on <50% of the area) | 68 | 79 | 86 | 89 |
| Fair condition (grass cover on 50% to 75% of the area) | 49 | 69 | 79 | 84 |
| Good condition (grass cover on >75% of the area) | 39 | 61 | 74 | 80 |
| **Impervious Areas:** | | | | |
| Open water bodies: lakes, wetlands, ponds, etc. | 100 | 100 | 100 | 100 |
| Paved parking lots, roofs, driveways, etc. (excluding right of way) | 98 | 98 | 98 | 98 |
| **Porous Pavers and Permeable Interlocking Concrete (assumed as 85% impervious and 15% lawn):** | | | | |
| Fair lawn condition (weighted average CNs) | 95 | 96 | 97 | 97 |
| Gravel (including right of way) | 76 | 85 | 89 | 91 |
| Dirt (including right of way) | 72 | 82 | 87 | 89 |
| **Pasture, Grassland, or Range – Continuous Forage for Grazing:** | | | | |
| Poor condition (ground cover <50% or heavily grazed with no mulch) | 68 | 79 | 86 | 89 |
| Fair condition (ground cover 50% to 75% and not heavily grazed) | 49 | 69 | 79 | 84 |
| Good condition (ground cover >75% and lightly or only occasionally grazed) | 39 | 61 | 74 | 80 |
| **Cultivated Agricultural Lands:** | | | | |
| Row Crops (good), e.g., corn, sugar beets, soy beans | 64 | 75 | 82 | 85 |
| Small Grain (good), e.g., wheat, barley, flax | 60 | 72 | 80 | 84 |
| **Meadow (continuous grass, protected from grazing, and generally mowed for hay):** | 30 | 58 | 71 | 78 |
| **Brush (brush-weed-grass mixture, with brush the major element):** | | | | |
| Poor (<50% ground cover) | 48 | 67 | 77 | 83 |
| Fair (50% to 75% ground cover) | 35 | 56 | 70 | 77 |
| Good (>75% ground cover) | 30[2] | 48 | 65 | 73 |
| **Woods-Grass Combination (orchard or tree farm):**[3] | | | | |
| Poor | 57 | 73 | 82 | 86 |
| Fair | 43 | 65 | 76 | 82 |
| Good | 32 | 58 | 72 | 79 |
| **Woods:** | | | | |
| Poor (forest litter, small trees, and brush are destroyed by heavy grazing or regular burning) | 45 | 66 | 77 | 83 |
| Fair (woods are grazed but not burned, and some forest litter covers the soil) | 36 | 60 | 73 | 79 |
| Good (woods are protected from grazing, and litter and brush adequately cover the soil) | 30 | 55 | 70 | 77 |
| **Herbaceous (mixture of grass, weeds, and low-growing brush, with brush the minor element):**[4] | | | | |
| Poor (<30% ground cover) | | 80 | 87 | 93 |
| Fair (30% to 70% ground cover) | | 71 | 81 | 89 |
| Good (>70% ground cover) | | 62 | 74 | 85 |
| **Sagebrush With Grass Understory:**[4] | | | | |
| Poor (<30% ground cover) | | 67 | 80 | 85 |
| Fair (30% to 70% ground cover) | | 51 | 63 | 70 |
| Good (>70% ground cover) | | 35 | 47 | 55 |

For a more detailed and complete description of land use curve numbers, refer to Chapter Two (2) of the Soil Conservation Service's Technical Release No. 55 (210-VI-TR-55, Second Ed., June 1986).

[1] Composite CNs may be computed for other combinations of open space cover type.

[2] Actual curve number is less than 30; use CN = 30 for runoff computations.

[3] CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

[4] Curve numbers have not been developed for Group A soils.

## Table 4B-4 Curve number conversions for different antecedent moisture conditions (case Ia = 0.2 S).

| CN for AMC II | CN for AMC I | CN for AMC III |
|---|---|---|
| 100 | 100 | 100 |
| 99 | 97 | 100 |
| 98 | 94 | 99 |
| 97 | 91 | 99 |
| 96 | 89 | 99 |
| 95 | 87 | 98 |
| 94 | 85 | 98 |
| 93 | 83 | 98 |
| 92 | 81 | 97 |
| 91 | 80 | 97 |
| 90 | 78 | 96 |
| 89 | 76 | 96 |
| 88 | 75 | 95 |
| 87 | 73 | 95 |
| 86 | 72 | 94 |
| 85 | 70 | 94 |
| 84 | 68 | 93 |
| 83 | 67 | 93 |
| 82 | 66 | 92 |
| 81 | 64 | 92 |
| 80 | 63 | 91 |
| 79 | 62 | 91 |
| 78 | 60 | 90 |
| 77 | 59 | 89 |

| CN for AMC II | CN for AMC I | CN for AMC III |
|---|---|---|
| 76 | 58 | 89 |
| 75 | 57 | 88 |
| 74 | 55 | 88 |
| 73 | 54 | 87 |
| 72 | 53 | 86 |
| 71 | 52 | 86 |
| 70 | 51 | 85 |
| 69 | 50 | 84 |
| 68 | 48 | 84 |
| 67 | 47 | 83 |
| 66 | 46 | 82 |
| 65 | 45 | 82 |
| 64 | 44 | 81 |
| 63 | 43 | 80 |
| 62 | 42 | 79 |
| 61 | 41 | 78 |
| 60 | 40 | 78 |
| 59 | 39 | 78 |
| 58 | 38 | 76 |
| 57 | 37 | 75 |
| 56 | 36 | 75 |
| 55 | 35 | 74 |
| 54 | 34 | 73 |
| 50 | 31 | 70 |

Source: SCS-NEH4. Table 10.1.

## Table 4B-5 "n" and "k" values used in time calculations for hydrographs.

| "$n_s$" Sheet Flow Equation Manning's Values (for the initial 300 ft. of travel) | |
|---|---|
| **Manning's Values for sheet flow only; from Overton and Meadows 1976 (see TR-55, 1986)** | **$n_s$** |
| Smooth surfaces (concrete, asphalt, gravel, or bare, hand-packed soil) | 0.011 |
| Fallow fields or loose soil surface (no residue) | 0.05 |
| Cultivated soil with residue cover ≤20% | 0.06 |
| Cultivated soil with residue cover >20% | 0.17 |
| Short prairie grass and lawns | 0.15 |
| Dense grasses | 0.24 |
| Bermuda grass | 0.41 |
| Range (natural) | 0.13 |
| Woods or forest with light underbrush | 0.40 |
| Woods or forest with dense underbrush | 0.80 |
| (210-VI-TR-55, Second Ed., June 1986) | |
| **"k" Values Used in Travel Time/Time of Concentration Calculations** | |
| **Shallow Concentrated Flow (after the initial 300 ft. of sheet flow, R = 0.1)** | **$k_s$** |
| 1. Forest with heavy ground litter and meadows (n = 0.10) | 3 |
| 2. Brushy ground with some trees (n = 0.060) | 5 |
| 3. Fallow or minimum tillage cultivation (n = 0.040) | 8 |
| 4. High grass (n = 0.035) | 9 |
| 5. Short grass, pasture, and lawns (n = 0.030) | 11 |
| 6. Nearly bare ground (n = 0.025) | 13 |
| 7. Paved and gravel areas (n = 0.012) | 27 |
| **Channel Flow (intermittent) (at the beginning of visible channels, R = 0.2)** | **$k_c$** |
| 1. Forested swale with heavy ground litter (n = 0.10) | 5 |
| 2. Forested drainage course/ravine with defined channel bed (n = 0.050) | 10 |
| 3. Rock-lined waterway (n = 0.035) | 15 |
| 4. Grassed waterway (n = 0.030) | 17 |
| 5. Earth-lined waterway (n = 0.025) | 20 |
| 6. CMP pipe, uniform flow (n = 0.024) | 21 |
| 7. Concrete pipe, uniform flow (0.012) | 42 |
| 8. Other waterways and pipe | 0.508/n |
| **Channel Flow (continuous stream, R = 0.4)** | **$k_c$** |
| 9. Meandering stream with some pools (n = 0.040) | 20 |
| 10. Rock-lined stream (n = 0.035) | 23 |
| 11. Grass-lined stream (n = 0.030) | 27 |
| 12. Other streams, manmade channels, and pipe | 0.807/n |

## Table 4B-6 Values of the roughness coefficient, "n."

| Type of Channel and Description | Manning's "n"* (Normal) | Type of Channel and Description | Manning's "n"* (Normal) |
|---|---|---|---|
| **A. Constructed Channels** | | 6. Sluggish reaches, weedy | |
| a. *Earth, straight and uniform* | | deep pools | 0.070 |
| 1. Clean, recently completed | 0.018 | 7. Very weedy reaches, deep | |
| 2. Gravel, uniform selection, | 0.025 | pools, or floodways with | |
| clean | | heavy stand of timber and | |
| 3. With short grass, few | 0.027 | underbrush | 0.100 |
| weeds | | b. *Mountain streams, no vegetation* | |
| b. *Earth, winding and sluggish* | | *in channel, banks usually steep,* | |
| 1. No vegetation | 0.025 | *trees and brush along banks* | |
| 2. Grass, some weeds | 0.030 | *submerged at high stages* | |
| 3. Dense weeds or aquatic | | 1. Bottom: gravel, cobbles, and | |
| plants in deep channels | 0.035 | few boulders | 0.040 |
| 4. Earth bottom and rubble | | 2. Bottom: cobbles with large | |
| sides | 0.030 | boulders | 0.050 |
| 5. Stony bottom and weedy | | B-2 Flood plains | |
| banks | 0.035 | a. *Pasture, no brush* | |
| 6. Cobble bottom and clean | | 1. Short grass | 0.030 |
| sides | 0.040 | 2. High grass | 0.035 |
| c. *Rock-lined* | | b. *Cultivated areas* | |
| 1. Smooth and uniform | 0.035 | 1. No crop | 0.030 |
| 2. Jagged and irregular | 0.040 | 2. Mature row crops | 0.035 |
| d. *Channels not maintained,* | | 3. Mature field crops | 0.040 |
| *weeds and brush uncut* | | c. *Brush* | |
| 1. Dense weeds, high as flow | | 1. Scattered brush, heavy | |
| depth | 0.080 | weeds | 0.050 |
| 2. Clean bottom, brush on | | 2. Light brush and trees | 0.060 |
| sides | 0.050 | 3. Medium to dense brush | 0.070 |
| 3. Same, highest stage of | | 4. Heavy, dense brush | 0.100 |
| flow | 0.070 | d. *Trees* | |
| 4. Dense brush, high stage | 0.100 | 1. Dense willows, straight | 0.150 |
| **B. Natural Streams** | | 2. Cleared land with tree | |
| B-1 Minor streams (top width at | | stumps, no sprouts | 0.040 |
| flood stage < 100 ft.) | | 3. Same as above, but with | |
| a. *Streams on plain* | | heavy growth of sprouts | 0.060 |
| 1. Clean, straight, full stage, | | 4. Heavy stand of timber, a few | |
| no rifts or deep pools | 0.030 | downed trees, little | |
| 2. Same as above, but more | | undergrowth, flood stage | |
| stones and weeds | 0.035 | below branches | 0.100 |
| 3. Clean, winding, some | | 5. Same as above, but with | |
| pools and shoals | 0.040 | flood stage reaching | |
| 4. Same as above, but some | | branches | 0.120 |
| weeds | 0.040 | | |
| 5. Same as 4, but more stones | 0.050 | | |

* Note: These "n" values are "normal" values for use in analysis of channels. For conservative design for channel capacity, the maximum values listed in other references should be considered. For channel bank stability, the minimum values should be considered.

**APPENDIX 4C**

# Eastern Washington Design Storm Events

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# Appendix 4C
# Eastern Washington Design Storm Events

The design storms to be used in eastern Washington are based on two parameters:

- Total rainfall volume (depth in inches)
- Rainfall distribution (dimensionless)

The design storm event is specified by return period (months and/or years) and duration. The following sections explain total rainfall depth and rainfall distribution associated with a design storm.

All storm event hydrograph methods require the input of a rainfall distribution or design storm hyetograph. Essentially, the design storm hyetograph is a plot of rainfall depth versus time for a given design period and duration. It is usually presented as a dimensionless plot of unit rainfall depth (incremental rainfall depth for each time interval divided by the total rainfall depth) versus time.

Design storm distribution for all eastern Washington Climatic Regions – 1, 2, 3, and 4:

- **Flow-Based BMPs**: The short-duration storm distribution.
- **Volume-Based BMPs**: The SCS Type 1A storm distribution (Regions 2 and (3) or the regional long-duration storm (Regions 1–4).

## 4C-1 SCS Type II and Type 1A Hyetographs

The Type II hyetograph is a standard SCS (NRCS) rainfall distribution that has a high intensity peak. It has been used in eastern Washington since the 1970s and is also used throughout much of the United States. The Type IA hyetograph is also a standard NRCS rainfall distribution. It is applicable to western Washington and Climatic Regions 2 and 3 in eastern Washington. These are two of four 24-hour storm distribution types commonly used in SCS hydrograph methods.

For graphical representation of these two SCS hyetographs, see Figures 4C-1 and 4C-2. Tabular values of these hyetographs are in Tables 4C-3 and 4C-4.

## 4C-2 Custom Design Storm Hyetographs

When rainfall patterns during storms were analyzed in eastern Washington (see Appendix 4A), it was concluded that the SCS Type II rainfall distribution does not match the historical records for two storm types of interest for stormwater analyses in eastern Washington: the short-duration thunderstorm and the long-duration winter storm.

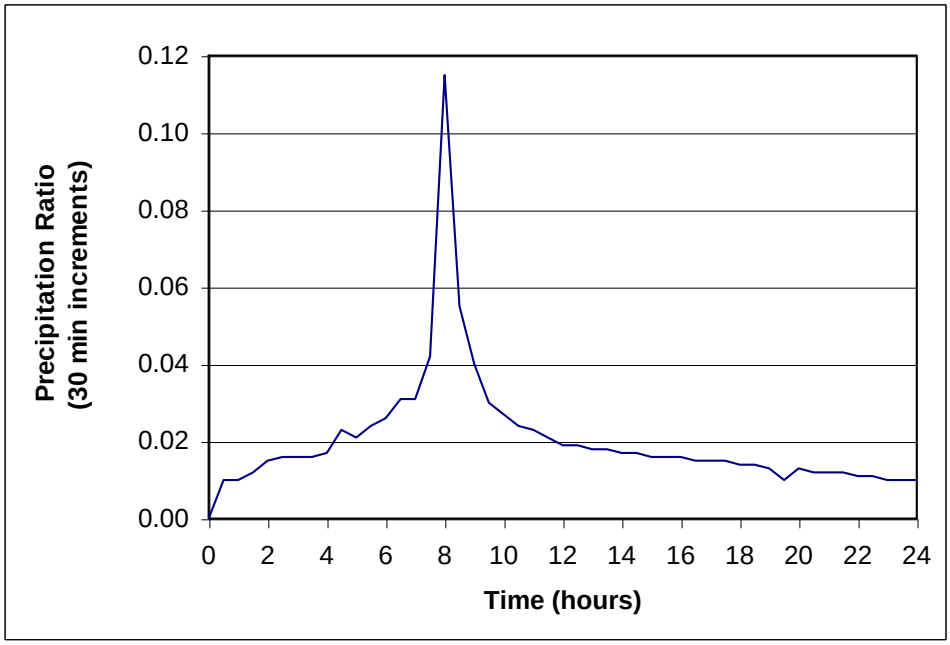



**Figure 4C-1 SCS Type 1A hyetograph.**

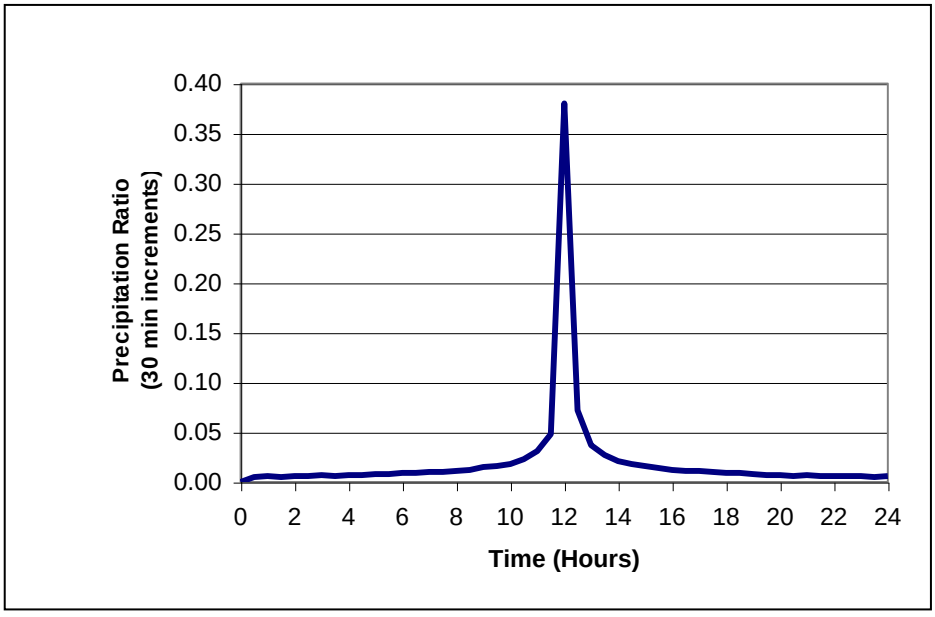
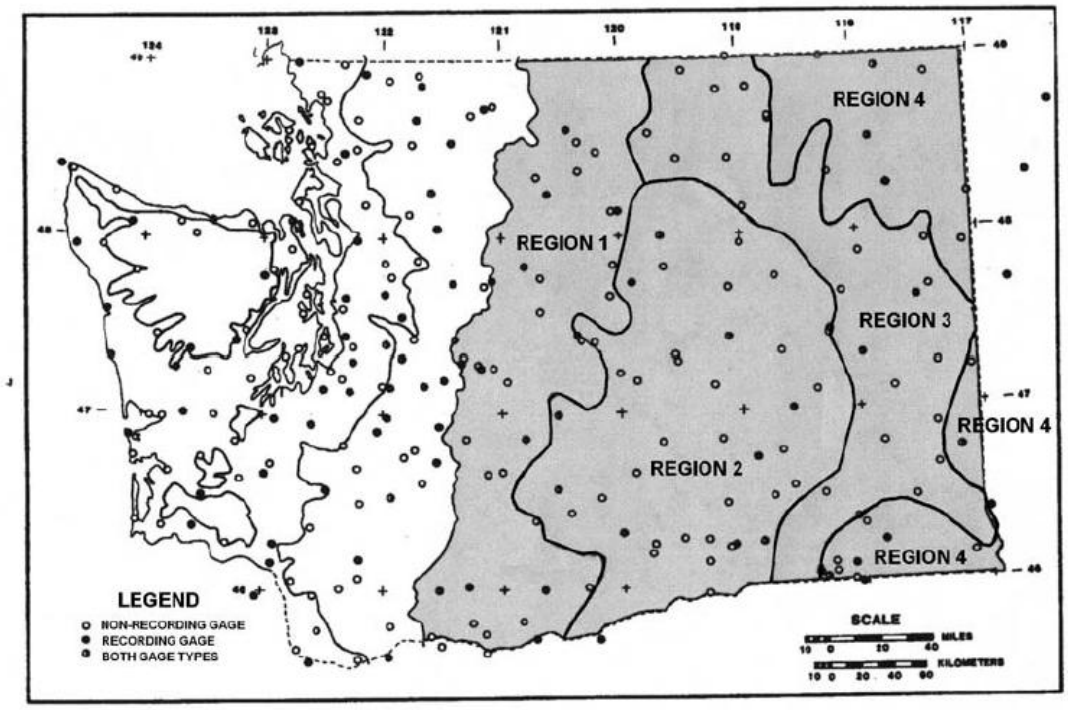



**Figure 4C-2 SCS Type II hyetograph.**

Short-duration thunderstorms can occur in late spring through early fall and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash flooding in urban areas and are important where flood peak discharge and/or erosion are design considerations.

Long-duration general storms can occur at any time of the year, but are more common in late fall through winter and in late spring and early summer. General storms in eastern Washington are characterized by sequences of storms and intervening dry periods, often occurring over several days. Low-to-moderate intensity precipitation is typical during the periods of storm activity. These types of events can produce floods with moderate peak discharge and large runoff volumes. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early spring storms. These types of storm events are important where both runoff volume and peak discharge are design considerations.

When using the custom design storms, it is necessary to note that eastern Washington has been divided into four climatic regions to reflect the differences in storm characteristics and the seasonality of storms. The four climatic regions are shown as follows:




## Region 1 – East Slopes of the Cascade Mountains

This region is comprised of mountain areas on the east slopes of the Cascade Mountains. It is bounded on the west by the Cascade crest and generally bounded to the east by the contour line of 16 inches mean annual precipitation.

### Region 2 – Central Basin

The Central Basin Region is comprised of the Columbia Basin and adjacent low elevation areas in central Washington. It is generally bounded on the west by the contour line of 16 inches mean annual precipitation at the base of the east slopes of the Cascade Mountains. The region is bounded on the north and east by the contour line of 12 inches mean annual precipitation. Most of this region receives about 8 inches of mean annual precipitation. Many of the larger cities in eastern Washington are in this region, including Ellensburg, Kennewick, Moses Lake, Pasco, Richland, Wenatchee, and Yakima.

### Region 3 – Okanogan, Spokane, Palouse

This region is comprised of intermountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded on the northwest by the contour line of 16 inches mean annual precipitation at the base of the east slopes of the Cascade Mountains. It is bounded on the south and west by the contour line of 12 inches mean annual precipitation at the eastern edge of the Central Basin. It is bounded on the northeast by the Kettle River Range and Selkirk Mountains at approximately the contour line of 22 inches mean annual precipitation. It is bounded on the southeast by the Blue Mountains; also at the contour line of 22 inches mean annual precipitation.

### Region 4 – Northeastern Mountains and Blue Mountains

This region is comprised of mountain areas in the easternmost part of Washington State. It includes portions of the Kettle River Range and Selkirk Mountains in the northeast and the Blue Mountains in the southeast corner of eastern Washington. Mean annual precipitation ranges from a minimum of 22 inches to over 60 inches. The western boundary of this region is the contour line of 22 inches mean annual precipitation.

## 4C-3 Storm Analysis

Based on analyses of historical storms in eastern Washington, it has been concluded that the short-duration summer thunderstorm typically generates the greatest peak discharges for small urban watersheds. Use of short-duration thunderstorms is therefore appropriate for designing conveyance structures and biofiltration swales. Analyses also indicate that the long-duration winter storm typically generates the greatest runoff volume. Long-duration design storms are therefore appropriate for designing stormwater detention and runoff treatment facilities where runoff volume is the primary concern. The Type 1A storm distribution is used for volume-based BMPs in Climatic Regions 2 and 3, or the regional long-duration distribution can be used in Climatic Regions 1–4.

Based on these analyses, synthetic design storms were developed for the short-duration thunderstorm and long-duration winter storm. The design storms were developed in a manner that replicated temporal characteristics observed in storms from areas climatologically similar to eastern Washington.

- **Short-Duration Storm**

  Short duration, high intensity, and smaller volumes characterize summer thunderstorms. The short-duration storm was selected to be 3 hours in duration. The storm temporal pattern is shown in Figure 4C-3 as a unit hyetograph. Tabular values are listed in Table 4C-5. Total precipitation is 1.06 times the 2-year, 2-hour precipitation amount to derive the 2-year, 3-hour storm. (See Table 4C-12 for further guidance.) There is one short-duration storm for all climatic regions in eastern Washington.

- **Long-Duration Storm** (varies by region)

  The long-duration storm varies by region and is comprised of a series of storm events separated by a dry intervening period, occurring during a 72-hour period of time. A sample 72-hour long-duration storm hyetograph is shown in Figure 4C-4.

The smaller event (from 6 to 21 hours, above) is insufficient to generate the runoff that is present when the larger precipitation commences. For that reason, it is not necessary to directly model the smaller precipitation event. Only the larger portion (commencing at 36 hours, as shown above) is necessary to directly model.

The larger portion is similar to the 24-hour SCS Type 1A storm. For Climatic Regions 2 and 3, the SCS Type IA storm is sufficiently similar to the four regional long-duration storm hyetographs to use directly.

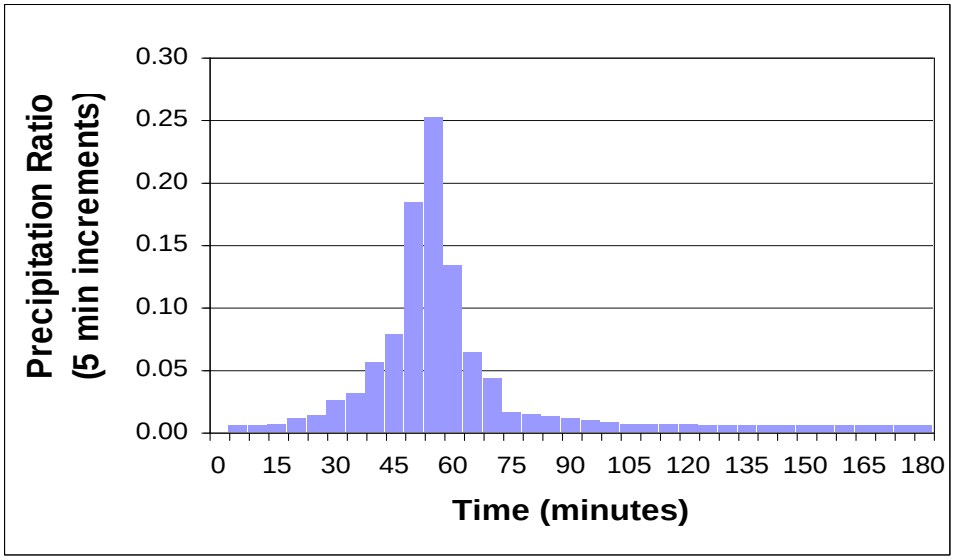



**Figure 4C-3 Short-duration storm unit hyetograph.**

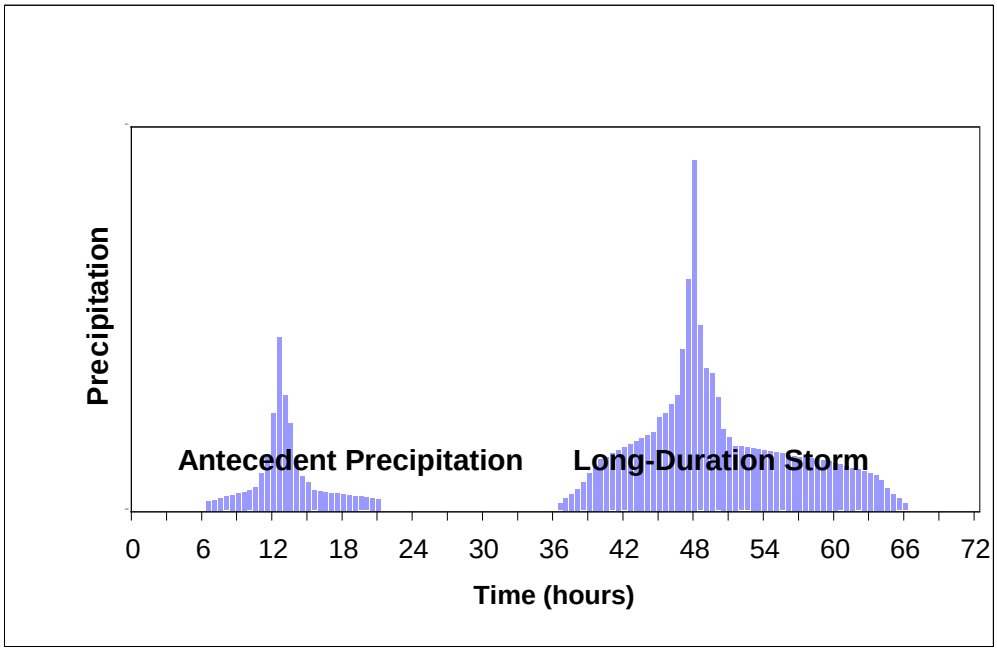



**Figure 4C-4 Sample long-duration storm hyetograph.**

Tabular values of the regional long-duration storm hyetographs are listed in Tables 4C-8 to 4C-11.

If the 24-hour SCS Type 1A storm is used for the long-duration storm, the precipitation totals are the 24-hour amounts without adjustment. If the regional long-duration hyetographs are used, the precipitation totals need to be adjusted as indicated for Regions 1 and 4, using Table 4C-11.

## 4C-4 Antecedent Moisture Condition

Regardless whether the 24-hour SCS Type 1A or regional hyetographs are used for long-duration storm modeling, the prior soil wetting produced by the smaller storm event (from 6 hours to 21 hours, above) that is not modeled needs to be accounted for. The amount of antecedent precipitation can be expressed as a percentage of the total precipitation modeled, as shown in Table 4C-3.

Curve number adjustments are to be considered, based on engineering analysis and judgment of the antecedent precipitation, soils characteristics, and surface conditions. The Antecedent Moisture Condition (AMC) is one basis for adjustment. Another is use of the Soil Conservation Service county surveys that include estimates of permeability and/or infiltration rates. Following is an example of the AMC:

For a 25-year Type 1A storm in Spokane (2.2"), determine whether AMC adjustments need to be considered in the analysis. If so, take the following steps:

1. From Table 4C-1, multiply 2.2" by 27% (Region 3), which equals 0.7". This is the amount of precipitation from the first hump of the long-duration storm.

**Table 4C-1 Antecedent precipitation prior to long-duration storm.**

| Region # | Region Name | Antecedent Precipitation as Percentage of 24-Hour SCS Type 1A Storm Precipitation |
|---|---|---|
| 1 | East Slope Cascades | 33% |
| 2 | Central Basin | 19% |
| 3 | Okanogan, Spokane, Palouse | 27% |
| 4 | NE & Blue Mountains | 36% |

| Region # | Region Name | Antecedent Precipitation as Percentage of Regional Long-Duration Storm Hyetograph Precipitation |
|---|---|---|
| 1 | East Slope Cascades | 28% |
| 2 | Central Basin | 19% |
| 3 | Okanogan, Spokane, Palouse | 25% |
| 4 | NE & Blue Mountains | 34% |

2. Next, determine whether the AMC will affect the CN values using Table 4C-2. If the precipitation from the first storm is over 1.1 or less than 0.5, the CN value will need to be adjusted using Appendix 4B. CN values are generally assumed to be AMC II.

**Table 4C-2 Total 5-day antecedent rainfall (inches).**

| AMC | Dormant Season | Growing Season |
|---|---|---|
| I | Less than 0.5 | Less than 1.4 |
| II | 0.5 to 1.1 | 1.4 to 2.1 |
| III | Over 1.1 | Over 2.1 |

# 4C-5 Precipitation Magnitude/Frequency Analysis

The current source for precipitation magnitude/frequency estimates is NOAA Atlas II, which is based on data collected from about 1940 through 1966, and NOAA Technical Report Number 36, which uses data through the late 1970s. In both of these studies, precipitation statistics were computed for each gage and used to produce point precipitation estimates at each site. The accuracy of the estimates was strongly related to the length of record at each site. Better estimates were obtained for more common events, with lesser accuracy for more rare events.

NOAA published the total depth of rainfall (in tenths of an inch) for storms of 24-hour duration and 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. The information is presented in the form of "isopluvial" maps for each state. Isopluvial maps are contour maps where the contours represent total inches of rainfall for a specific duration.

The web link to the isopluvial map for eastern Washington for the 2-year recurrence interval for the 2-hour duration storm event is in Appendix 4A. This map is from the Dam Safety Guidelines, Technical Note 3, Design Storm Construction, Washington State Department of Ecology, Water Resources Program, Report 92-55G, April 1993. This map is used for designs based on the short-duration storm.

Web links to the isopluvial maps for eastern Washington for the 2-, 10-, 25-, 50- and 100-year recurrence interval for 24-hour duration storm events is in Appendix 4A. These are excerpted from NOAA Atlas 2. The 24-hour isopluvial maps are used for designs based on the long-duration storm and 24-hour storms.

## Table 4C-3 SCS Type 1A storm hyetograph values.

| Time (0.1 hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 0.0 | 0.000 | 0.000 |
| 0.1 | 0.002 | 0.002 |
| 0.2 | 0.002 | 0.004 |
| 0.3 | 0.002 | 0.006 |
| 0.4 | 0.002 | 0.008 |
| 0.5 | 0.002 | 0.010 |
| 0.6 | 0.002 | 0.012 |
| 0.7 | 0.002 | 0.014 |
| 0.8 | 0.002 | 0.016 |
| 0.9 | 0.002 | 0.018 |
| 1.0 | 0.002 | 0.020 |
| 1.1 | 0.003 | 0.023 |
| 1.2 | 0.003 | 0.026 |
| 1.3 | 0.003 | 0.029 |
| 1.4 | 0.003 | 0.032 |
| 1.5 | 0.003 | 0.035 |
| 1.6 | 0.003 | 0.038 |
| 1.7 | 0.003 | 0.041 |
| 1.8 | 0.003 | 0.044 |
| 1.9 | 0.003 | 0.047 |
| 2.0 | 0.003 | 0.050 |
| 2.1 | 0.003 | 0.053 |
| 2.2 | 0.003 | 0.056 |
| 2.3 | 0.004 | 0.060 |
| 2.4 | 0.003 | 0.063 |
| 2.5 | 0.003 | 0.066 |
| 2.6 | 0.003 | 0.069 |
| 2.7 | 0.003 | 0.072 |
| 2.8 | 0.004 | 0.076 |
| 2.9 | 0.003 | 0.079 |
| 3.0 | 0.003 | 0.082 |
| 3.1 | 0.003 | 0.085 |
| 3.2 | 0.003 | 0.088 |
| 3.3 | 0.003 | 0.091 |
| 3.4 | 0.004 | 0.095 |
| 3.5 | 0.003 | 0.098 |
| 3.6 | 0.003 | 0.101 |
| 3.7 | 0.004 | 0.105 |
| 3.8 | 0.004 | 0.109 |
| 3.9 | 0.003 | 0.112 |
| 4.0 | 0.004 | 0.116 |
| 4.1 | 0.004 | 0.120 |
| 4.2 | 0.003 | 0.123 |
| 4.3 | 0.004 | 0.127 |
| 4.4 | 0.004 | 0.131 |
| 4.5 | 0.004 | 0.135 |
| 4.6 | 0.004 | 0.139 |
| 4.7 | 0.004 | 0.143 |
| 4.8 | 0.004 | 0.147 |
| 4.9 | 0.005 | 0.152 |
| 5.0 | 0.004 | 0.156 |
| 5.1 | 0.005 | 0.161 |
| 5.2 | 0.004 | 0.165 |
| 5.3 | 0.005 | 0.170 |
| 5.4 | 0.005 | 0.175 |
| 5.5 | 0.005 | 0.180 |
| 5.6 | 0.005 | 0.185 |
| 5.7 | 0.005 | 0.190 |
| 5.8 | 0.005 | 0.195 |
| 5.9 | 0.005 | 0.200 |
| 6.0 | 0.006 | 0.206 |
| 6.1 | 0.006 | 0.212 |
| 6.2 | 0.006 | 0.218 |
| 6.3 | 0.006 | 0.224 |
| 6.4 | 0.007 | 0.231 |
| 6.5 | 0.006 | 0.237 |
| 6.6 | 0.006 | 0.243 |
| 6.7 | 0.006 | 0.249 |
| 6.8 | 0.006 | 0.255 |
| 6.9 | 0.006 | 0.261 |
| 7.0 | 0.007 | 0.268 |
| 7.1 | 0.007 | 0.275 |
| 7.2 | 0.008 | 0.283 |
| 7.3 | 0.008 | 0.291 |
| 7.4 | 0.009 | 0.300 |
| 7.5 | 0.010 | 0.310 |
| 7.6 | 0.021 | 0.331 |
| 7.7 | 0.024 | 0.355 |
| 7.8 | 0.024 | 0.379 |
| 7.9 | 0.024 | 0.403 |
| 8.0 | 0.022 | 0.425 |
| 8.1 | 0.014 | 0.439 |
| 8.2 | 0.013 | 0.452 |
| 8.3 | 0.010 | 0.462 |
| 8.4 | 0.010 | 0.472 |
| 8.5 | 0.008 | 0.480 |
| 8.6 | 0.009 | 0.489 |
| 8.7 | 0.009 | 0.498 |
| 8.8 | 0.007 | 0.505 |
| 8.9 | 0.008 | 0.513 |
| 9.0 | 0.007 | 0.520 |
| 9.1 | 0.007 | 0.527 |
| 9.2 | 0.006 | 0.533 |
| 9.3 | 0.006 | 0.539 |
| 9.4 | 0.006 | 0.545 |
| 9.5 | 0.005 | 0.550 |
| 9.6 | 0.006 | 0.556 |
| 9.7 | 0.005 | 0.561 |
| 9.8 | 0.006 | 0.567 |
| 9.9 | 0.005 | 0.572 |
| 10.0 | 0.005 | 0.577 |
| 10.1 | 0.005 | 0.582 |
| 10.2 | 0.005 | 0.587 |
| 10.3 | 0.005 | 0.592 |
| 10.4 | 0.004 | 0.596 |
| 10.5 | 0.005 | 0.601 |
| 10.6 | 0.005 | 0.606 |
| 10.7 | 0.004 | 0.610 |
| 10.8 | 0.005 | 0.615 |
| 10.9 | 0.005 | 0.620 |
| 11.0 | 0.004 | 0.624 |
| 11.1 | 0.004 | 0.628 |
| 11.2 | 0.005 | 0.633 |
| 11.3 | 0.004 | 0.637 |
| 11.4 | 0.004 | 0.641 |
| 11.5 | 0.004 | 0.645 |
| 11.6 | 0.004 | 0.649 |
| 11.7 | 0.004 | 0.653 |
| 11.8 | 0.004 | 0.657 |
| 11.9 | 0.003 | 0.660 |
| 12.0 | 0.004 | 0.664 |
| 12.1 | 0.004 | 0.668 |
| 12.2 | 0.003 | 0.671 |
| 12.3 | 0.004 | 0.675 |
| 12.4 | 0.004 | 0.679 |
| 12.5 | 0.004 | 0.683 |
| 12.6 | 0.004 | 0.687 |
| 12.7 | 0.003 | 0.690 |
| 12.8 | 0.004 | 0.694 |
| 12.9 | 0.003 | 0.697 |
| 13.0 | 0.004 | 0.701 |
| 13.1 | 0.004 | 0.705 |
| 13.2 | 0.003 | 0.708 |
| 13.3 | 0.004 | 0.712 |
| 13.4 | 0.004 | 0.716 |

## Table 4C-3. SCS Type IA storm hyetograph values (continued).

| Time (0.1 hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 13.5 | 0.003 | 0.719 |
| 13.6 | 0.003 | 0.722 |
| 13.7 | 0.004 | 0.726 |
| 13.8 | 0.003 | 0.729 |
| 13.9 | 0.004 | 0.733 |
| 14.0 | 0.003 | 0.736 |
| 14.1 | 0.003 | 0.739 |
| 14.2 | 0.004 | 0.743 |
| 14.3 | 0.003 | 0.746 |
| 14.4 | 0.003 | 0.749 |
| 14.5 | 0.004 | 0.753 |
| 14.6 | 0.003 | 0.756 |
| 14.7 | 0.003 | 0.759 |
| 14.8 | 0.004 | 0.763 |
| 14.9 | 0.003 | 0.766 |
| 15.0 | 0.003 | 0.769 |
| 15.1 | 0.003 | 0.772 |
| 15.2 | 0.004 | 0.776 |
| 15.3 | 0.003 | 0.779 |
| 15.4 | 0.003 | 0.782 |
| 15.5 | 0.003 | 0.785 |
| 15.6 | 0.003 | 0.788 |
| 15.7 | 0.004 | 0.792 |
| 15.8 | 0.003 | 0.795 |
| 15.9 | 0.003 | 0.798 |
| 16.0 | 0.003 | 0.801 |
| 16.1 | 0.003 | 0.804 |
| 16.2 | 0.003 | 0.807 |
| 16.3 | 0.003 | 0.810 |
| 16.4 | 0.003 | 0.813 |
| 16.5 | 0.003 | 0.816 |
| 16.6 | 0.003 | 0.819 |
| 16.7 | 0.003 | 0.822 |
| 16.8 | 0.003 | 0.825 |
| 16.9 | 0.003 | 0.828 |
| 17.0 | 0.003 | 0.831 |
| 17.1 | 0.003 | 0.834 |
| 17.2 | 0.003 | 0.837 |
| 17.3 | 0.003 | 0.840 |
| 17.4 | 0.003 | 0.843 |
| 17.5 | 0.003 | 0.846 |
| 17.6 | 0.003 | 0.849 |
| 17.7 | 0.002 | 0.851 |
| 17.8 | 0.003 | 0.854 |
| 17.9 | 0.003 | 0.857 |
| 18.0 | 0.003 | 0.860 |
| 18.1 | 0.003 | 0.863 |
| 18.2 | 0.002 | 0.865 |
| 18.3 | 0.003 | 0.868 |
| 18.4 | 0.003 | 0.871 |
| 18.5 | 0.003 | 0.874 |
| 18.6 | 0.002 | 0.876 |
| 18.7 | 0.003 | 0.879 |
| 18.8 | 0.003 | 0.882 |
| 18.9 | 0.002 | 0.884 |
| 19.0 | 0.003 | 0.887 |
| 19.1 | 0.003 | 0.890 |
| 19.2 | 0.002 | 0.892 |
| 19.3 | 0.003 | 0.895 |
| 19.4 | 0.002 | 0.897 |
| 19.5 | 0.003 | 0.900 |
| 19.6 | 0.003 | 0.903 |
| 19.7 | 0.002 | 0.905 |
| 19.8 | 0.003 | 0.908 |
| 19.9 | 0.002 | 0.910 |
| 20.0 | 0.003 | 0.913 |
| 20.1 | 0.002 | 0.915 |
| 20.2 | 0.003 | 0.918 |
| 20.3 | 0.002 | 0.920 |
| 20.4 | 0.002 | 0.922 |
| 20.5 | 0.003 | 0.925 |
| 20.6 | 0.002 | 0.927 |
| 20.7 | 0.003 | 0.930 |
| 20.8 | 0.002 | 0.932 |
| 20.9 | 0.002 | 0.934 |
| 21.0 | 0.003 | 0.937 |
| 21.1 | 0.002 | 0.939 |
| 21.2 | 0.002 | 0.941 |
| 21.3 | 0.003 | 0.944 |
| 21.4 | 0.002 | 0.946 |
| 21.5 | 0.002 | 0.948 |
| 21.6 | 0.003 | 0.951 |
| 21.7 | 0.002 | 0.953 |
| 21.8 | 0.002 | 0.955 |
| 21.9 | 0.002 | 0.957 |
| 22.0 | 0.002 | 0.959 |
| 22.1 | 0.003 | 0.962 |
| 22.2 | 0.002 | 0.964 |
| 22.3 | 0.002 | 0.966 |
| 22.4 | 0.002 | 0.968 |
| 22.5 | 0.002 | 0.970 |
| 22.6 | 0.002 | 0.972 |
| 22.7 | 0.002 | 0.974 |
| 22.8 | 0.002 | 0.976 |
| 22.9 | 0.002 | 0.978 |
| 23.0 | 0.002 | 0.980 |
| 23.1 | 0.002 | 0.982 |
| 23.2 | 0.002 | 0.984 |
| 23.3 | 0.002 | 0.986 |
| 23.4 | 0.002 | 0.988 |
| 23.5 | 0.002 | 0.990 |
| 23.6 | 0.002 | 0.992 |
| 23.7 | 0.002 | 0.994 |
| 23.8 | 0.002 | 0.996 |
| 23.9 | 0.002 | 0.998 |
| 24.0 | 0.002 | 1.000 |

## Table 4C-4 SCS Type II storm hyetograph values.

| Time (0.1 hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 0.0 | 0.000 | 0.000 |
| 0.1 | 0.001 | 0.001 |
| 0.2 | 0.001 | 0.002 |
| 0.3 | 0.001 | 0.003 |
| 0.4 | 0.001 | 0.004 |
| 0.5 | 0.001 | 0.005 |
| 0.6 | 0.001 | 0.006 |
| 0.7 | 0.001 | 0.007 |
| 0.8 | 0.001 | 0.008 |
| 0.9 | 0.001 | 0.009 |
| 1.0 | 0.002 | 0.011 |
| 1.1 | 0.001 | 0.012 |
| 1.2 | 0.001 | 0.013 |
| 1.3 | 0.001 | 0.014 |
| 1.4 | 0.001 | 0.015 |
| 1.5 | 0.001 | 0.016 |
| 1.6 | 0.001 | 0.017 |
| 1.7 | 0.001 | 0.018 |
| 1.8 | 0.002 | 0.020 |
| 1.9 | 0.001 | 0.021 |
| 2.0 | 0.001 | 0.022 |
| 2.1 | 0.001 | 0.023 |
| 2.2 | 0.001 | 0.024 |
| 2.3 | 0.002 | 0.026 |
| 2.4 | 0.001 | 0.027 |
| 2.5 | 0.001 | 0.028 |
| 2.6 | 0.001 | 0.029 |
| 2.7 | 0.002 | 0.031 |
| 2.8 | 0.001 | 0.032 |
| 2.9 | 0.001 | 0.033 |
| 3.0 | 0.002 | 0.035 |
| 3.1 | 0.001 | 0.036 |
| 3.2 | 0.001 | 0.037 |
| 3.3 | 0.001 | 0.038 |
| 3.4 | 0.002 | 0.040 |
| 3.5 | 0.001 | 0.041 |
| 3.6 | 0.001 | 0.042 |
| 3.7 | 0.002 | 0.044 |
| 3.8 | 0.001 | 0.045 |
| 3.9 | 0.002 | 0.047 |
| 4.0 | 0.001 | 0.048 |
| 4.1 | 0.001 | 0.049 |
| 4.2 | 0.002 | 0.051 |
| 4.3 | 0.001 | 0.052 |
| 4.4 | 0.002 | 0.054 |
| 4.5 | 0.001 | 0.055 |
| 4.6 | 0.002 | 0.057 |
| 4.7 | 0.001 | 0.058 |
| 4.8 | 0.002 | 0.060 |
| 4.9 | 0.001 | 0.061 |
| 5.0 | 0.002 | 0.063 |
| 5.1 | 0.002 | 0.065 |
| 5.2 | 0.001 | 0.066 |
| 5.3 | 0.002 | 0.068 |
| 5.4 | 0.002 | 0.070 |
| 5.5 | 0.001 | 0.071 |
| 5.6 | 0.002 | 0.073 |
| 5.7 | 0.002 | 0.075 |
| 5.8 | 0.001 | 0.076 |
| 5.9 | 0.002 | 0.078 |
| 6.0 | 0.002 | 0.080 |
| 6.1 | 0.002 | 0.082 |
| 6.2 | 0.002 | 0.084 |
| 6.3 | 0.001 | 0.085 |
| 6.4 | 0.002 | 0.087 |
| 6.5 | 0.002 | 0.089 |
| 6.6 | 0.002 | 0.091 |
| 6.7 | 0.002 | 0.093 |
| 6.8 | 0.002 | 0.095 |
| 6.9 | 0.002 | 0.097 |
| 7.0 | 0.002 | 0.099 |
| 7.1 | 0.002 | 0.101 |
| 7.2 | 0.002 | 0.103 |
| 7.3 | 0.002 | 0.105 |
| 7.4 | 0.002 | 0.107 |
| 7.5 | 0.002 | 0.109 |
| 7.6 | 0.002 | 0.111 |
| 7.7 | 0.002 | 0.113 |
| 7.8 | 0.003 | 0.116 |
| 7.9 | 0.002 | 0.118 |
| 8.0 | 0.002 | 0.120 |
| 8.1 | 0.002 | 0.122 |
| 8.2 | 0.003 | 0.125 |
| 8.3 | 0.002 | 0.127 |
| 8.4 | 0.003 | 0.130 |
| 8.5 | 0.002 | 0.132 |
| 8.6 | 0.003 | 0.135 |
| 8.7 | 0.003 | 0.138 |
| 8.8 | 0.003 | 0.141 |
| 8.9 | 0.003 | 0.144 |
| 9.0 | 0.003 | 0.147 |
| 9.1 | 0.003 | 0.150 |
| 9.2 | 0.003 | 0.153 |
| 9.3 | 0.004 | 0.157 |
| 9.4 | 0.003 | 0.160 |
| 9.5 | 0.003 | 0.163 |
| 9.6 | 0.003 | 0.166 |
| 9.7 | 0.004 | 0.170 |
| 9.8 | 0.003 | 0.173 |
| 9.9 | 0.004 | 0.177 |
| 10.0 | 0.004 | 0.181 |
| 10.1 | 0.004 | 0.185 |
| 10.2 | 0.004 | 0.189 |
| 10.3 | 0.005 | 0.194 |
| 10.4 | 0.005 | 0.199 |
| 10.5 | 0.005 | 0.204 |
| 10.6 | 0.005 | 0.209 |
| 10.7 | 0.006 | 0.215 |
| 10.8 | 0.006 | 0.221 |
| 10.9 | 0.007 | 0.228 |
| 11.0 | 0.007 | 0.235 |
| 11.1 | 0.008 | 0.243 |
| 11.2 | 0.008 | 0.251 |
| 11.3 | 0.010 | 0.261 |
| 11.4 | 0.010 | 0.271 |
| 11.5 | 0.012 | 0.283 |
| 11.6 | 0.024 | 0.307 |
| 11.7 | 0.047 | 0.354 |
| 11.8 | 0.077 | 0.431 |
| 11.9 | 0.137 | 0.568 |
| 12.0 | 0.095 | 0.663 |
| 12.1 | 0.019 | 0.682 |
| 12.2 | 0.017 | 0.699 |
| 12.3 | 0.014 | 0.713 |
| 12.4 | 0.012 | 0.725 |
| 12.5 | 0.010 | 0.735 |
| 12.6 | 0.008 | 0.743 |
| 12.7 | 0.008 | 0.751 |
| 12.8 | 0.008 | 0.759 |
| 12.9 | 0.007 | 0.766 |
| 13.0 | 0.006 | 0.772 |
| 13.1 | 0.006 | 0.778 |
| 13.2 | 0.006 | 0.784 |
| 13.3 | 0.005 | 0.789 |
| 13.4 | 0.005 | 0.794 |

## Table 4C-4. SCS Type II storm hyetograph values (continued).

| Time (0.1 hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 13.5 | 0.005 | 0.799 |
| 13.6 | 0.005 | 0.804 |
| 13.7 | 0.004 | 0.808 |
| 13.8 | 0.004 | 0.812 |
| 13.9 | 0.004 | 0.816 |
| 14.0 | 0.004 | 0.820 |
| 14.1 | 0.004 | 0.824 |
| 14.2 | 0.003 | 0.827 |
| 14.3 | 0.004 | 0.831 |
| 14.4 | 0.003 | 0.834 |
| 14.5 | 0.004 | 0.838 |
| 14.6 | 0.003 | 0.841 |
| 14.7 | 0.003 | 0.844 |
| 14.8 | 0.003 | 0.847 |
| 14.9 | 0.003 | 0.850 |
| 15.0 | 0.004 | 0.854 |
| 15.1 | 0.002 | 0.856 |
| 15.2 | 0.003 | 0.859 |
| 15.3 | 0.003 | 0.862 |
| 15.4 | 0.003 | 0.865 |
| 15.5 | 0.003 | 0.868 |
| 15.6 | 0.002 | 0.870 |
| 15.7 | 0.003 | 0.873 |
| 15.8 | 0.002 | 0.875 |
| 15.9 | 0.003 | 0.878 |
| 16.0 | 0.002 | 0.880 |
| 16.1 | 0.002 | 0.882 |
| 16.2 | 0.003 | 0.885 |
| 16.3 | 0.002 | 0.887 |
| 16.4 | 0.002 | 0.889 |
| 16.5 | 0.002 | 0.891 |
| 16.6 | 0.002 | 0.893 |
| 16.7 | 0.002 | 0.895 |
| 16.8 | 0.003 | 0.898 |
| 16.9 | 0.002 | 0.900 |
| 17.0 | 0.002 | 0.902 |
| 17.1 | 0.002 | 0.904 |
| 17.2 | 0.002 | 0.906 |
| 17.3 | 0.002 | 0.908 |
| 17.4 | 0.002 | 0.910 |
| 17.5 | 0.002 | 0.912 |
| 17.6 | 0.002 | 0.914 |
| 17.7 | 0.001 | 0.915 |
| 17.8 | 0.002 | 0.917 |
| 17.9 | 0.002 | 0.919 |
| 18.0 | 0.002 | 0.921 |
| 18.1 | 0.002 | 0.923 |
| 18.2 | 0.002 | 0.925 |
| 18.3 | 0.001 | 0.926 |
| 18.4 | 0.002 | 0.928 |
| 18.5 | 0.002 | 0.930 |
| 18.6 | 0.001 | 0.931 |
| 18.7 | 0.002 | 0.933 |
| 18.8 | 0.002 | 0.935 |
| 18.9 | 0.001 | 0.936 |
| 19.0 | 0.002 | 0.938 |
| 19.1 | 0.001 | 0.939 |
| 19.2 | 0.002 | 0.941 |
| 19.3 | 0.001 | 0.942 |
| 19.4 | 0.002 | 0.944 |
| 19.5 | 0.001 | 0.945 |
| 19.6 | 0.002 | 0.947 |
| 19.7 | 0.001 | 0.948 |
| 19.8 | 0.001 | 0.949 |
| 19.9 | 0.002 | 0.951 |
| 20.0 | 0.001 | 0.952 |
| 20.1 | 0.001 | 0.953 |
| 20.2 | 0.002 | 0.955 |
| 20.3 | 0.001 | 0.956 |
| 20.4 | 0.001 | 0.957 |
| 20.5 | 0.001 | 0.958 |
| 20.6 | 0.002 | 0.960 |
| 20.7 | 0.001 | 0.961 |
| 20.8 | 0.001 | 0.962 |
| 20.9 | 0.002 | 0.964 |
| 21.0 | 0.001 | 0.965 |
| 21.1 | 0.001 | 0.966 |
| 21.2 | 0.001 | 0.967 |
| 21.3 | 0.001 | 0.968 |
| 21.4 | 0.002 | 0.970 |
| 21.5 | 0.001 | 0.971 |
| 21.6 | 0.001 | 0.972 |
| 21.7 | 0.001 | 0.973 |
| 21.8 | 0.002 | 0.975 |
| 21.9 | 0.001 | 0.976 |
| 22.0 | 0.001 | 0.977 |
| 22.1 | 0.001 | 0.978 |
| 22.2 | 0.001 | 0.979 |
| 22.3 | 0.002 | 0.981 |
| 22.4 | 0.001 | 0.982 |
| 22.5 | 0.001 | 0.983 |
| 22.6 | 0.001 | 0.984 |
| 22.7 | 0.001 | 0.985 |
| 22.8 | 0.001 | 0.986 |
| 22.9 | 0.002 | 0.988 |
| 23.0 | 0.001 | 0.989 |
| 23.1 | 0.001 | 0.990 |
| 23.2 | 0.001 | 0.991 |
| 23.3 | 0.001 | 0.992 |
| 23.4 | 0.001 | 0.993 |
| 23.5 | 0.001 | 0.994 |
| 23.6 | 0.002 | 0.996 |
| 23.7 | 0.001 | 0.997 |
| 23.8 | 0.001 | 0.998 |
| 23.9 | 0.001 | 0.999 |
| 24.0 | 0.001 | 1.000 |

## Table 4C-5 Short-duration storm hyetograph values: All regions.

Use 2-hour precipitation value times 1.06 to determine 3-hour total precipitation amount.

| Time (minutes) | Time (hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|---|
| 0 | 0 | 0.0000 | 0.0000 |
| 5 | 0.08 | 0.0047 | 0.0047 |
| 10 | 0.17 | 0.0047 | 0.0094 |
| 15 | 0.25 | 0.0057 | 0.0151 |
| 20 | 0.33 | 0.0104 | 0.0255 |
| 25 | 0.42 | 0.0123 | 0.0378 |
| 30 | 0.50 | 0.0236 | 0.0614 |
| 35 | 0.58 | 0.0292 | 0.0906 |
| 40 | 0.67 | 0.0528 | 0.1434 |
| 45 | 0.75 | 0.0736 | 0.2170 |
| 50 | 0.83 | 0.1736 | 0.3906 |
| 55 | 0.92 | 0.2377 | 0.6283 |
| 60 | 1.00 | 0.1255 | 0.7538 |
| 65 | 1.08 | 0.0604 | 0.8142 |
| 70 | 1.17 | 0.0406 | 0.8548 |
| 75 | 1.25 | 0.0151 | 0.8699 |
| 80 | 1.33 | 0.0132 | 0.8831 |
| 85 | 1.42 | 0.0113 | 0.8944 |
| 90 | 1.50 | 0.0104 | 0.9048 |
| 95 | 1.58 | 0.0085 | 0.9133 |
| 100 | 1.67 | 0.0075 | 0.9208 |
| 105 | 1.75 | 0.0057 | 0.9265 |
| 110 | 1.83 | 0.0057 | 0.9322 |
| 115 | 1.92 | 0.0057 | 0.9379 |
| 120 | 2.00 | 0.0057 | 0.9436 |
| 125 | 2.08 | 0.0047 | 0.9483 |
| 130 | 2.17 | 0.0047 | 0.9530 |
| 135 | 2.25 | 0.0047 | 0.9577 |
| 140 | 2.33 | 0.0047 | 0.9624 |
| 145 | 2.42 | 0.0047 | 0.9671 |
| 150 | 2.50 | 0.0047 | 0.9718 |
| 155 | 2.58 | 0.0047 | 0.9765 |
| 160 | 2.67 | 0.0047 | 0.9812 |
| 165 | 2.75 | 0.0047 | 0.9859 |
| 170 | 2.83 | 0.0047 | 0.9906 |
| 175 | 2.92 | 0.0047 | 0.9953 |
| 180 | 3.00 | 0.0047 | 1.0000 |

## Table 4C-6 Long-duration storm hyetograph values: Region 1 – Cascade Mountains.

Use 24-hour precipitation value times 1.16 to determine long-duration storm precipitation total.

| Time (hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 0.0 | 0.0000 | 0.0000 |
| 0.5 | 0.0024 | 0.0024 |
| 1.0 | 0.0036 | 0.0060 |
| 1.5 | 0.0040 | 0.0101 |
| 2.0 | 0.0047 | 0.0148 |
| 2.5 | 0.0051 | 0.0199 |
| 3.0 | 0.0054 | 0.0253 |
| 3.5 | 0.0058 | 0.0311 |
| 4.0 | 0.0062 | 0.0374 |
| 4.5 | 0.0066 | 0.0439 |
| 5.0 | 0.0078 | 0.0517 |
| 5.5 | 0.0096 | 0.0614 |
| 6.0 | 0.0120 | 0.0733 |
| 6.5 | 0.0138 | 0.0871 |
| 7.0 | 0.0150 | 0.1022 |
| 7.5 | 0.0157 | 0.1179 |
| 8.0 | 0.0164 | 0.1343 |
| 8.5 | 0.0171 | 0.1513 |
| 9.0 | 0.0178 | 0.1691 |
| 9.5 | 0.0185 | 0.1876 |
| 10.0 | 0.0192 | 0.2067 |
| 10.5 | 0.0198 | 0.2266 |
| 11.0 | 0.0205 | 0.2471 |
| 11.5 | 0.0212 | 0.2683 |
| 12.0 | 0.0220 | 0.2904 |
| 12.5 | 0.0226 | 0.3130 |
| 13.0 | 0.0235 | 0.3364 |
| 13.5 | 0.0243 | 0.3608 |
| 14.0 | 0.0297 | 0.3905 |
| 14.5 | 0.0338 | 0.4243 |
| 15.0 | 0.0507 | 0.4750 |
| 15.5 | 0.0315 | 0.5066 |
| 16.0 | 0.0283 | 0.5349 |
| 16.5 | 0.0257 | 0.5606 |
| 17.0 | 0.0231 | 0.5837 |
| 17.5 | 0.0214 | 0.6051 |
| 18.0 | 0.0183 | 0.6234 |
| 18.5 | 0.0168 | 0.6402 |
| 19.0 | 0.0165 | 0.6566 |
| 19.5 | 0.0161 | 0.6728 |
| 20.0 | 0.0158 | 0.6886 |
| 20.5 | 0.0154 | 0.7040 |
| 21.0 | 0.0151 | 0.7191 |
| 21.5 | 0.0148 | 0.7339 |
| 22.0 | 0.0144 | 0.7483 |
| 22.5 | 0.0141 | 0.7623 |
| 23.0 | 0.0137 | 0.7761 |
| 23.5 | 0.0134 | 0.7894 |
| 24.0 | 0.0130 | 0.8025 |
| 24.5 | 0.0127 | 0.8151 |
| 25.0 | 0.0123 | 0.8275 |
| 25.5 | 0.0120 | 0.8395 |
| 26.0 | 0.0117 | 0.8512 |
| 26.5 | 0.0115 | 0.8627 |
| 27.0 | 0.0112 | 0.8739 |
| 27.5 | 0.0110 | 0.8849 |
| 28.0 | 0.0107 | 0.8956 |
| 28.5 | 0.0104 | 0.9060 |
| 29.0 | 0.0102 | 0.9162 |
| 29.5 | 0.0099 | 0.9261 |
| 30.0 | 0.0097 | 0.9358 |
| 30.5 | 0.0088 | 0.9446 |
| 31.0 | 0.0079 | 0.9525 |
| 31.5 | 0.0071 | 0.9596 |
| 32.0 | 0.0063 | 0.9659 |
| 32.5 | 0.0058 | 0.9717 |
| 33.0 | 0.0054 | 0.9772 |
| 33.5 | 0.0050 | 0.9822 |
| 34.0 | 0.0047 | 0.9869 |
| 34.5 | 0.0043 | 0.9912 |
| 35.0 | 0.0039 | 0.9950 |
| 35.5 | 0.0030 | 0.9981 |
| 36.0 | 0.0019 | 1.0000 |

## Table 4C-7 Long-duration storm hyetograph values: Region 2 – Central Basin.

Use 24-hour precipitation value times 1.00 to determine long-duration storm precipitation total.

| Time (hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 0.0 | 0.0000 | 0.0000 |
| 0.5 | 0.0054 | 0.0054 |
| 1.0 | 0.0086 | 0.0140 |
| 1.5 | 0.0100 | 0.0240 |
| 2.0 | 0.0120 | 0.0360 |
| 2.5 | 0.0130 | 0.0490 |
| 3.0 | 0.0140 | 0.0630 |
| 3.5 | 0.0150 | 0.0780 |
| 4.0 | 0.0160 | 0.0940 |
| 4.5 | 0.0170 | 0.1110 |
| 5.0 | 0.0187 | 0.1297 |
| 5.5 | 0.0228 | 0.1525 |
| 6.0 | 0.0283 | 0.1808 |
| 6.5 | 0.0305 | 0.2113 |
| 7.0 | 0.0335 | 0.2448 |
| 7.5 | 0.0365 | 0.2813 |
| 8.0 | 0.0484 | 0.3297 |
| 8.5 | 0.0622 | 0.3919 |
| 9.0 | 0.0933 | 0.4852 |
| 9.5 | 0.0527 | 0.5380 |
| 10.0 | 0.0402 | 0.5782 |
| 10.5 | 0.0372 | 0.6154 |
| 11.0 | 0.0348 | 0.6502 |
| 11.5 | 0.0331 | 0.6833 |
| 12.0 | 0.0289 | 0.7122 |
| 12.5 | 0.0252 | 0.7374 |
| 13.0 | 0.0219 | 0.7593 |
| 13.5 | 0.0191 | 0.7783 |
| 14.0 | 0.0167 | 0.7950 |
| 14.5 | 0.0148 | 0.8098 |
| 15.0 | 0.0134 | 0.8232 |
| 15.5 | 0.0123 | 0.8355 |
| 16.0 | 0.0116 | 0.8471 |
| 16.5 | 0.0110 | 0.8581 |
| 17.0 | 0.0105 | 0.8686 |
| 17.5 | 0.0103 | 0.8789 |
| 18.0 | 0.0103 | 0.8892 |
| 18.5 | 0.0104 | 0.8996 |
| 19.0 | 0.0105 | 0.9100 |
| 19.5 | 0.0105 | 0.9205 |
| 20.0 | 0.0104 | 0.9309 |
| 20.5 | 0.0102 | 0.9412 |
| 21.0 | 0.0100 | 0.9512 |
| 21.5 | 0.0097 | 0.9609 |
| 22.0 | 0.0093 | 0.9702 |
| 22.5 | 0.0087 | 0.9789 |
| 23.0 | 0.0083 | 0.9872 |
| 23.5 | 0.0078 | 0.9950 |
| 24.0 | 0.0050 | 1.0000 |

## Table 4C-8 Long-duration storm hyetograph values: Region 3 – Okanogan, Spokane, Palouse.

Use 24-hour precipitation value times 1.06 to determine long-duration storm precipitation total.

| Time (hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 0.0 | 0.0000 | 0.0000 |
| 0.5 | 0.0017 | 0.0017 |
| 1.0 | 0.0030 | 0.0047 |
| 1.5 | 0.0041 | 0.0088 |
| 2.0 | 0.0053 | 0.0141 |
| 2.5 | 0.0068 | 0.0209 |
| 3.0 | 0.0092 | 0.0301 |
| 3.5 | 0.0108 | 0.0409 |
| 4.0 | 0.0126 | 0.0535 |
| 4.5 | 0.0132 | 0.0667 |
| 5.0 | 0.0139 | 0.0806 |
| 5.5 | 0.0147 | 0.0952 |
| 6.0 | 0.0154 | 0.1106 |
| 6.5 | 0.0162 | 0.1268 |
| 7.0 | 0.0169 | 0.1437 |
| 7.5 | 0.0177 | 0.1614 |
| 8.0 | 0.0184 | 0.1798 |
| 8.5 | 0.0192 | 0.1990 |
| 9.0 | 0.0228 | 0.2219 |
| 9.5 | 0.0238 | 0.2457 |
| 10.0 | 0.0260 | 0.2717 |
| 10.5 | 0.0282 | 0.2999 |
| 11.0 | 0.0395 | 0.3394 |
| 11.5 | 0.0564 | 0.3958 |
| 12.0 | 0.0855 | 0.4813 |
| 12.5 | 0.0451 | 0.5265 |
| 13.0 | 0.0348 | 0.5612 |
| 13.5 | 0.0335 | 0.5948 |
| 14.0 | 0.0276 | 0.6223 |
| 14.5 | 0.0199 | 0.6422 |
| 15.0 | 0.0179 | 0.6601 |
| 15.5 | 0.0158 | 0.6759 |
| 16.0 | 0.0156 | 0.6915 |
| 16.5 | 0.0154 | 0.7069 |
| 17.0 | 0.0152 | 0.7221 |
| 17.5 | 0.0150 | 0.7372 |
| 18.0 | 0.0148 | 0.7519 |
| 18.5 | 0.0145 | 0.7664 |
| 19.0 | 0.0142 | 0.7806 |
| 19.5 | 0.0139 | 0.7945 |
| 20.0 | 0.0136 | 0.8081 |
| 20.5 | 0.0133 | 0.8215 |
| 21.0 | 0.0131 | 0.8346 |
| 21.5 | 0.0130 | 0.8475 |
| 22.0 | 0.0128 | 0.8603 |
| 22.5 | 0.0126 | 0.8729 |
| 23.0 | 0.0123 | 0.8852 |
| 23.5 | 0.0120 | 0.8972 |
| 24.0 | 0.0116 | 0.9088 |
| 24.5 | 0.0112 | 0.9200 |
| 25.0 | 0.0108 | 0.9308 |
| 25.5 | 0.0104 | 0.9412 |
| 26.0 | 0.0100 | 0.9512 |
| 26.5 | 0.0096 | 0.9607 |
| 27.0 | 0.0092 | 0.9699 |
| 27.5 | 0.0086 | 0.9785 |
| 28.0 | 0.0074 | 0.9859 |
| 28.5 | 0.0054 | 0.9913 |
| 29.0 | 0.0040 | 0.9953 |
| 29.5 | 0.0030 | 0.9983 |
| 30.0 | 0.0017 | 1.0000 |

## Table 4C-9 Long-duration storm hyetograph values: Region 4 – Northeastern Mountains and Blue Mountains.

Use 24-hour precipitation value times 1.07 to determine long-duration storm precipitation total.

| Time (hours) | Incremental Rainfall | Cumulative Rainfall |
|---|---|---|
| 0.0 | 0.0000 | 0.0000 |
| 0.5 | 0.0015 | 0.0015 |
| 1.0 | 0.0031 | 0.0046 |
| 1.5 | 0.0047 | 0.0094 |
| 2.0 | 0.0064 | 0.0158 |
| 2.5 | 0.0082 | 0.0239 |
| 3.0 | 0.0104 | 0.0343 |
| 3.5 | 0.0115 | 0.0458 |
| 4.0 | 0.0123 | 0.0581 |
| 4.5 | 0.0130 | 0.0711 |
| 5.0 | 0.0137 | 0.0848 |
| 5.5 | 0.0145 | 0.0993 |
| 6.0 | 0.0152 | 0.1145 |
| 6.5 | 0.0160 | 0.1305 |
| 7.0 | 0.0167 | 0.1472 |
| 7.5 | 0.0174 | 0.1646 |
| 8.0 | 0.0182 | 0.1828 |
| 8.5 | 0.0190 | 0.2019 |
| 9.0 | 0.0207 | 0.2226 |
| 9.5 | 0.0232 | 0.2458 |
| 10.0 | 0.0260 | 0.2717 |
| 10.5 | 0.0278 | 0.2996 |
| 11.0 | 0.0399 | 0.3394 |
| 11.5 | 0.0531 | 0.3925 |
| 12.0 | 0.0796 | 0.4722 |
| 12.5 | 0.0441 | 0.5162 |
| 13.0 | 0.0329 | 0.5492 |
| 13.5 | 0.0303 | 0.5795 |
| 14.0 | 0.0291 | 0.6086 |
| 14.5 | 0.0199 | 0.6284 |
| 15.0 | 0.0166 | 0.6451 |
| 15.5 | 0.0155 | 0.6606 |
| 16.0 | 0.0153 | 0.6759 |
| 16.5 | 0.0151 | 0.6910 |
| 17.0 | 0.0149 | 0.7059 |
| 17.5 | 0.0148 | 0.7207 |
| 18.0 | 0.0146 | 0.7353 |
| 18.5 | 0.0144 | 0.7496 |
| 19.0 | 0.0142 | 0.7639 |
| 19.5 | 0.0140 | 0.7779 |
| 20.0 | 0.0137 | 0.7915 |
| 20.5 | 0.0134 | 0.8049 |
| 21.0 | 0.0132 | 0.8181 |
| 21.5 | 0.0131 | 0.8312 |
| 22.0 | 0.0129 | 0.8441 |
| 22.5 | 0.0129 | 0.8570 |
| 23.0 | 0.0128 | 0.8697 |
| 23.5 | 0.0127 | 0.8825 |
| 24.0 | 0.0127 | 0.8951 |
| 24.5 | 0.0126 | 0.9077 |
| 25.0 | 0.0124 | 0.9201 |
| 25.5 | 0.0121 | 0.9322 |
| 26.0 | 0.0116 | 0.9438 |
| 26.5 | 0.0109 | 0.9547 |
| 27.0 | 0.0101 | 0.9647 |
| 27.5 | 0.0090 | 0.9738 |
| 28.0 | 0.0077 | 0.9814 |
| 28.5 | 0.0061 | 0.9875 |
| 29.0 | 0.0051 | 0.9926 |
| 29.5 | 0.0045 | 0.9971 |
| 30.0 | 0.0029 | 1.0000 |

# 4C-6 Precipitation Magnitude for 24-Hour and Long- and Short-Duration Runoff Treatment Storm

The frequency of the long-duration runoff treatment storm is a 6-month recurrence interval or twice per year return period. Unfortunately, the NOAA Atlas 2 maps require the conversion of 2-year, 24-hour precipitation to 6-month, 24-hour precipitation.

The following equation is used to determine the 6-month precipitation:

$$P_{wqs} = C_{wqs} (P_{2yr24hr})$$

where: $P_{wqs}$ is the 24-hour precipitation (inches) for the storm recurrence interval of 6 months; this precipitation is used with the long-duration storm hyetograph or 24-hour SCS (NRCS) Type IA or Type II hyetographs, depending on the design storm option selected by the jurisdiction;

$C_{wqs}$ is a coefficient from Table 4C-10 for computing the 6-month, 24-hour precipitation based on the climatic region; and

$P_{2yr24hr}$ is the 2-year, 24-hour precipitation in Appendix 4A.

Values of the coefficient $C_{wqs}$ are shown in Table 4C-10 for all four regions.

**Table 4C-10 Coefficients $C_{wqs}$ for computing 6-month, 24-hour precipitation.**

| Region # | Region Name | $C_{wqs}$ |
|---|---|---|
| 1 | East Slope Cascades | 0.70 |
| 2 | Central Basin | 0.66 |
| 3 | Okanogan, Spokane, Palouse | 0.69 |
| 4 | NE & Blue Mountains | 0.70 |

# 4C-7 Precipitation Magnitude for Long-Duration Storms

Table 4C-11 provides the multipliers, by region, for the conversion of the 24-hour precipitation to the regional long-duration storm precipitation. Using the precipitation values from the isopluvial maps and the conversion factor in Table 4C-11, the precipitation can be adjusted for the long-duration hyetograph. The design of volume-based BMPs requires the regional long-duration storm in Regions 1 and 4. For Regions 2 and 4, designers can choose either the SCS Type 1A storm distribution or the regional long-duration storm. When the Type 1A storm distribution is used, the conversion factors in Table 4C-11 do not apply.

**Table 4C-11 Conversion factor for 24-hour to regional long-duration storm precipitation.**

| Region # | Region Name | Conversion Factor |
|---|---|---|
| 1 | East Slope Cascades | 1.16 |
| 2 | Central Basin | 1.00 |
| 3 | Okanogan, Spokane, Palouse | 1.06 |
| 4 | NE & Blue Mountains | 1.07 |

The following equation is used to determine the long-duration precipitation for a selected return period:

$$P_{sds} = C_F (P_{N\text{-}yr\ 24\text{-}hr})$$

where: $P_{sds}$ is the precipitation (inches) adjusted for a selected long-duration hyetograph;

$C_F$ is a conversion factor from Table 4C-11, by region, for converting the 24-hour precipitation to the regional long-duration storm precipitation; and

$P_{N\text{-}yr\ 24\text{-}hr}$ is the precipitation from the isopluvial maps for N years and 24 hours, Appendix 4A.

## 4C-8 Precipitation Magnitude for Short-Duration Storms

The only mapped frequency of the short-duration storm is a 2-year, 2-hour recurrence interval. The design of flow-based treatment BMPs using the Single Event Hydrograph Model requires conversion of the 2-year, 2-hour precipitation to the 6-month, 2-hour precipitation. The design of other BMPs or conveyance elements based on the short-duration storm could also require the conversion of the 2-year, 2-hour precipitation to a different recurrence interval.

The following equation is used to determine the 3-hour precipitation for a selected return period:

$$P_{sds} = C_{sds} (P_{2yr2hr})$$

where: $P_{sds}$ is the 3-hour precipitation (inches) for a selected return period for the short-duration storm;

$C_{sds}$ is a coefficient from Table 4C-12 for computing the 2-hour precipitation for a selected return period based on the 2-year, 2-hour precipitation; and

$P_{2yr2hr}$ is the 2-year, 2-hour precipitation in Appendix 4A.

Values of the coefficient $C_{sds}$ are based on the Generalized Extreme Value (GEV) distribution, whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington. Table 4C-12 lists values of the coefficient $C_{sds}$ for selected return periods for various magnitudes of mean annual precipitation. The web link for an isopluvial map of mean annual precipitation is in Appendix 4A (the map can be used to determine the mean annual precipitation for the site).

**Table 4C-12 Precipitation for selected return periods ($C_{sds}$).**

| Region # | Mean Annual Precipitation (in.) | 6-Month | 1-Year | 2-Year | 10-Year | 25-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|---|---|
| | 6-8 | 0.65 | 0.84 | 1.06 | 1.73 | 2.30 | 2.84 | 3.49 |
| | 8-10 | 0.66 | 0.85 | 1.06 | 1.70 | 2.22 | 2.70 | 3.28 |
| 2 | 10-12 | 0.68 | 0.86 | 1.06 | 1.65 | 2.14 | 2.59 | 3.10 |
| 2, 3 | 12-16 | 0.70 | 0.87 | 1.06 | 1.60 | 2.01 | 2.40 | 2.82 |
| 3 | 16-22 | 0.71 | 0.88 | 1.06 | 1.56 | 1.93 | 2.26 | 2.63 |
| | 22-28 | 0.73 | 0.89 | 1.06 | 1.52 | 1.84 | 2.13 | 2.45 |
| | 28-40 | 0.74 | 0.90 | 1.06 | 1.48 | 1.78 | 2.04 | 2.32 |
| | 40-60 | 0.76 | 0.91 | 1.06 | 1.44 | 1.71 | 1.93 | 2.17 |
| 1, 4 | 60-120 | 0.78 | 0.92 | 1.06 | 1.41 | 1.64 | 1.84 | 2.05 |

# CHAPTER 5

# Stormwater Best Management Practices

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# Chapter 5. Stormwater Best Management Practices

## 5-1 Introduction

The intent of this chapter is to provide designers of Washington State Department of Transportation (WSDOT) facilities with specific guidelines and criteria on the proper selection, design, and application of stormwater management techniques. A selection process is presented, along with design considerations for each best management practice (BMP). This chapter also presents ways to combine or enhance the different types of facilities to maximize their efficiency or to better fit within the project site.

Stormwater BMPs are the *physical*, *structural*, and *managerial* practices that, when used singly or in combination, prevent or reduce the detrimental impacts of stormwater, such as the pollution of water, degradation of channels, damage to structures, and flooding. These BMPs can be further characterized as performing the following three essential, yet distinct, functions:

- **Source control:** Prevents or reduces the introduction of pollutants to stormwater.
- **Flow control:** Offsets and attenuates the increased rate of discharge caused by impervious surfaces.
- **Runoff treatment:** Intercepts and reduces the physical, chemical, and biological pollutant loads generated primarily from highway use.

The typical pollutants found in highway runoff that must be considered for treatment include total suspended solids (TSS) and sediments; dissolved metals (such as cadmium, copper, zinc, and lead); polycyclic aromatic hydrocarbons (PAHs); oil and grease; road salts and deicing agents; temperature; and, in some watersheds, nutrients (such as nitrogen and phosphorus).

The BMPs in this manual have been developed using the best available science, and they have been approved by the Washington State Department of Ecology (Ecology). The required application of these BMPs is based on the state-adopted standard of using all known, available, and reasonable technologies (AKART) and methods of prevention, control, and treatment. When used and maintained in conjunction with operational source controls, BMPs can provide a long-term, effective means of preventing violations of water quality standards. However, it is essential that utmost care be taken in the proper selection and site application of the various BMPs for every project to ensure the maximum benefit is obtained.

Many of the BMPs covered in this manual include general recommendations regarding the conditions under which a practice applies, as well as the advantages and disadvantages of that practice. However, it is strongly recommended that designers take an iterative approach to selecting BMPs based on site-specific criteria. This entails being flexible and somewhat creative when determining a final stormwater management solution that works best in each situation. It also requires that stormwater management considerations be wholly integrated

throughout the entire project development decision-making process (see Chapter 2 for further guidelines).

Design guidelines for most of the commonly used permanent BMPs for highway applications can be found in Section 5.4. Guidelines for the design of temporary BMPs used during construction are given in Appendix 6A. For guidelines and criteria on the design of source control BMPs, refer to Volume IV of Ecology's *Stormwater Management Manual for Western Washington* (SMMWW) and Chapter 8 of the *Stormwater Management Manual for Eastern Washington* (SMMEW). For guidelines and criteria on the design and application of temporary spill prevention and containment BMPs during construction, see Section 6-3.

## 5-2 Types and Functions of Permanent Stormwater BMPs

This section of the manual provides a general overview of the currently available BMPs and the circumstances under which they are typically used. Specific design criteria for each BMP can be found in Section 5-4.

Permanent stormwater BMPs are management features that are designed into a project and remain in place throughout the service life of the project. The designer must make sure that the BMPs will provide the desired results and can be maintained within the guidelines established in Section 5-5. The project should be designed to take advantage of the topography, soils, waterways, and natural vegetation at the site. At each stage of the design, the designer should evaluate the potential for stormwater degradation and choose the design with the least impact. The designer must plan the project so construction activities will not generate excessive sediment and runoff leaving the site. Finally, the project must be designed so that stormwater facilities are reasonably accessible to perform the required maintenance.

### 5-2.1 BMPs for Stormwater Source Control

The first consideration in design should be *source control*. Stormwater source controls are designed to prevent pollutants from entering stormwater by eliminating the source of pollution or by preventing the contact of pollutants with rainfall and runoff. Source control BMPs must be applied to the entire project, both existing and new project areas. According to Volume IV, Chapter 2, of the SMMWW and Chapter 8 of the SMMEW, source control BMPs apply to the following WSDOT activities or settings:

- Deicing and anti-icing for streets and highways
- Dust control at disturbed land areas and unpaved roadways and parking lots
- Fueling at dedicated stations
- Illicit connections to storm drains (that is, unpermitted sanitary or process water discharges to a storm drain rather than a sanitary sewer connection)
- Landscaping and lawn/vegetation management
- Maintenance and repair of vehicles and equipment

- Maintenance of roadside ditches
- Maintenance of stormwater drainage and treatment systems
- Painting of buildings and structures (bridges and docks)
- Parking and storage of vehicles and equipment
- Railroad yards
- Spills of oil and hazardous substances
- Storage or transfer (outside) of solid raw materials, byproducts, or finished products
- Urban streets
- Washing and steam cleaning of vehicles, equipment, and building structures

Only a few permanent source control BMPs (such as street sweeping, deicing, and spill control) can be regularly used for a roadway. Source control BMPs are used more commonly during construction and for the permanent portion of nonroadway projects such as rest areas and park-and-ride lots. The source control BMPs for use during construction are detailed in Chapter 6. The designer should refer to Volume IV of the SMMWW and Chapter 8 of the SMMEW for guidelines on selecting proper source control BMPs for permanent facilities. Contact the Environmental Services Office, Hazardous Materials and Solid Waste, for further assistance when a project involves the storage or transfer of hazardous materials or waste products.

## 5-2.2 BMPs for Stormwater Runoff Treatment

Runoff treatment BMPs designed to remove pollutants contained in runoff use a variety of mechanisms, including sedimentation, filtration, plant uptake, ion exchange, adsorption, precipitation, and bacterial decomposition.

Hydrologic criteria and analysis methods for sizing runoff treatment BMPs in western Washington are discussed in Section 4-3. Hydrologic criteria and analysis methods for sizing runoff treatment BMPs in eastern Washington are discussed in Section 4-4. The following overview provides information on the most commonly used runoff treatment BMPs available for highway application.

### 5-2.2.1 Infiltration BMPs

Infiltration BMPs for runoff treatment are discussed in Section 5-4.1.1 and include the following:

- IN.01 – Bioinfiltration Pond
- IN.02 – Infiltration Pond
- IN.03 – Infiltration Trench

- IN.04 – Infiltration Vault
- IN.05 – Drywell

In addition to being the preferred method for flow control, infiltration is a preferred method for runoff treatment, offering the highest level of pollutant removal. Treatment is achieved through settling, biological action, and filtration. One important advantage to using infiltration is that it recharges the groundwater, thereby helping to maintain summertime base flows of streams. Infiltration also produces a natural reduction in stream temperature, which is an important factor in maintaining a healthy habitat for resident species and other in-stream biota.

Infiltration facilities must be preceded by a presettling basin for removing most of the sediment particles that would otherwise reduce the infiltrative capacity of the soil. Infiltration strategies intended to meet runoff treatment goals may be challenging for many project locations in western Washington due to the large space requirements and strict soil and water table requirements (see Sections 5-4.1.1 and 5-4.2.1 for site restrictions). There are generally more opportunities for the use of infiltration BMPs in eastern Washington.

### 5-2.2.2 Dispersion BMPs

Dispersion BMPs are discussed in Section 5-4.1.2 and include the following:

- FC.01 – Natural Dispersion
- FC.02 – Engineered Dispersion

Perhaps the single most promising and effective approach to mitigating the effects of highway runoff in nonurbanized areas is to look for opportunities to use the existing natural area capacity to remove pollutants. Natural dispersion requires that runoff cannot become concentrated in any way as it flows into a preserved naturally vegetated area. The preserved naturally vegetated area must have topographic, soil, and vegetation characteristics that provide for the removal of pollutants. Pollutant removal typically occurs through a combined process of vegetative filtration and shallow surface infiltration.

The most notable benefits associated with natural dispersion are that it maintains and preserves the natural functions; reduces the possibility of further impacts to the adjacent natural areas associated with the construction of physical treatment facilities; and can be very cost-effective. In most cases, this method not only meets the requirements for runoff treatment, but also provides flow attenuation. If channelized drainage features are present and close to the runoff areas requiring treatment, then other types of engineered solutions might be more appropriate.

*Engineered dispersion* techniques use the same removal processes as natural dispersion. For engineered dispersion, a constructed conveyance system directs concentrated runoff to the dispersion area (via storm sewer pipe, ditch, or other methods). The concentrated flow is dispersed at the end of the conveyance system to mimic sheet flow conditions into the dispersion area. Engineered dispersion techniques enhance the modified area with compost-amended soils and additional vegetation. These upgrades help ensure the dispersion area has the capacity and ability to infiltrate surface runoff.

Like any other stormwater BMP, preservation and maintenance protocols must be followed when dispersion techniques are used. Because the terrain features used to provide treatment are, for the most part, indistinguishable from other typical natural or landscaped areas, it is essential that these areas be readily identifiable so they are not altered or destroyed by general maintenance practices or future development. (See Section 5-5 for further criteria.)

### 5-2.2.3 Biofiltration BMPs

Biofiltration BMPs are discussed in Section 5-4.1.3 and include the following:

- RT.02 – Vegetated Filter Strip (basic, narrow area, and compost-amended or CAVFS)
- RT.04 – Biofiltration Swale (basic and compost-amended or CABS)
- RT.05 – Wet Biofiltration Swale
- RT.06 – Continuous Inflow Biofiltration Swale
- RT.07 – Media Filter Drain (previously referred to as Ecology Embankment)
- RT.08 – Bioretention Area

Runoff treatment to remove pollutants can be best accomplished before concentrating the flow. A *vegetated filter strip* provides a very efficient and cost-effective runoff treatment option. Vegetated filter strips function by slowing runoff velocities and filtering out sediment and other pollutants and by providing some infiltration into underlying soils. Vegetated filter strips consist of gradually sloping areas that run adjacent to the roadway. As highway runoff sheets off the roadway surface, it flows through the grass filter. The flow can then be intercepted by a ditch or other conveyance system and routed to a flow control BMP or outfall.

One challenge associated with vegetated filter strips is that sheet flow can sometimes be difficult to maintain. Consequently, vegetated filter strips can be short-circuited by concentrated flows, which create eroded rills or flow channels across the strips. This results in little or no treatment of stormwater runoff. Note: Vegetated filter strips are not recommended for use in arid climates. In semiarid climates, drought-tolerant grasses should be specified.

*Biofiltration swales* also provide an effective means of removing conventional pollutants and offer a relatively low-cost treatment solution. A biofiltration swale consists of a flat-bottomed, shallow-sloped swale planted with grasses. The swales function by slowing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils. Concentrated flow from the roadway section is directed to the high end of the swale. For wider swales, flow spreaders or diffusers are often incorporated into the bioswale to maintain sheet flow and to prevent the formation of small channels within the swale bottom. In addition, the swale design should be analyzed for erosion potential from larger storm events.

Biofiltration swales can also be integrated into the stormwater conveyance system. Existing roadside ditches may be good candidates for upgrading to biofiltration swales. Biofiltration swales are not recommended for use in arid climates. In semiarid climates, drought-tolerant grasses should be specified.

*A wet biofiltration swale* (a variation of a basic biofiltration swale) is for use where the longitudinal slope is slight, the water table is high, or continuous low base flow will likely result in saturated soil conditions.

Another variation of a basic biofiltration swale is the *continuous inflow biofiltration swale* for applications where water enters a biofiltration swale continuously along the side slope, rather than being concentrated at the upstream end.

A number of BMPs are available that integrate amendments into their soil composition. Soil amendments can be a variety of materials but usually consist of a 2- to 6-inch-thick blanket of compost, spread over the existing soil. They may be left as a blanket or incorporated into the soil to improve soil quality and texture, and thus improve infiltration. Soil amendments bind to dissolved metals, while biota in organic soil break down and neutralize the surface runoff pollutants. Soil amendments also have a very high capacity to hold moisture (up to 1½ times their weight) and can significantly reduce off-site flows. For more information on soil properties and composition, see Section 5-4.3.2, Soil Amendments.

The *media filter drain* is another option to provide significant pollution reduction and flow attenuation by simply modifying the effective treatment surface of the roadway prism beyond the edge of pavement. Its application is limited to highways located in relatively flat terrain, but this BMP can often be constructed with little or no additional right of way, making it a cost-effective solution to managing highway runoff.

Another similar and effective BMP using soil amendments is the *compost-amended vegetated filter strip* (CAVFS), which is a variation of the standard vegetated filter strip. This BMP incorporates compost amendments and subsurface gravel courses to augment the vegetation's basic treatment properties while also supplementing the need for a flow control system by providing a limited amount of storage.

### 5-2.2.4 Wet Pool BMPs

Wet pool BMPs are discussed in Section 5-4.1.4 and include the following:

- RT.12 – Wet Pond
- CO.01 – Combined Wet/Detention Pond
- RT.13 – Constructed Stormwater Treatment Wetland
- CO.02 – Combined Stormwater Treatment Wetland/Detention Pond

*Wet ponds* are constructed basins containing a permanent pool of water throughout the wet season. Wet ponds function by settling suspended solids. The biological action of plants and bacteria provides some additional treatment. Not only can wet ponds be designed for the treatment of conventional pollutants, they can also be modified to enhance removal of

nutrients or dissolved metals. Wet ponds are usually more effective and efficient when constructed using multiple cells (a series of individual smaller basins) where coarser sediments become trapped in the first cell or forebay. Wet pond designs can also provide flow control by adding detention volume (live storage) above the dead storage. Because the function of a wet pond depends upon maintaining a permanent pool of water to provide treatment, this BMP is generally not recommended for use in arid or semiarid climates.

A wet pool BMP must be an on-line facility receiving runoff from only new impervious areas or equivalent areas. If a decision has been made to treat runoff from existing impervious surfaces per the retrofit instructions in Section 3-4, then the wet pool BMP would be an on-line facility receiving runoff from the new plus existing impervious areas or equivalent areas.

Constructed stormwater treatment wetlands can be designed for runoff treatment alone or to serve the dual function of runoff treatment and flow control. This BMP requires the collection and conveyance of stormwater to the facility inlet. Sediment and associated pollutants are removed in the first cell of these systems via settling. The processes of *settling*, *biofiltration*, *biodegradation*, and *bioaccumulation* provide additional treatment in the subsequent cell or cells. In general, constructed stormwater treatment wetlands could be incorporated into the drainage design wherever water can be collected and conveyed to a maintainable artificial basin.

Constructed stormwater treatment wetlands offer a suitable alternative to wet ponds or biofiltration swales and can also provide treatment for dissolved metals. However, designers must consider the availability of water and the water needs of plants used in the stormwater wetland. The landscape context for stormwater wetland placement must be appropriate for the creation of an artificial wetland (groundwater, soils, and surrounding vegetation). Natural wetlands cannot be used for stormwater treatment purposes. (See Section 3-3.7 for further guidelines on protecting existing wetlands.)

Very few constructed stormwater wetlands exist in Washington State. Limited information is available concerning the long-term viability of vegetation installed in these facilities and the maintenance requirements. However, constructed stormwater wetlands can be a preferred option for stormwater management relative to other surface treatment and flow control facilities. In general, this option is a more aesthetically appealing alternative to ponds. Secondary functions include the creation of habitat for terrestrial wildlife, visual screening, and reduced obtrusiveness of drainage facilities.

### 5-2.2.5 Oil Control BMPs

Oil control BMPs are discussed in Sections 5-3.4, 5-4.1.3, 5-4.1.5, and 5-4.2.1 and include the following:

- RT.22 – Oil Containment Boom (high-use sites)
- IN.01 – Bioinfiltration Pond (eastern Washington high-use roadways and parking areas)

- RT.02 – Vegetative Filter Strip: Only Compost-Amended Vegetative Filter Strip (CAVFS) approved for eastern Washington high-use roadway and parking areas)

### 5-2.2.6 Phosphorous Control BMPs

Phosphorous control BMPs are discussed in Sections 5-4.1.3 and 5-4.1.4 and include the following:

- RT.12 – Wet Pond (large)
- RT.07 – Media Filter Drain (previously referred to as the Ecology Embankment)

## 5-2.3 BMPs for Stormwater Flow Control

Stormwater flow control BMPs are designed to control the flow rate or the amount of runoff leaving a site after development. The primary mechanisms used to manage flow control include *dispersion*, *infiltration*, and *detention*. Increased flows can cause downstream damage due to flooding, erosion, and scour, as well as degradation of water quality and in-stream habitat because of channel and streambank erosion.

Hydrologic criteria and analysis methods for sizing flow control BMPs are discussed in Section 4-3 for western Washington and Section 4-4 for eastern Washington. The following provides an overview of the most commonly used flow control BMPs for highway application.

### 5-2.3.1 Infiltration BMPs

Infiltration BMPs for flow control are discussed in Section 5-4.2.1 and include the following:

- IN.01 – Bioinfiltration Pond (eastern Washington only)
- IN.02 – Infiltration Pond
- IN.03 – Infiltration Trench
- IN.04 – Infiltration Vault
- IN.05 – Drywell
- IN.06 – Permeable Pavement Surfaces

A bioinfiltration pond is categorized in this manual under infiltration BMPs for convenience and consistency. It actually functions as both a filtering BMP and an infiltration BMP and can therefore provide runoff treatment and flow control on a limited basis.

Two commonly used types of infiltration systems are *infiltration ponds* and *subsurface infiltration*. An infiltration pond consists of a shallow impoundment designed to infiltrate stormwater into the soil. Subsurface infiltration may occur via an infiltration trench, vault, or drywell subject to the underground injection control (UIC) rules: www.ecy.wa.gov/programs/wq/grndwtr/uic/index.html. (See Sections 2-6.1.3 and 4-5.1 for further guidelines on wellhead protection areas.)

An infiltration trench (also termed an infiltration gallery) consists of a rock-filled trench with no outlet. Typically, the trench also incorporates a large underdrain pipe to increase capacity. Runoff is then stored in the pipe and rock voids and slowly infiltrates through the bottom and sides of the trench and into the soil matrix over a couple of days. For trenches, this process is also referred to as *exfiltration*. Drywells consist of perforated manhole structures surrounded by drain rock and function similarly to trenches.

Infiltration systems are practicable only in areas where groundwater tables are sufficiently below the bottom of the facility and in highly permeable soil conditions. Infiltration systems can help recharge the groundwater, thus restoring base flows to stream systems. However, to protect the groundwater and prevent clogging of the system, stormwater runoff must first pass through some combination of pretreatment measures, such as a swale or sediment basin, before entering an infiltration system. Compared with other stormwater flow control practices, infiltration systems can be problematic due to siltation.

Subsurface infiltration systems should be considered only when room is inadequate to construct an infiltration pond. These systems are difficult to maintain and verify whether they are functioning properly.

### 5-2.3.2 Dispersion BMPs

Dispersion BMPs for flow control are discussed in Section 5-4.2.2 and include the following:

- FC.01 – Natural Dispersion
- FC.02 – Engineered Dispersion

For an overview of dispersion techniques, see Section 5-2.2.2.

### 5-2.3.3 Detention BMPs

Detention BMPs are discussed in Section 5-4.2.3 and includes the following:

- FC.03 – Detention Pond

Detention facilities generally take the form of either a pond or an underground vault or tank. They operate by providing a volume of live storage with an outlet control structure designed to release flow at a reduced rate over time. A pond can be configured as a dry pond to control flow only or combined with a wet pond to also provide runoff treatment within the same footprint.

## 5-3 BMP Selection Process

This section provides guidelines and criteria to the designer on the selection of permanent BMPs for WSDOT projects. BMP selection is necessary to address permanent stormwater management for a project and complete the Hydraulic Report. The following subsections outline the decision-making process for selecting BMPs for projects.

### 5-3.1 Part I: Determine the Applicable Minimum Requirements and Project-Specific Considerations

Read Chapter 3 to determine the applicable minimum requirements for the project. Start at Section 3-2.1 and analyze the project as a whole. Minimum requirements apply to the project based on the project size from beginning project limit to end project limit within right of way boundaries. Use Figure 3-1 and Figure 3-2 to determine which minimum requirements apply at the project level. If necessary, use Figure 3-3 to determine the applicable minimum requirement at the threshold discharge area (TDA) level. Next, go to those subsequent sections in Chapter 3 for each applicable minimum requirement and take time to thoroughly read and understand each minimum requirement.

Minimum Requirement 5 (Runoff Treatment) in Section 3-3.5 has a list of water bodies that require only basic treatment. Project TDAs that discharge to water bodies on this list must provide basic runoff treatment, but not enhanced treatment for phosphorus or dissolved metals removal. Minimum Requirement 6 (Flow Control) in Section 3-3.6 lists exempted water bodies. Project TDAs discharging to water bodies on this list do not require flow control. Section 1-1.5 points out where local stormwater requirements could supersede or supplement the guidelines provided herein. Check with a Region or Headquarters (HQ) Hydraulics Office representative when there are questions regarding local jurisdictional requirements.

The existing stormwater outfalls along the project limits should have been identified during the scoping phase of the project (see Section 2-3 for guidelines). If any existing outfalls will be retrofitted, determine the design requirements before continuing the BMP selection process. Check with a Region or HQ Hydraulics Office representative or the HQ Environmental Services Office (ESO), Stormwater & Watersheds Program, for more information about stormwater outfalls and the necessary design requirements.

### 5-3.2 Part II: Select Source Control BMPs

Certain types of activities and facilities may require source control BMPs. Determine whether there are pollutant-generating activities or facilities in the project that warrant source controls. For detailed descriptions of the source control activities and associated BMPs, see Section 2.2 of Volume IV of Ecology's SMMWW or Chapter 8 of the SMMEW. Source control BMPs for the activities listed in Section 5-2.1 must be specified to reduce pollutants. Any deviations from the source control BMPs listed in either the SMMWW or the SMMEW must provide equivalent pollution source control benefits. The Project File must include documentation for why the deviation is considered equivalent. Section 5-3.5.3 describes the process for seeking approval of such deviations. The project may have additional source control responsibilities as a result of area-specific pollution control plans (such as watershed or basin plans, water cleanup plans, groundwater management plans, or lake management plans), ordinances, and regulations.

## 5-3.3 Part III: Select Flow Control BMPs

***For each TDA in the project that exceeds the triggers set forth in Minimum Requirement 6 (see Section 3-3.6 and Figure 3-3, Step 8) and that cannot apply a flow exemption listed in Section 3-3.6.2, select a flow control BMP by using the following process (see Figure 5.3.1).***

**Step 1: Determine whether stormwater mitigation and management can be handled by the natural landscape.**

Dispersion has two components: natural dispersion and engineered dispersion.

**Natural dispersion** (see BMP FC.01 in Section 5-4.2.2) is further divided into two types of dispersion:

- Sheet flow dispersion, which discharges unconcentrated runoff directly into areas adjacent to the roadway that are naturally vegetated.
- Channeled flow dispersion, which collects, conveys, and redisperses runoff into areas that are naturally vegetated.

**Engineered dispersion** (see BMP FC.02 in Section 5-4.2.2) is further divided into two types of dispersion:

- Sheet flow dispersion, which discharges unconcentrated runoff directly into areas adjacent to the roadway that have been landscaped and redeveloped to mimic the benefits of a forested area or native vegetation (eastern Washington).
- Channeled flow dispersion, which collects, conveys, and redisperses runoff into areas that have been landscaped and redeveloped to mimic the benefits of a forested area. The stormwater may not have flowed to the engineered dispersion area before the project. Channeled flows must be redispersed with a flow spreading or dispersal structure.

**Step 2: Determine whether stormwater mitigation can be handled by infiltration.**

***Option 1:*** The first option is to infiltrate runoff through soils that meet the site characterization and site suitability criteria for both flow control and runoff treatment. Infiltration treatment facilities must be preceded by a pretreatment facility such as a presettling basin (see Section 5-4.3.1) to reduce plugging. Any of the basic runoff treatment BMPs can also be used for pretreatment. The facility should be designed to meet the requirements for runoff treatment and flow control. Sections 4-5 and 5-4.2.1 provide guidelines and criteria on applications and design of infiltration facilities (see BMPs IN.01, IN.02, IN.03, and IN.04) that provide both flow control and runoff treatment.

***Option 2:*** The second option is to infiltrate runoff through rapidly draining soils that do not meet the site characterization and site suitability criteria for providing adequate runoff treatment. Refer to Section 5-4.2.1 for design criteria for infiltration facilities intended to provide flow control without runoff treatment (see BMPs IN.02 through IN.05). In this option, a basic runoff treatment facility must be added upstream of the facility. The infiltration facility must provide adequate storage volume to achieve the flow control standards of Minimum Requirement 6 (see Section 3-3.6).

**Step 3: Determine whether a regional detention facility is within or near the project limits.**

Regional detention facilities are usually owned and operated by the local jurisdiction. A fee is paid to the local jurisdiction to allow project stormwater to flow to the regional facility. This method of stormwater mitigation is useful when the project is within a well-developed watershed with very little right of way to allow for infiltration, dispersion, or detention BMPs.

The project office must work with the local jurisdiction to determine whether the regional detention facility has adequate capacity and the ability to meet target discharge rates to mitigate for project stormwater. This requires that the designer verify with the local jurisdiction the design criteria used to size the pond and outlet control structure. If the regional facility was not designed to control flow durations, or has not received approval from Ecology as an alternative in accordance with Ecology's SMMWW or the SMMEW, then WSDOT cannot fully rely on that facility to meet its flow control needs.

**Step 4: Determine whether a combined flow control and runoff treatment facility can be designed for the project.**

Combination stormwater BMPs provide both runoff treatment and flow control in one facility; therefore, a combined facility is often less expensive to construct and has reduced maintenance costs when compared to two separate facilities. If the TDA must provide enhanced runoff treatment, evaluate whether a combination stormwater wetland/detention pond should be used. Items to consider with this BMP are maintenance and monitoring. (Refer to BMPs CO.01 and CO.02 in Section 5-4.1.4 for design criteria for combination stormwater BMPs.) For eastern Washington, a bioinfiltration pond (see BMP IN.01) combined with a drywell (see BMP IN.05) can also be used as a combination facility.

**Step 5: Select a detention BMP.**

If the strategies listed in the preceding four steps cannot mitigate for all TDA flow control requirements, choose a detention BMP (see FC.03) from Section 5-4.2.3.

**Step 6: Document site constraints and select alternative BMP.**

If the strategies listed in the preceding five steps cannot mitigate for all TDA flow control requirements, go to Appendix 2A and document the site constraints. Seek authorization for an alternative BMP using the process discussed in Section 5-3.6.

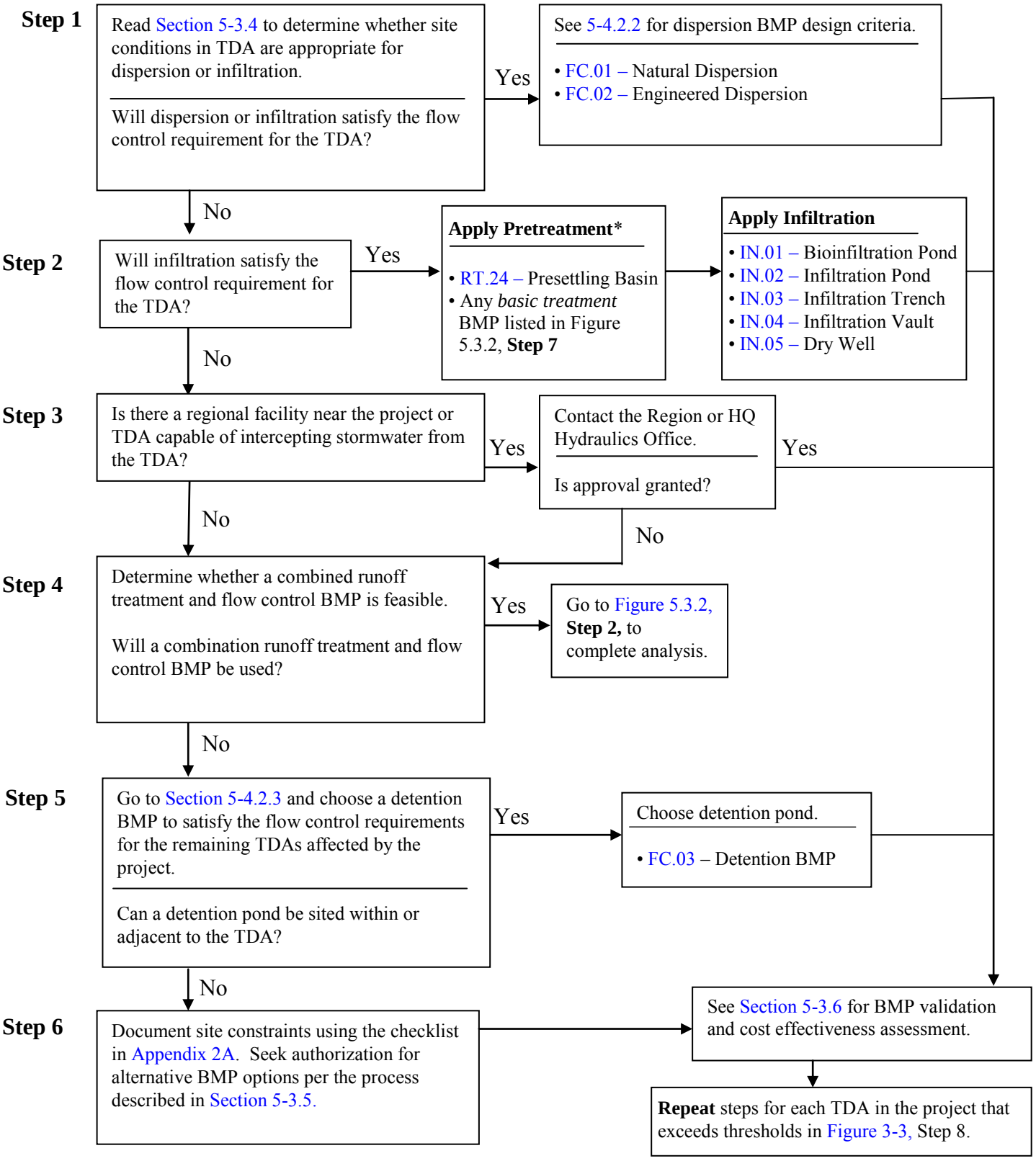



**Figure 5.3.1 Flow control BMP selection flow chart.**

## 5-3.4 Part IV: Select Runoff Treatment BMPs

***For each TDA in the project that exceeds the triggers set forth in Minimum Requirement 5 (see Section 3-3.5 and Figure 3-3, Step 7), select a runoff treatment BMP by using the following process (see Figure 5.3.2).***

**Step 1: If dispersion was selected in Step 1 of Figure 5.3.1, no further steps are required.**

**Step 2: Determine whether an oil control facility or device is required.**

Oil control devices are required for projects that exceed the oil control thresholds in Section 3-3.5.4.

If oil control is required, select and apply an oil treatment facility. (See Figure 5.3.2 for available options that provide oil control and Table 4-9 for a list of other oil control BMPs used for stormwater discharges to UIC facilities.) You must first read and understand the requirements of Section 5-3.6 before moving forward with choosing an oil control BMP from this section. Place oil control BMPs as close to the source as possible, but protected from sediment.

**Step 3: If infiltration was selected in Step 2 of Figure 5.3.1, see Section 4-5 for detailed infiltration design criteria.**

**Step 4: Determine the receiving waters, possible pollutants of concern, and any additional local jurisdictional requirements.**

To obtain a more complete determination of the potential impacts of a stormwater discharge, conduct a downstream analysis to determine the natural receiving waters (groundwater, wetland, lake, river, stream, or marine water) for the stormwater drainage from the project site. This is necessary to determine the applicable treatment menu from which to select treatment facilities. Verify the receiving waters with the responsible local jurisdiction. If the discharge is to a local municipal storm drainage system, the receiving waters for the drainage system must be determined.

- Consult the local jurisdiction to determine whether any type of water quality management plans, local ordinances, or local regulations have established specific requirements for the receiving waters. If approved by Ecology, requirements in these documents should replace or supplement guidelines and criteria given herein with regard to stormwater flow control and runoff treatment. Examples of such plans include the following:

- **Watershed or basin plans:** These plans may cover a wide variety of geographic scales (such as water resource inventory areas or subbasins of a few square miles). They may be focused solely on establishing stormwater requirements (such as stormwater basin plans) or may address a number of pollution and water quantity issues, including urban stormwater (for example, Puget Sound nonpoint action plans).

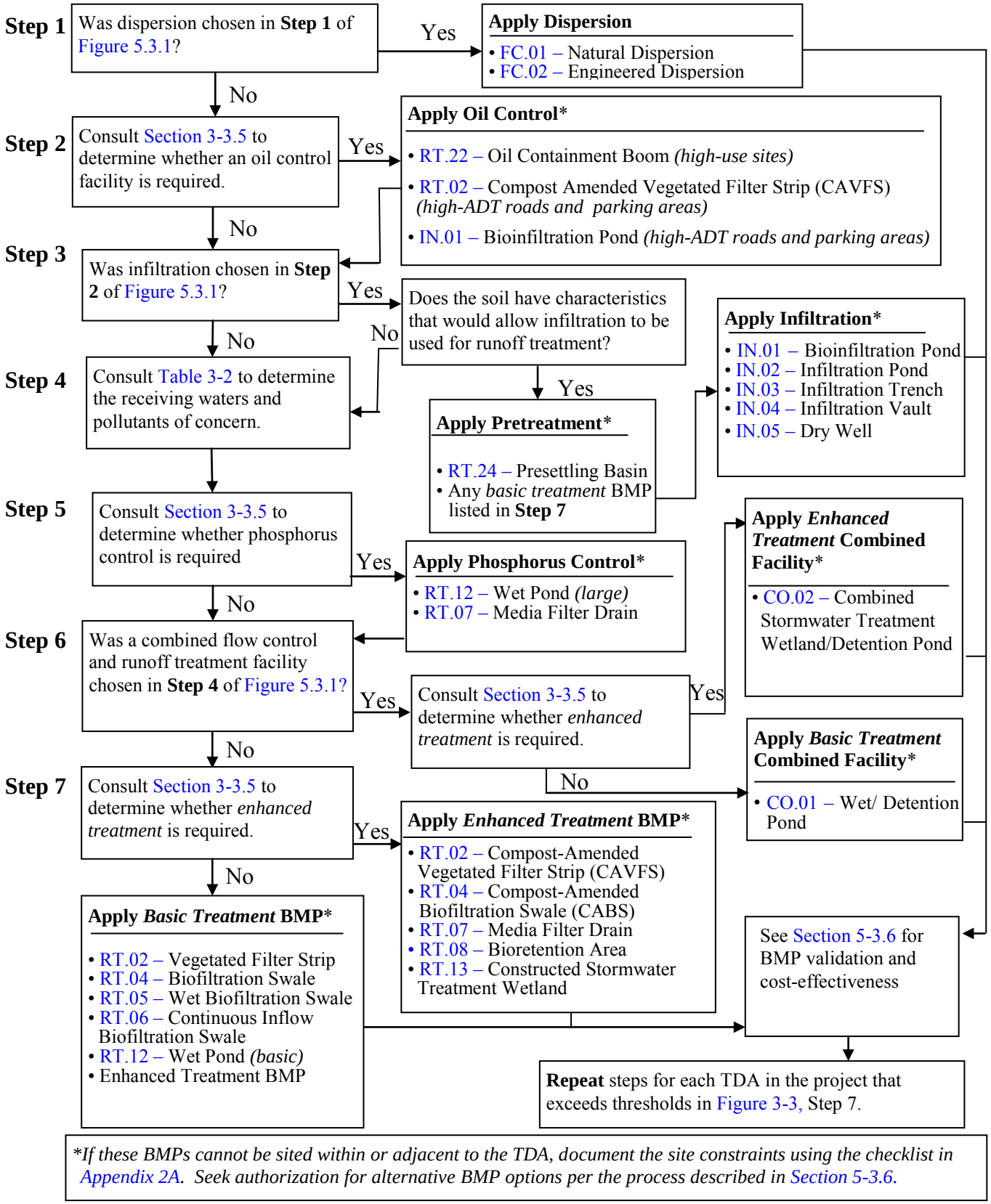



**Figure 5.3.2 Runoff treatment BMP selection flow chart.**

- **Water cleanup plans:** These plans are written to establish a total maximum daily load (TMDL) of a pollutant or pollutants in a specific receiving water or basin and to identify actions necessary to remain below that maximum loading. The plans may identify discharge limitations or management limitations (such as use of specific treatment facilities) for stormwater discharges from new and redevelopment projects.
- **Groundwater management plans** (wellhead protection plans and sole-source aquifers): To protect groundwater quality and quantity, these plans may identify actions required of stormwater discharges.
- **Lake management plans:** These plans are developed to protect lakes from eutrophication due to phosphorus-laden runoff from the drainage basin. Control of phosphorus from new development is a likely requirement in any such plans.

**Step 5: Determine whether phosphorus control is required.**

Please refer to the plans, ordinances, and regulations mentioned in Step 3 as sources of information. The requirement to provide phosphorus control is determined by the local jurisdiction, Ecology, or the U.S. Environmental Protection Agency (U.S. EPA).

The local jurisdiction may have developed a management plan and implementing ordinances or regulations for control of phosphorus discharging to receiving waters from runoff of the new/development areas.

If phosphorus control is required, select and apply a phosphorus treatment facility (see Figure 5.3.2 for available options that provide phosphorus control). If enhanced treatment for dissolved metals removal is required in addition to phosphorus control, select the media filter drain since it provides both phosphorus and enhanced runoff treatment.

**Step 6: Was a combined flow control and runoff treatment facility chosen in Step 4 of Figure 5.3.1?**

To determine whether basic or enhanced runoff treatment is necessary, see Section 3-3.5 and use Table 3-1. Select a constructed stormwater wetland/detention pond for enhanced runoff treatment or select a wet/detention pond if only basic runoff treatment is required for the TDA.

**Step 7: Determine whether enhanced treatment is required.**

To determine whether basic or enhanced runoff treatment is necessary, see Section 3-3.5 and use Table 3-1. Select an appropriate enhanced runoff treatment or basic runoff treatment BMP from Figure 5.3.2, Step 7.

Repeat Figure 5.3.2 for each TDA in the project.

## 5-3.5 Seeking Authorization for Alternative BMP Options

*Note: Prior to seeking approval, designers should consult the Postpublication Updates in the online Highway Runoff Manual (HRM) to check whether the alternative BMP has been added as an available option.*

This chapter contains Ecology-approved permanent BMPs that WSDOT finds acceptable for highway applications. However, site and project constraints or programmatic constraints may compel a designer to consider alternatives to BMPs available in this manual. The pursuit of alternative options falls into the following categories:

1. Ecology-approved BMPs not included in this manual because WSDOT does not consider them viable for widespread highway application due to cost considerations associated with their maintenance. BMPs falling under this category received approval for *general use* by Ecology.

2. BMPs with potential for widespread highway applications that have not received *general use* approval by Ecology. A BMP falling under this category is considered an emerging technology and may or may not have received a *conditional use* or *pilot use* designation by Ecology.

3. Project- or site-specific approaches for seeking compliance with federal and state water quality regulations via the *demonstrative approach*.

Figures 5.3.6.1 and 5.3.6.2 are general descriptions of the processes for seeking approval for runoff treatment and flow control BMPs not currently contained in the HRM. ***To help avoid delays in processing requests, consult Region Hydraulics Office and HQ ESO Stormwater & Watersheds Program staff prior to initiating this process***.

### 5-3.5.1 Category 1: Ecology-Approved BMPs Not in the HRM

Ecology-approved BMPs not included in the HRM require Region Hydraulics Office and Maintenance Superintendent approval for use. Design criteria for these BMPs are available on WSDOT's HRM website: http://www.wsdot.wa.gov/nr/rdonlyres/b415daa4-2c2a-4cc8-93ed-d0cdb9a46560/0/hrmcategory1.pdf. However, if WSDOT approval is not granted, an acceptable alternative must be selected.

### 5-3.5.2 Category 2: Emerging Technologies

Ecology's stormwater management guidance manuals make provisions for using emerging BMP technologies, which they define as:

> *Technologies that have not been evaluated using approved protocols, but for which preliminary data indicate that they may provide a desirable level of stormwater pollutant removal.*

Use of an emerging technology requires WSDOT as well as Ecology approvals, as described in Figure 5.3.6.2.[1] Designers should seek authorization far enough in advance to allow for contingencies if use of the emerging technology is denied. Note: Internal review and approval of an emerging technology's conceptual design and approach can take at least three months.

In some instances, an emerging technology may have already received a *pilot use* or *conditional use* designation from Ecology.[2] For emerging technologies not currently in widespread use, the *pilot use* designation allows limited use by projects to enable field-testing of its performance, subject to an Ecology-approved monitoring plan and the limitations imposed on the number and location of such installations.

Ecology's *conditional use* designation applies to emerging technologies currently in widespread use in Washington (or considered equivalent to Ecology-approved technologies) that it considers likely to attain a *general use* designation—provided that a necessary field evaluation to obtain a *general use* designation is completed within a specified time period.

*Conditional use* BMPs **included** in the HRM can be used on any project location that meets the terms of the *conditional use* designation. However, the designer must contact the HQ ESO Stormwater & Watersheds Program to learn whether WSDOT wants to use the site to fulfill the monitoring requirement of the *conditional use* designation.

Ideally, the project design team identifies the need for potentially pursuing an emerging technologies approach during scoping (the project definition phase) or early in the design phase. This allows the design team, in consultation with the HQ ESO Stormwater & Watersheds Program, to account for the expenses involved in monitoring and evaluating the BMP's performance when programming project costs.

During the project design phase, the design team develops the conceptual design and documents the technical and engineering basis for the approach (*conceptual design thesis*). The conceptual design thesis provides the necessary background to enable the Region Hydraulics Office and the HQ ESO Stormwater & Watersheds Program to make an informed decision about whether it is in the department's interest to invest in the evaluation of the technology.[3] Region Hydraulics Office and HQ ESO Stormwater & Watersheds Program assistance may be sought in preparing this documentation, which should include:

- A description of the emerging technology and its application.
- Rationale for its development and use.
- Existing hydraulic and treatment performance data for the emerging technology (if available).

[1] Ecology's *Emerging Technologies* web page contains additional information regarding Ecology's program to evaluate emerging stormwater treatment technologies.
[2] Ecology's *Emerging Technologies* web page contains the designation status of emerging technologies undergoing evaluation.
[3] This documentation already exists for BMPs with an Ecology *pilot*- or *conditional-use* designation and is available on Ecology's *Emerging Technologies* web page.

- General design and construction considerations.
- Site-suitability characteristics.
- Hydraulic design.
- Operation and maintenance requirements.

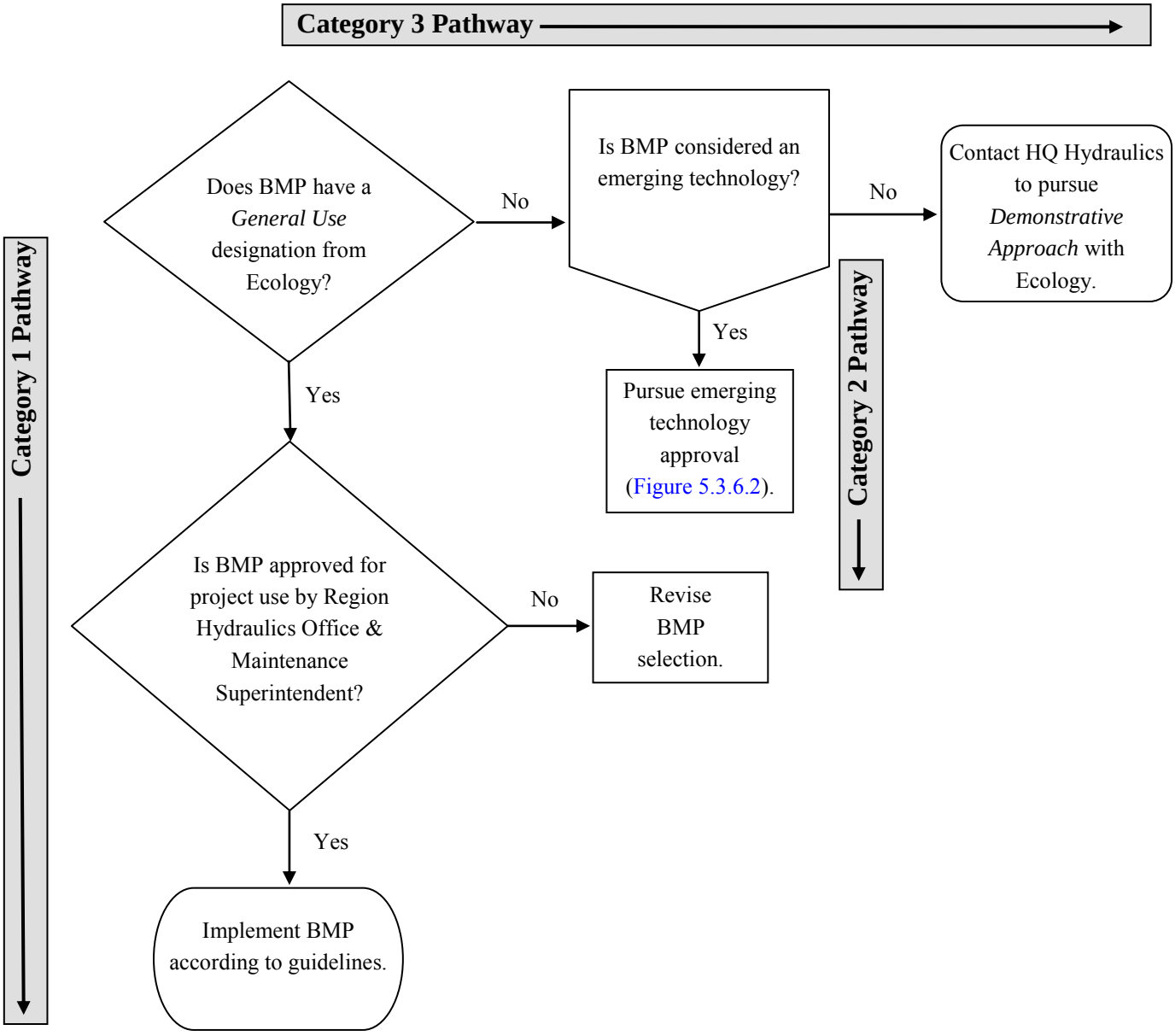



**Figure 5.3.6.1 Process for using BMPs not in the HRM.**

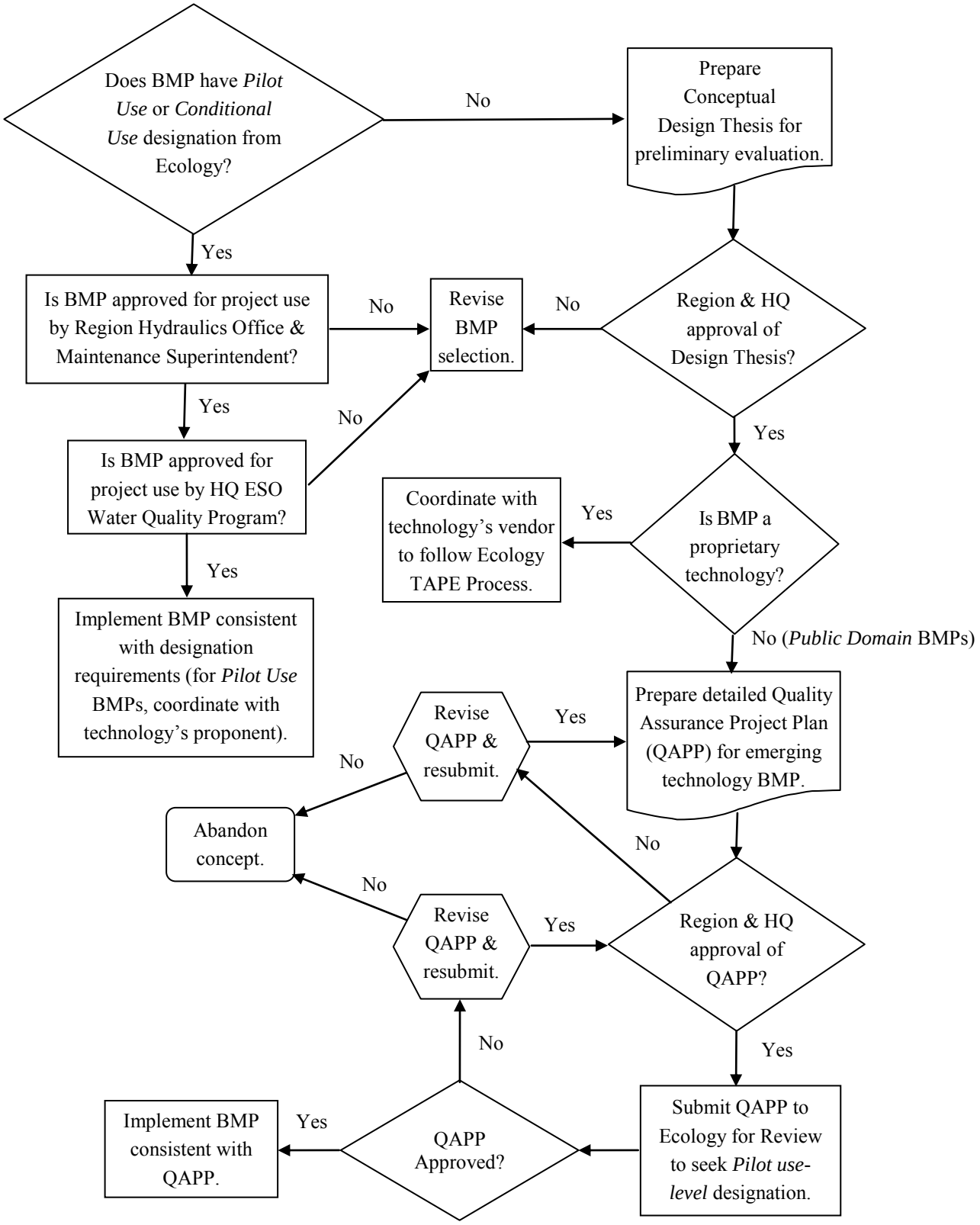



**Figure 5.3.6.2 Emerging technology approval process: Category 2 pathway.**

Pursuing evaluation of an emerging proprietary technology requires coordination with the technology's vendor to follow Ecology's Technology Assessment Protocol (TAPE) and evaluation process. Additional information on the TAPE protocol can be found on Ecology's *Emerging Technologies* web page.

Public domain technologies require preparation of a detailed Quality Assurance Project Plan (QAPP) for evaluating the proposed emerging technology that is acceptable to WSDOT and Ecology. In addition to covering the elements included in the design thesis, the QAPP describes the procedures to be followed in evaluating the emerging technology. Region Hydraulics Office and HQ ESO Stormwater & Watersheds Program assistance should be sought in preparing the QAPP. Ecology's January 2008 publication, *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*, presents detailed instructions on preparing a QAPP. The project's environmental permit coordinator needs to include the design thesis and QAPP in project submittals early in the permitting process. Upon Ecology's approval of the QAPP, the design team must remain involved through completion of construction to ensure proper installation of the facility and any monitoring-related elements.

Once the facility is operational, HQ ESO Stormwater & Watersheds Program staff will assist the region in implementing the QAPP; completing the evaluation package (including monitoring data and data analysis); petitioning Ecology for evaluation and assignment of use-level designation; and continuing development of the technology where applicable.

### 5-3.5.3 Category 3: The Demonstrative Approach

Projects have the option of seeking compliance with water quality regulations via the *demonstrative approach* (see Section 1-1.3 for a comparison of the *demonstrative approach* with the *presumptive approach*). The *demonstrative approach* requires submittal of a site-specific stormwater management proposal to the HQ Hydraulics Office for Ecology review and approval.

Ecology approval requires demonstrating that the project will not adversely affect water quality by providing appropriate supporting data showing that the alternative approach satisfies state and federal water quality laws. In developing alternate treatment and control options, it is important to consider and document the site limitations using the *Engineering and Economic Feasibility Evaluation Checklist* (see Section 2-7.4 and Appendix 2A). While this evaluative tool will provide some of the necessary background information to make decisions regarding alternative approaches, it will not in and of itself satisfy federal and state requirements to make maximum extent practicable (MEP) and all known, available and reasonable technologies (AKART) determinations. Projects pursuing this approach should contact the HQ Hydraulics Office directly, as the timeline and expectations for providing this technical justification may be extensive (depending on the complexity of the individual project and the nature of the receiving water environment).

Depending on the nature of the alternative approach proposal, a dilution analysis may be needed to demonstrate that the project will not adversely affect water quality. If applicable to the proposal, the dilution analysis needs to be based on (1) critical flow rates of the discharge and the receiving water and (2) estimated concentrations of pollutants of

concern in the discharge and the upgradient receiving water. A standard procedure for determining the value of those four variables has yet to be developed by Ecology. Until it is developed, Ecology will have to make case-by-case decisions concerning valid approaches to the analysis.

## 5-3.6 BMP Validation and Cost-Effectiveness

Once a stormwater BMP is selected, the designer should be aware that there are costs and obligations involved in the long-term operation and maintenance of the BMP. For this reason, the designer should contact the local maintenance office and discuss the proposed stormwater BMPs and overall stormwater design to determine any area-specific BMP restrictions or requirements. Table 5.3.1 helps the designer evaluate the cost-effectiveness of different stormwater BMPs by assessing typical construction costs, annual operation and maintenance (O&M) expenses, and effective life (how soon the BMP may need to be replaced).

**Table 5.3.1 Relative rankings of cost elements and effective life of BMP options.**

| BMP | Capital Costs | O&M Costs | Effective Life[1] |
|---|---|---|---|
| Vegetated Filter Strip | Low | Low | 20–50 years |
| Wet Biofiltration Swale | Low to Moderate | Low to Moderate | 5–20 years |
| Continuous Inflow Biofiltration Swale | Low to Moderate | Low | 5–20 years |
| Media Filter Drain | Low | Low to Moderate | 5–20 years[2] |
| Compost-Amended Vegetated Filter Strip | Low | Low | 5–20 years[2] |
| Wet Pond | Moderate to High | Low to Moderate | 20–50 years |
| Combined Wet/Detention Pond | Moderate | Low to Moderate | 20–50 years |
| Constructed Stormwater Treatment Wetland | Moderate to High | Moderate | 20–50 years |
| Combined Stormwater Wetland/Detention Pond | Low to Moderate | Moderate | 20–50 years |
| Wet Vault (Category 1 BMP) | Moderate to High | High | 50–100 years |
| Combined Wet/Detention Vault (Category 1 BMP) | Moderate to High | High | 50–100 years |
| Bioinfiltration Pond | Low to Moderate | Low | 5–20 years |
| Infiltration Pond | Moderate | Moderate | 5–10 years before deep tilling required |
| Infiltration Trench | Moderate to High | Moderate | 10–15 years |
| Infiltration Vault | Moderate | Moderate to High | 5–10 years |
| Drywell | Low to Moderate | Low to Moderate | 5–20 years |
| Engineered and Natural Dispersion | Low | Low | 50–100 years |
| Detention Pond | Moderate | Low | 20–50 years |
| Detention Vault (Category 1 BMP) | Moderate to High | High | 50–100 years |
| Detention Tank (Category 1 BMP) | Moderate to High | High | 50–100 years |
| Presettling Basin | Low to Moderate | Moderate | |
| Proprietary Presettling Devices | Moderate | Moderate | 50–100 years |
| Bioretention | Moderate | Moderate | 5–12 years |

Sources: Adapted from Young et al. (1996); Claytor and Schueler (1996); U.S. EPA (1993); and others.

[1] Assumes regular maintenance, occasional removal of accumulated materials, and removal of any clogged media.

[2] Estimated based on best professional judgment.

### 5-3.6.1 General Maintenance Requirements

Design with maintenance in mind. Maintenance is crucial to performance of runoff treatment and flow control BMPs; therefore, provisions to facilitate maintenance operations must be built into the project when the BMP is installed. Maintenance must be a basic consideration in design and in determination of cost. Include maintenance personnel early and throughout the design process. During discussions with maintenance personnel, describe the maintenance procedures that will need to be performed on the BMP. This will help ensure future maintenance work and potential access needs are clearly understood.

#### General Maintenance Access Requirements

***Access Roads***

- Maximum grade for access roads will vary depending on what type of vehicle the local area maintenance office uses. The designer should contact the local area maintenance office to discuss this issue.
- Outside turning radius should be a minimum of 40 feet.
- Access roads should be 15 feet wide on curves and 12 feet wide (minimum) on straight sections.
- Access roads may be constructed with an asphalt or gravel surface or with modular grid pavement. All surfaces must conform to the WSDOT *Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications)* and to manufacturer's specifications if the surfacing material is a vendor product.
- A paved apron must be provided where access roads connect to paved public roadways.
- Access roads used by Vactor trucks must be built to support loads up to 80,000 pounds.

- Access roads used by trackhoes or dump trucks must be built to support loads up to 40,000 pounds.
- Other access roads must be built to support loads up to 30,000 pounds.
- Fence gates should be located only on straight sections of road.
- If a fence is required, access should be limited by a double-posted gate or by bollards—that is, two fixed bollards on each side of the access road and two removable bollards located equally between the fixed bollards. (See the *Design Manual* for guidelines on fencing requirements).
- The fence gate should be located so there is an adequate area in front of the gate to park a vehicle, out of traffic, while the gate is being opened. The parking area should be sized based on the largest vehicle that will be needed to perform BMP maintenance.

### *Other*

- Side slopes for earthen/grass embankments should not exceed 3H:1V to facilitate mowing. If side slopes are greater than 3H:1V, consult with local area maintenance personnel to ensure tall grass does not restrict site access or pose other issues. Steep embankments may need to be planted with low-maintenance, low-growing ground cover.
- It is recommended that BMPs that require removal of sediment have a fixed vertical sediment depth marker installed in the structure to measure sediment deposition over time. Consult the local area maintenance office regarding the design and use of this marker.

## Vaults/Tanks/Catch Basins/Manholes

### *Access Roads*

- Vaults and tanks should be located out of the roadway prism whenever possible. In most areas, closure of traffic lanes to clean vaults or tanks is not allowed during daylight hours. Maintenance at night involves additional risk and requires worksite lighting and possibly noise restrictions.
- Access roads are needed to the stormwater structure access panel if applicable; the inlet and outlet control structure; and at least one access point per cell.
- Manhole and catch basin lids must be set within or at the edge of the access road and at least 3 feet from a property line. Manhole and catch basin lids for control structures must be locking and rim elevations must match proposed finish grade.
- The Vactor truck needs to park directly adjacent to the stormwater structure. Within 6 feet of the truck, the boom has swing-and-lift capability; however, for most vaults, the operator needs to be able to center the boom directly over the suction point.

- For deep vaults, the operator typically starts at one end and moves the Vactor truck along the vault to clean it from end to end. The deeper the suction tubes, the harder it becomes to drag the boom around, so it must be centered directly above the crew person working down in the stormwater structure.
- Right of way may be needed for vault and tank maintenance. It is recommended that any tract not abutting WSDOT right of way have a 15- to 20-foot-wide extension of the tract to an acceptable access location. Enough room must be designed around all underground vaults and tanks to provide space for necessary support equipment, including holding tanks, towed pumps, and equipment for confined-space entry. Consult with the local area maintenance office on access needs for support equipment.

### *Openings*

- Access must be provided over the inlet pipe, over the outlet structure, and to each cell.
- Access openings must be positioned a maximum of 50 feet from any location within the vault or tank. Additional access points may be needed on large vaults and tanks.
- If more than one V is provided in the vault floor, access to each V must be provided.
- For vaults with greater than 1250 square feet of floor area, a 5- by 10-foot removable panel (instead of a standard frame, grate, and solid cover) should be provided over the inlet pipe.
- Removable panels over vaults must be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- Vaults with widths of 10 feet or less must have removable lids.
- For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided.
- All access openings, except those covered by removable panels, may have round solid locking lids or 3-foot-square locking diamond plate covers.
- Tank access openings may have round, solid locking lids (usually ½- to ⅝-inch-diameter Allen-head cap screws).
- For tanks, riser-type manholes constructed of 36-inch-minimum-diameter corrugated metal pipe 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.

### *Entry*

- Ladders and handholds need be provided only at the outlet pipe and inlet pipe, and as needed to meet WISHA confined-space requirements.
- Stormwater structures must comply with the WISHA 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, just under the access lid.
- If ladders are greater than 20 feet long, fall protection that meets WISHA requirements must be provided.
- Ventilation pipes—minimum 12-inch-diameter or equivalent—should be provided in all four corners of vaults and tanks to allow for artificial ventilation for maintenance personnel.
- Vaults with manhole access at 12-foot intervals or with removable panels over the entire vault need not provide corner ventilation pipes as specified above.
- Internal structural walls of large vaults should be provided with openings sufficient for maintenance access between cells. When applicable, the openings should be sized and situated to allow access to the V in the vault floor.
- The minimum internal height should be 7 feet from the highest point of the vault floor (not sump), and the minimum width should be 4 feet. The minimum internal height requirement may not be applicable for any areas covered by removable panels.

### *Other Access Issues*

- All vaults and tanks need a bypass or valve to take the BMP off-line.
- The gravity drain criteria for ponds (see below) should apply to the wet vaults and combined wet/detention vaults.
- For maintenance access, the maximum depth from finished grade to the bottom of the vault or tank should be 20 feet or less. Most Vactor trucks become inefficient below this depth. Contact the local area maintenance office to discuss operating depths of the equipment for the area.

## Ponds

### *Access Roads*

- One or more access roads must be provided to the outlet control structure and other drainage structures associated with the pond (such as inlet or bypass structures) to allow for inspection and maintenance.
- An access roadway is needed for removal of sediment with a trackhoe and truck. A ramp must extend to the pond bottom if the pond bottom area is greater than 1500 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 1500 square feet (measured without the ramp).

- At large, deep ponds, truck access to the pond bottom via an access ramp is necessary so that excavated sediment and other material can be loaded into a truck in the pond bottom. At small, deep ponds, the truck can remain on the ramp for loading. At small, shallow ponds, a ramp to the bottom may not be required if the trackhoe can load a truck parked at the pond edge or on the internal berm of a detention pond (trackhoes can negotiate interior pond side slopes). These requirements may change based on discussion with the local area maintenance office regarding the type of vehicle typically used for that area.

- Access ramps must be a minimum of 3H:1V.

***Other Access Issues***

- Wet ponds, constructed wetlands, and other stormwater structures with high base flows must have a bypass or valve to take the BMP off-line.

- For wet ponds, combined wet/detention ponds, wet vaults, combined wet/ detention vaults, constructed stormwater treatment wetlands, and combined stormwater treatment wetlands/detention ponds, gravity drains for maintenance shall be installed. (See each BMP description for the number of gravity drains needed for each BMP.)

  *Intent: It is anticipated that in most cases, sediment removal will be needed only for the first cell. 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. If the second cell cannot be drained due to elevation differences or backflow potential, the first cell's gravity drain should discharge to a separate conveyance system.*

- The gravity drain must be at least 8 inches in diameter.

- The gravity drain, controlled by a shut-off valve, shall be provided that can dewater the cell to the elevation listed in each BMP within 24 hours of initial opening. 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.*

- If placed within a dividing berm or baffle, the gravity drain invert must be at least 6 inches below the top elevation of the dividing berm or baffle.

  *Intent: Highly sediment-laden water will be less likely to be released from the pond when it is drained for maintenance.*

- Operational access to the valve must be provided at the finished ground surface.

- The shut-off valve location must be accessible and well marked, with 1 foot of paving placed around the box. It must also be protected from damage and unauthorized operation.

- The shut-off valve casing shall be clearly labeled showing the closed position (normal operation) and open position (dewatering position). The primary purpose of the gravity drain is to provide maintenance to each cell.
- A valve box is allowed to a maximum depth of 5 feet without an access manhole. If the valve box is over 5 feet deep, an access manhole or vault is required.
- Specify that all metal parts must be corrosion-resistant. Galvanized materials should not be used unless unavoidable.

  *Intent: Galvanized metal contributes zinc to stormwater, sometimes in very high concentrations.*

## 5-4 BMP Design Criteria

**Note: Follow the BMP selection process in Section 5-3 before selecting a BMP.**

The stormwater management methods in this section have been categorized in order of preferred use and grouped according to similar composition and function. Each BMP has an associated number to distinguish it from other BMPs with similar names. The numbering convention represents the following classifications:

- RT.XX – Runoff Treatment BMPs
- FC.XX – Flow Control BMPs
- IN.XX – Infiltration BMPs
- CO.XX – Combination BMPs

### 5-4.1 Runoff Treatment Methods

The primary function of the BMPs listed in this section is to meet Minimum Requirement 5 (Runoff Treatment) in Section 3-3.5.

#### 5-4.1.1 Infiltration BMPs

Some infiltration BMPs (IN.01, Bioinfiltration Pond, IN.02, Infiltration Pond, IN.03, Infiltration Trench, and IN.04, Infiltration Vault) can provide both runoff treatment and flow control functions. These BMPs are discussed in detail in Section 5-4.2.1. (See the *Site Suitability Criteria* in Section 4-5.1 for additional requirements.)

#### 5-4.1.2 Dispersion BMPs

Dispersion BMPs (FC.01, Natural Dispersion, and FC.02, Engineered Dispersion) provide both runoff treatment and flow control functions. These BMPs are discussed in detail in Section 5-4.2.2.

## 5-4.1.3 Biofiltration BMPs

### *RT.02 – Vegetated Filter Strip*

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

**Description:** Densely vegetated areas of land with a flat cross slope. Designed to maintain sheet flow which slows runoff and traps sediment and pollutants coming directly off the pavement.

**Geometry Limitations**

| | |
|---|---|
| Resultant Slope | ≤ 9.4% |
| Contributing Flow Path | ≤ 150' |
| Embankment Slope | 2%-33% |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☑ Oil Control (CAVFS E. WA Only)
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced (CAVFS Only)

**Effective Life (Years)**

➲ 20-50

| Capitol Cost | O & M Cost |
|---|---|
| ➲ Low | ➲ Low |

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria (CAVFS only)
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☑ Soil Amendments/Compost
- ☑ Energy Dissipater/Level Spreader
- ☐ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☐ | Fecal Coliform |
| ☑ | ☐ | Phosphorus (CAVFS Only) |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☑ | Dissolved Metals (CAVFS Only) |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☑ | Oil/Grease (CAVFS E. WA only) |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☐ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☑ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5.

## Introduction

### *General Description*

*Vegetated filter strips* are land areas of planted vegetation and amended soils situated between the pavement surface and a surface water collection system, pond, wetland, stream, or river. (See Figure RT.02.1 for an illustration of a typical vegetated filter strip.) The term *buffer strip* is sometimes used interchangeably with vegetated filter strip, but in this manual, buffer strip refers to an area of natural indigenous vegetation that can be enhanced or preserved as part of a riparian buffer or stormwater dispersion system.

Vegetated filter strips accept overland sheet flow runoff from adjacent impervious areas. They rely on their flat cross slope and dense vegetation to maintain sheet flows. Their primary purpose is to remove sediments and other pollutants coming directly off the pavement. Vegetated filter strips function by slowing runoff velocities, trapping sediment and other pollutants, and providing some infiltration and biologic uptake.

The design approach for vegetated filter strips involves site design techniques to maintain prescribed maximum sheet flow distances, as well as to ensure adequate temporary storage, so that the design storm runoff is treated. There is limited ponding or storage associated with vegetated filter strips unless soil amendments and subsurface storage are incorporated into the design to reduce runoff volumes and peak discharges.

Vegetated filter strips can also be used as a pretreatment BMP in conjunction with bioretention, biofiltration, media filtration, or infiltration BMPs. The sediment and particulate pollutant load that could reach the primary BMP is reduced by the pretreatment, which in turn reduces maintenance costs and enhances the pollutant-removal capabilities of the primary BMP.

There are three methods described in this section for designing vegetated filter strips: *basic* vegetated filter strips, *compost-amended* vegetated filter strips (CAVFS), and *narrow area* vegetated filter strips. The narrow area vegetated filter strip is the simplest method to design; however, its use is limited to impervious flow paths less than 30 feet. If space is available to use the basic vegetated filter strip design or the CAVFS, either of the two designs should be used in preference to the narrow area vegetated filter strip. For flow paths greater than 30 feet, designers should follow the design method for the basic vegetated filter strip or the CAVFS.

The basic vegetated filter strip is a compacted roadside embankment that is subsequently hydroseeded. The CAVFS is a variation of the basic vegetated filter strip that adds soil amendments to the roadside embankment. The soil amendments improve infiltration characteristics, increase surface roughness, and improve plant sustainability.

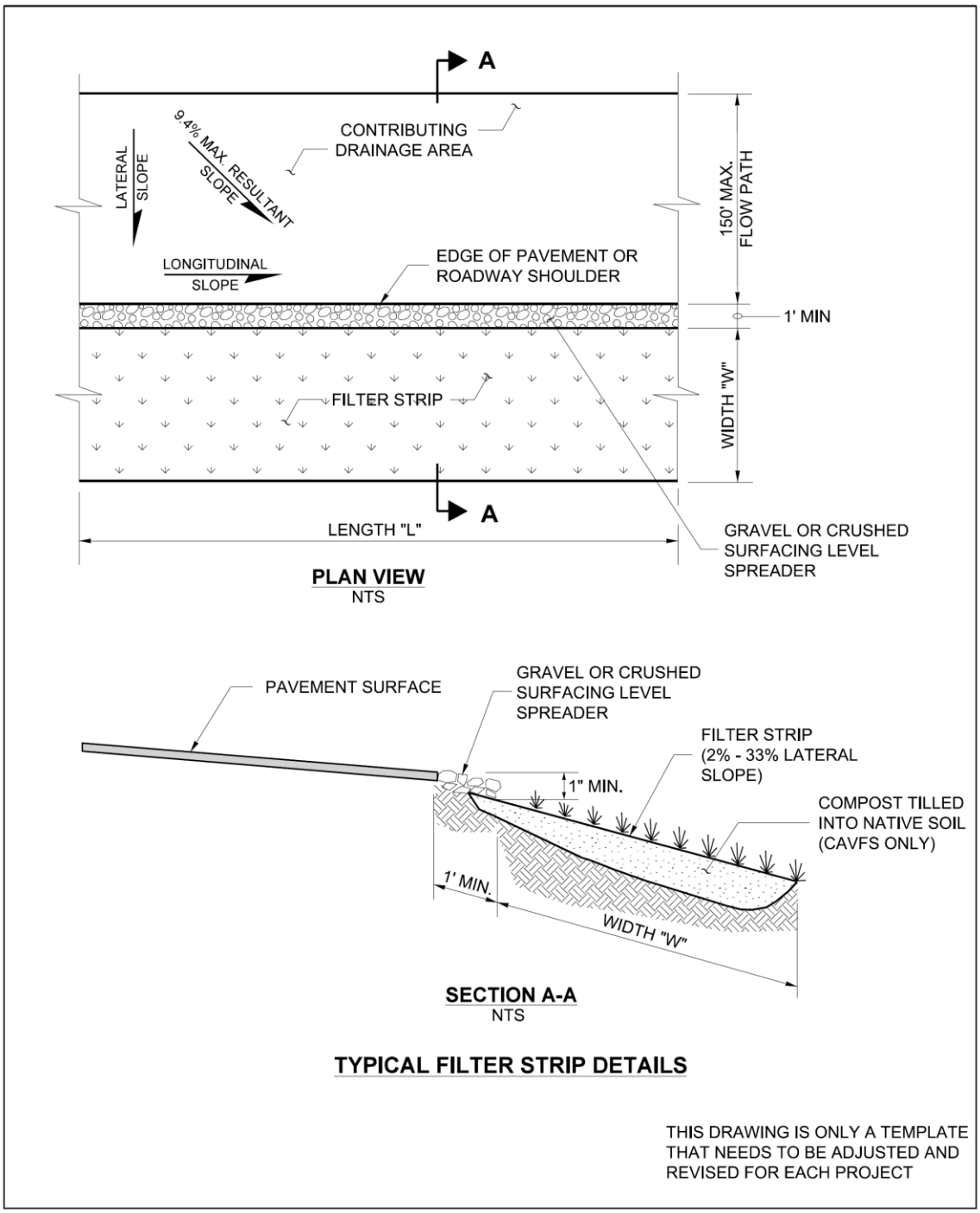



**Figure RT.02.1 Typical vegetated filter strip.**

The CAVFS design incorporates compost into the native soils per the criteria in Section 5-4.3.2. The CAVFS bed should have a final organic content of 10%. Once permanent vegetation is established, the advantages 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. Compost-amended systems have somewhat higher construction costs due to more expensive materials, but require less land area for runoff treatment, which can reduce overall costs.

### *Applications and Limitations*

Vegetated filter strips (*narrow area* and *basic*) can be used to meet basic runoff treatment objectives (see Table 3-1) or as part of a treatment train to provide additional removal of phosphorus or dissolved metals. (See Tables 4.1 and 4.2 at the following web link on Category 1 BMPs: http://www.wsdot.wa.gov/nr/rdonlyres/b415daa4-2c2a-4cc8-93ed-d0cdb9a46560/0/hrmcategory1.pdf.)

CAVFS can be used to meet basic runoff treatment and enhanced runoff treatment objectives, and oil control in eastern Washington only.

*Applications*

- Vegetated filter strips can be effective in reducing sediments and the pollutants associated with sediments such as phosphorus, pesticides, or insoluble metallic salts.
- Because they do not pond water on the surface for long periods, vegetated filter strips help maintain the temperature norms of the water and deter the creation of habitat for disease vectors such as mosquitoes.
- In less urbanized areas, vegetated filter strips can generally be located on existing roadside embankments, reducing the need for additional right of way acquisitions.
- Designs can be modified to reduce runoff volumes and peak flows when needed or desired to reduce right of way acquisitions.

*Limitations*

- If sheet flow cannot be maintained, vegetated filter strips will not be effective.
- Vegetated filter strips are generally not suitable for steep slopes or large impervious areas that can generate high-velocity runoff.
- Use of vegetated filter strips can be impracticable in watersheds where open land is scarce or expensive.
- For most project applications where less than 10 feet of roadside embankment is available for water quality treatment, the media filter drain (see BMP RT.07) is a more suitable BMP option.
- Improper grading can render this BMP ineffective.
- The flow attenuation properties of vegetated filter strips and amended vegetated filter strips are largely unknown. Qualitative evidence indicates that on outwash soils (National Resources Conservation Service [NRCS] Groups A and B), the compost-amended vegetated filter strip (CAVFS) can attenuate large quantities of runoff. Monitoring studies are being conducted to evaluate these properties and ultimately give designers the ability to model water losses in vegetated filter strips.

- Design methodology for sizing CAVFS in western Washington (see Section 4-5.3.3.1) is different than the design methodology for sizing basic vegetated filter strips in western Washington.
- Design methodology for sizing CAVFS in eastern Washington is identical to the design methodology for sizing basic vegetated filter strips in eastern Washington.

## Design Flow Elements

### *Flows to Be Treated*

Vegetated filter strips must be designed to treat the runoff treatment flow rate discussed in Section 3-3.5 under Minimum Requirement 5 and the guidelines and criteria provided in this section. Hydrologic methods are presented in Sections 4-3 and 4-4.

CAVFS must be designed to provide the runoff treatment flow rate discussed in Section 4-5.3.3.1.

## Structural Design Considerations

### *Geometry*

*Design Criteria and Specifications*

Following are the key design elements of vegetated filter strip systems.

Drainage Area Limitations

- Vegetated filter strips are used to treat small drainage areas. Flow must enter the vegetated filter strip as sheet flow spread out over the length (long dimension perpendicular to flow) of the strip, generally no deeper than 1 inch. For basic vegetated filter strips and CAVFS, the greatest flow path from the contributing area delivering sheet flow to the vegetated filter strip should not exceed 150 feet. For the narrow area vegetated filter strip, the maximum contributing flow path should not exceed 30 feet.
- The resultant slope from the contributing drainage should be less than or equal to 9.4%, calculated using Equation FC.01-1[4] in Section 5-4.2.2.
- Vegetated filter strips should be fully integrated within site designs.
- Vegetated filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.

Vegetated Filter Strip Geometry

- Applicable for basic vegetated filter strips in eastern and western Washington and CAVFS in eastern Washington.[5]

[4] "Eastern Washington Steep Slope Research for Management of Highway Stormwater," WARD 77.1, Research Report, May 2011.
[5] "Eastern Washington Steep Slope Research for Management of Highway Stormwater," WARD 77.1, Research Report, May 2011.

- Vegetated filter strips must provide a minimum residence time of 9 minutes for full water quality treatment in eastern Washington. In western Washington, a flow rate adjustment (described below) is needed to use the 9-minute criterion.
- Vegetated filter strips can be used for pretreatment to another water quality BMP. Wherever a basic vegetated filter strip or CAVFS system cannot fit within the available space, a narrow area vegetated filter strip system can be used solely as a pretreatment device. A narrow area design should have a minimum width of 4 feet and should take advantage of all available space.
- Basic vegetated filter strips should be designed for lateral slopes (along the direction of flow) between 2% and 33%.[6] Steeper slopes encourage the development of concentrated flow; flatter slopes encourage standing water. Vegetated filter strips should not be used on soils that cannot sustain a dense grass cover with high flow retardance.

  In areas where enhanced treatment is required, designers should consider using a CAVFS or a media filter drain (see BMP RT.07). The media filter drain will usually require less treatment area to achieve the water quality treatment objectives.
- The minimum width of the vegetated filter strip generally is dictated by the design method.
- Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.
- The Manning's *n* to be used in the vegetated filter strip design calculations depends on the type of soil amendment and vegetation conditions used in the construction of the vegetated filter strip (see Table RT.02.1).
- When the runoff treatment peak flow rate $Q_{WQ}$ has been established, the design flow velocity can be estimated using Manning's equation to calculate the width of the vegetated filter strip parallel to the direction of flow.

The geometry guidelines above are applicable for CAVFS in western Washington except for the following clarifications:

- CAVFS design in western Washington does not have a residence time component or Manning's "*n*" component. (See Section 4-5.3.3 for design sizing criteria and Section 5-4.3.2 for information on soil amendments.)
- The CAVFS lateral slope (along the direction of flow) can be no steeper than 33% (3H:1V).[7]

[6] "Eastern Washington Steep Slope Research for Management of Highway Stormwater," WARD 77.1, Research Report, May 2011.
[7] "Eastern Washington Steep Slope Research for Management of Highway Stormwater," WARD 77.1, Research Report, May 2011.

**Table RT.02.1 Surface roughness/Manning's n for vegetated filter strip design calculations.**

| Option | Soil and Vegetation Conditions | Manning's *n* |
|---|---|---|
| 1 | Fully compacted and hydroseeded | 0.20 |
| 2 | Compaction minimized and soils amended, hydroseeded | 0.35 |
| 3 | Compaction minimized; soils amended to a minimum 10% organic content (see Section 5-4.3.2); hydroseeded; grass maintained at 95% density and 4-inch length via mowing; periodic reseeding; possible landscaping with herbaceous shrubs | 0.40* |
| 4 | Compost-amended vegetated filter strip: compaction minimized, soils amended to a minimum 10% organic content (see Section 5-4.3.2), vegetated filter strip top-dressed with ≥3 inches vegetated compost or compost/mulch (seeded or landscaped) | 0.55* |

* These values were estimated using the SCS TR-55 Peak Discharge and Runoff Calculator at: www.lmnoeng.com/hydrology/hydrology.htm. This tool lists the Manning's *n* values for woods: light underbrush at 0.4, and woods: dense underbrush at 0.8. The intent of Option 3 is to amend the soils so that they have surface roughness characteristics equivalent to forested conditions with light underbrush. Option 4 adds a 3-inch top dressing of compost or compost/mulch to simulate a thick forest duff layer, which warrants a higher Manning's *n*, estimated at 0.55.

Water Depth and Velocity

- The maximum depth of sheet flow through a vegetated filter strip for the runoff treatment design flow rate is 1.0 inch.
- The maximum flow velocity for the runoff treatment design flow velocity is 0.5 feet per second.

Maintain Sheet Flow Conditions

- Sheet flow conditions from the pavement into the vegetated filter strip should be maintained. A no-vegetation zone may help establish and maintain this condition.
- In areas where it may be difficult to maintain sheet flow conditions for embankment and VFS slopes steeper than 15%, use aggregate or gravel level spreaders.[8] They should be placed between the pavement surface and the vegetated filter strip. The aggregate should meet the specifications for crushed surfacing base course listed in Section 9-03.9(3) of the *Standard Specifications* or other aggregate providing the equivalent functionality.
- If there are concerns that water percolated within the aggregate flow spreader may exfiltrate into the highway prism, impervious geotextiles can be used to line the bottom of the aggregate layer.

[8] "Eastern Washington Steep Slope Research for Management of Highway Stormwater," WARD 77.1, Research Report, May 2011.

## Vegetated Filter Strip (eastern and western Washington basic vegetated filter strip and eastern Washington CAVFS)

### *Design Method*

- Verify the resultant slope is less than or equal to 9.4%, calculated using Equation FC.01.1 in Section 5-4.2.2.

- **Determine the runoff treatment design flow ($Q_{WQ}$).** In western Washington, the on-line design flow for runoff treatment is the flow rate derived from a continuous model (such as MGSFlood or WWHM) that calculates the flow rate from the drainage basin below which 91% of the average annual runoff volume occurs. In eastern Washington, the on-line design flow rate is determined based on the peak 5-minute interval for the short-duration design storm, which is the 6-month, 3-hour event. (See Chapter 4 for criteria and hydrologic methods.)

  **Western Washington flow rate adjustment.** In western Washington, design flow rates are calculated using a continuous simulation model. Most of the performance research on vegetated filter strips and biofiltration BMPs has been conducted on vegetated filter strips that used event-based designs. The 91st percentile flow event (as calculated by the continuous model) tends to be less than the estimated 6-month, 24-hour event flow rate in most cases.

  The ratio between the 91st percentile flow event and the estimated 6-month, 24-hour flow rate varies with location and percent of impervious area in the modeled drainage basin. When designing vegetated filter strips in western Washington, multiply the on-line water quality design flow rate by the coefficient $k$[9] given below to apply the 9-minute residence time criterion.

**Western Washington Design Flow Coefficient for Biofilters**

$$k = 1.41\ (P_{72\%,\ 2\text{-yr.}}) - 0.052 \qquad \textbf{(RT.02-1)}$$

where: $P_{72\%,\ 2\text{-yr}}$ = 72% of the 2-year, 24-hour precipitation depth (in.)

Note: The 6-month, 24-hour precipitation event can be estimated at 72% of the 2-year, 24-hour precipitation event if 6-month, 24-hour precipitation data are not available.

In eastern Washington, no design flow rate adjustment is needed, since the 6-month, 24-hour flow rate is calculated directly using SBUH-based models such as StormShed.

The vegetated filter strip design flow rate then becomes:

$$Q_{vfs} = kQ_{wq} \qquad \textbf{(RT.02-2)}$$

[9] Derived by calculating the linear regression of the ratios of the 91st percentile flow event at 15-minute intervals (determined by MGSFlood) vs. 72% of the 2-year, 24-hour event (determined by the rational method) at each of the major continuously-operating rain gages in western Washington.

- **Calculate the design flow depth at $Q_{vfs}$.** The design flow depth is calculated based on the length of the vegetated filter strip (same as the length of the pavement edge contributing runoff to the vegetated filter strip) and the lateral slope of the vegetated filter strip parallel to the direction of flow. Design flow depth is calculated using a form of Manning's equation:

$$Q_{vfs} = \frac{1.49}{n} L y^{5/3} s^{1/2} \qquad \textbf{(RT.02-3)}$$

where: $Q_{vfs}$ = vegetated filter strip design flow rate (cfs)

$n$ = Manning's roughness coefficient. Manning's $n$ can be adjusted by specifying soil and vegetation conditions at the project site, as specified in Table RT.02.1.

$y$ = design flow depth (ft), also assumed to be the hydraulic radius = 1.0 inch maximum = 0.083 feet

$L$ = length of vegetated filter strip parallel to pavement edge (ft)

$s$ = slope of vegetated filter strip parallel to direction of flow (ft/ft). Vegetated filter strip slopes should be greater than 2% and less than 15%, or ≤33% with a gravel level spreader. Vegetated filter strip slopes should be made as shallow as is feasible by site constraints. Gently sloping vegetated filter strips can produce the required residence time for runoff treatment using less space than steeper vegetated filter strips.

Rearranging Equation RT.02-3 to solve for $y$ yields:

$$y = \left[ \frac{n Q_{vfs}}{1.49 L s^{1/2}} \right]^{3/5} \qquad \textbf{(RT.02-4)}$$

If the calculated depth $y$ is greater than 1 inch, either adjust the vegetated filter strip geometry or use other runoff treatment BMPs.

- **Calculate the design flow velocity passing through the vegetated filter strip at the vegetated filter strip design flow rate.** The design flow velocity ($V_{WQ}$) is based on the vegetated filter strip design flow rate, the length of the vegetated filter strip, and the calculated design flow depth from Step 2:

$$V_{WQ} = \frac{Q_{vfs}}{L y} \qquad \textbf{(RT.02-5)}$$

where: $V_{WQ}$ = design flow velocity (ft/sec)

$y$ = design flow depth (ft, from Equation RT.02-4)

- **Calculate the vegetated filter strip width.** The width of the vegetated filter strip is determined by the residence time of the flow through the vegetated filter strip. A 9-minute (540-second) residence time is used to calculate vegetated filter strip width:

$$W = TV_{WQ} = 540V_{WQ} \quad \textbf{(RT.02-6)}$$

where: $W$ = vegetated filter strip width (ft)

$T$ = time (sec)

$V_{WQ}$ = *design flow velocity (ft/sec, from Equation RT.02-5)*

A minimum width of 8 feet is recommended in order to ensure the long-term effectiveness of the vegetated filter strip will occur.

### Narrow Area Vegetated Filter Strip

As previously mentioned, narrow area vegetated filter strips are limited to impervious flow paths less than 30 feet. For flow paths greater than 30 feet, designers should follow the basic vegetated filter strip guidelines. The sizing of a narrow area vegetated filter strip is based on the width of the roadway surface parallel to the flow path of the vegetated filter strip and the lateral slope of the vegetated filter strip.

- **Determine the width of the roadway surface parallel to the flow path draining to the narrow area vegetated filter strip.** Determine the width of the roadway surface parallel to the flow path from the upstream to the downstream edge of the impervious area draining to the vegetated filter strip. This is the same as the width of the paved area.

- **Determine the average lateral slope of the narrow area vegetated filter strip.** Calculate the lateral slope of the vegetated filter strip (parallel to the flow path), averaged over the total length of the vegetated filter strip. If the slope is less than 2%, use 2% for sizing purposes. The maximum lateral slope allowed is 15%. Where a gravel level spreader is located between the highway and the VFS, the maximum lateral slope allowed is 33%. For sizing purposes, the project office should use the 20% narrow area VFS slope limit (X-axis) in Figure RT.02.2, even though the narrow area VFS may be constructed on a slope up to 33%.

- **Determine the required width of the narrow area vegetated filter strip.** Use Figure RT.02.2 to size the vegetated filter strip. Locate the width of the impervious surface parallel with the flow path on one of the curves; interpolate between curves as necessary. Next, move along the curve to the point where the design lateral slope of the vegetated filter strip is directly below. Read the vegetated filter strip width to the left on the y-axis. The vegetated filter strip must be designed to provide this minimum width "W" along the entire stretch of pavement draining to it.

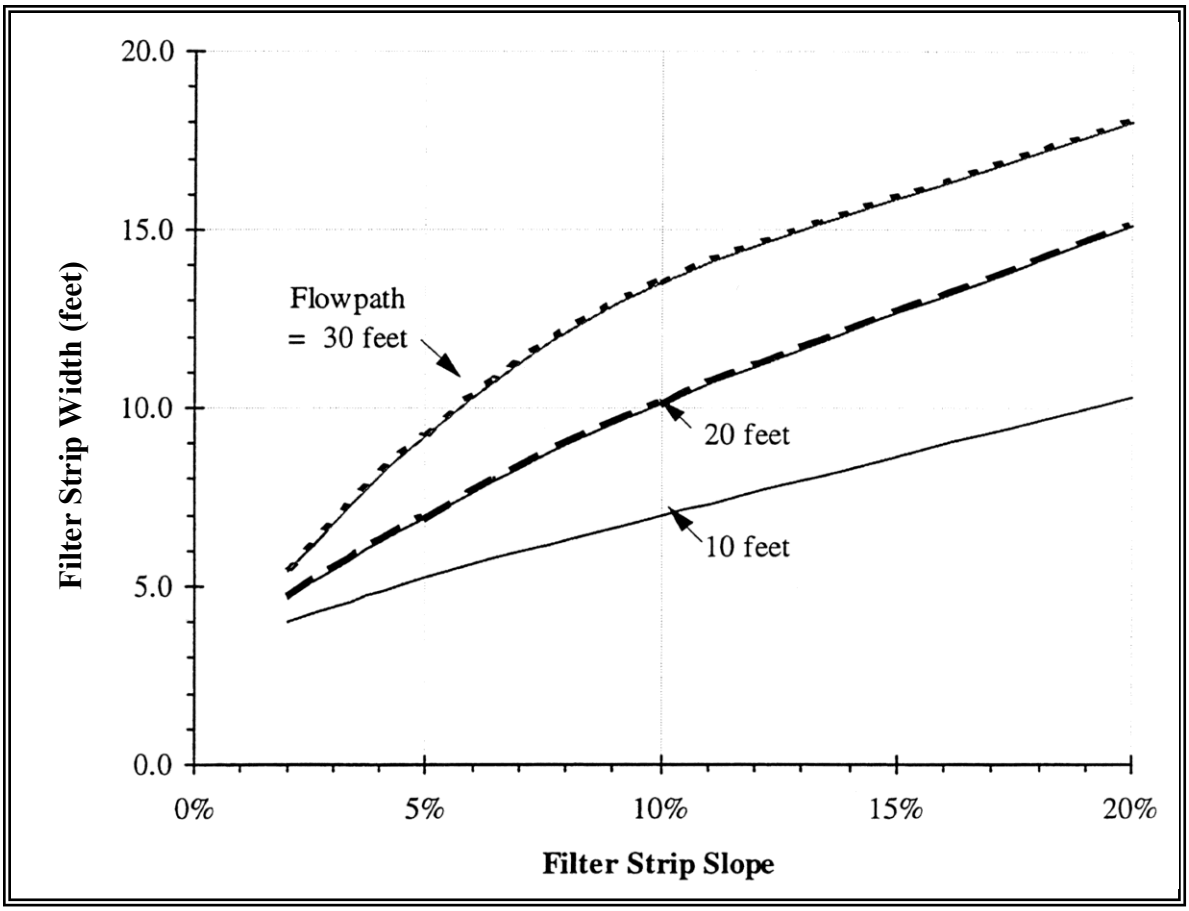



**Figure RT.02.2 Narrow area vegetated filter strip design graph.**

## Materials

### *Vegetation Establishment*

Vegetated filter strips should be planted with grass that can withstand relatively high-velocity flows as well as wet and dry periods. Filter strips may also incorporate native vegetation such as small herbaceous shrubs to make the system more effective in treating runoff and providing root penetration into subsoils, thereby enhancing infiltration. Consult with the Region Landscape Architect or the HQ Roadside and Site Development Section for a selection of grasses and plants suitable for the project site.

### *Soil Amendments*

Refer to Section 5-4.3.2, Soil Amendments.

## Site Design Elements

### *Maintenance Access Roads (Access Requirements)*

Access should be provided at the upper edge of all vegetated filter strips to enable maintenance of the gravel flow spreader and permit lawnmower entry to the vegetated filter strip.

### *Signage*

See Section 5-4.3.7 for signing requirements.

## *RT.04 – Biofiltration Swale*

Biofiltration Swale With Spreader Bar on SR 503 in Clark County

**Description:** Vegetation-lined channels designed to remove suspended solids from stormwater. Shallow concentrated flow, allows for the filtration of stormwater by soil, plants, and leaves.

**Geometry Limitations**

| | |
|---|---|
| Longitudinal Slope | 1.5-5% |
| Max Water Depth | 2-4" |
| Bed Width | 2-10' |
| Min Length | 100' |
| Max Side Slope | 3H:1V |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced (CABS Only)

**Effective Life (Years)**

➲ 5-20

**Capital Cost**

➲ Low to Moderate

**O & M Cost**

➲ Low to Moderate

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☑ Soil Amendments/Compost (CABS)
- ☑ Energy Dissipater/Level Spreader
- ☐ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☐ | Fecal Coliform |
| ☑ | ☐ | Phosphorus (CABS Only) |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☑ | Dissolved Metals (CABS Only) |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☑ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Table 5.5.8.

## Introduction

### *General Description*

*Biofiltration swales* are vegetation-lined channels designed to remove suspended solids from stormwater. The shallow, concentrated flow within these systems allows for the filtration of stormwater by plant stems and leaves. Biological uptake, biotransformation, sorption, and ion exchange are potential secondary pollutant-removal processes (see Figures RT.04.1 and RT.04.2). Biofiltration swales are approved for basic runoff treatment. Compost-amended biofiltration swales (CABS) are approved for basic and enhanced runoff treatment. Two design procedures are described below. The first is for both eastern and western Washington and the second is only for eastern Washington.

### *Applications and Limitations*

*Applications*

- Biofiltration swales and CABS have the flexibility to be located at the end of a stormwater collection system.
- In less urbanized areas, biofiltration swales and CABS can generally be located at the bottom of existing roadside embankments, reducing the need for additional right of way acquisitions.

*Limitations*

- CABS should not be installed in areas that have a TMDL for phosphorous.

## Design Flow Elements

### *Flows to Be Treated*

Biofiltration swales must be designed to treat the biofiltration design flow rate. Hydrologic methods are presented in Sections 4-3 and 4-4.

## Structural Design Considerations

### *Geometry*

The following procedure can be used in both eastern and western Washington.

*Sizing Procedure*

Preliminary Steps (P)

**P-1** Determine the runoff treatment design flow rate ($Q_{wq}$) (see Sections 4-3.1 and 4-4.1).

**P-2** Determine the biofiltration design flow rate ($Q_{biofil}$):

$$Q_{biofil} = kQ_{wq}$$

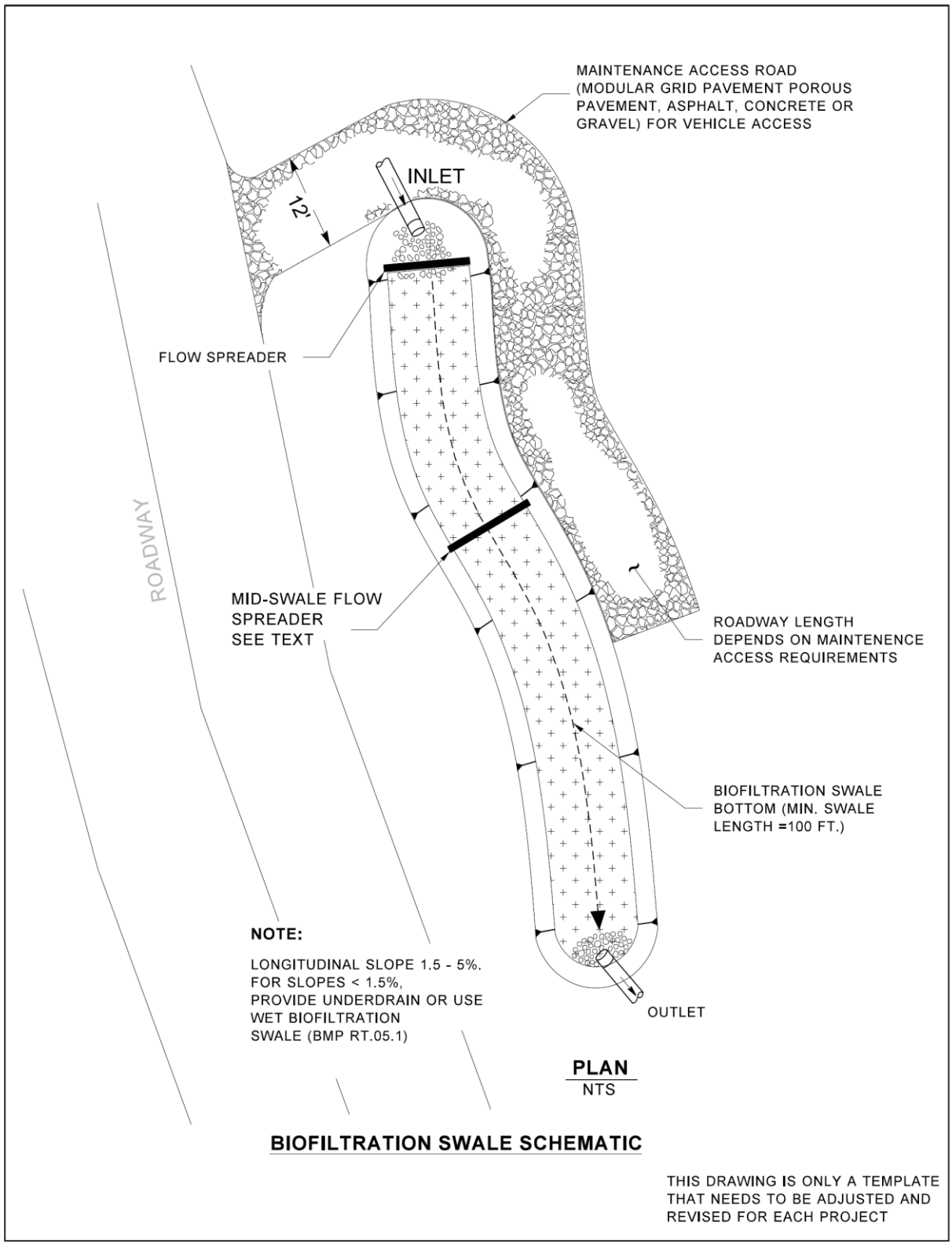



**Figure RT.04.1 Biofiltration swale: Plan view.**

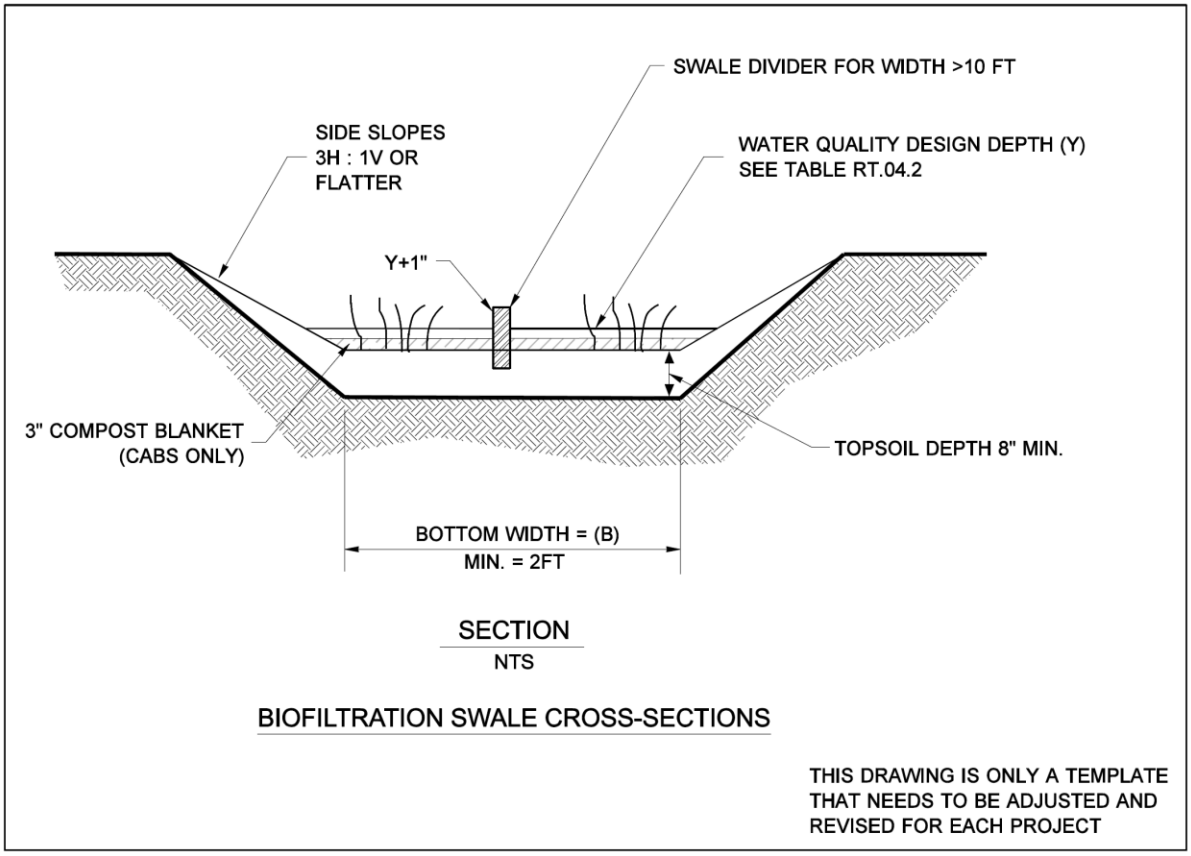



**Figure RT.04.2 Biofiltration swale: Cross section.**

For western Washington:[10]

$$k = 1.41\ (P_{72\%,\ 2\text{-yr.}}) - 0.052 \text{ (for on-line bioswales)}$$

$$k = 2.50\ (P_{72\%,\ 2\text{-yr.}}) - 0.052 \text{ (for off-line bioswales)}$$

where: $P_{72\%,\ 2\text{-yr}}$ = 72% of the 2-year, 24-hour precipitation depth (in.)

Note: If the 6-month, 24-hour precipitation depth (in.) is known for the project site, that value can be used instead of $P_{72\%,\ 2\text{-yr}}$.

For eastern Washington:

$$k = 1.0$$

**P-3** Establish the longitudinal slope of the proposed biofiltration swale (see Table RT.04.2 for criteria).

**P-4** Select a soil and vegetation cover suitable for the biofiltration swale (see Table RT.04.1).

[10] The coefficient *k* is derived by calculating the linear regression of the ratios of the 91st percentile flow event at 15-minute intervals (determined by MGSFlood) vs. 72% of the 2-year, 24-hour event (determined by the rational method) at each of the major continuously-operating rain gages in western Washington and applied to the design flow rate in order to meet the 9-minute residence time criteria.

Design Steps (D)

**D-1** Select the design depth of flow, *y* (see Table RT.04.2).

**D-2** Select a swale cross-sectional shape. Trapezoidal is preferred, however, rectangular or parabolic cross sections can be used if site-specific constraints so dictate.

**Table RT.04.1 Flow resistance coefficient in basic, wet, and continuous inflow biofiltration swales.**

| Soil and Cover | Manning's Coefficient |
|---|---|
| Grass-legume mix on compacted native soil | 0.20 |
| Grass-legume mix on lightly compacted, compost-amended[1] soil (CABS) | 0.22 |
| Grass-legume mix on lightly compacted, compost-amended[1] soil with surface roughness features[2] (CABS) | 0.35 |

[1] For information on compost-amended soils, refer to Section 5-4.3.2. (Note that swales do not require a mulch layer and that compost amendments shall be a 3-inch-thick blanket over the soil.)

[2] Acceptable surface roughness features are wattle check dams (Std. Spec. 8-01.3(6)D), gravel filter berms (Std. Spec. 8-01.3(9)B), or compost berms (Std. Plan I-14). These features must be placed every 50 feet (or closer) and should not exceed 1.5 feet in height above finished swale bottom. These features must not be used in place of level spreaders or energy dissipaters.

**Table RT.04.2 Biofiltration swale sizing criteria.**

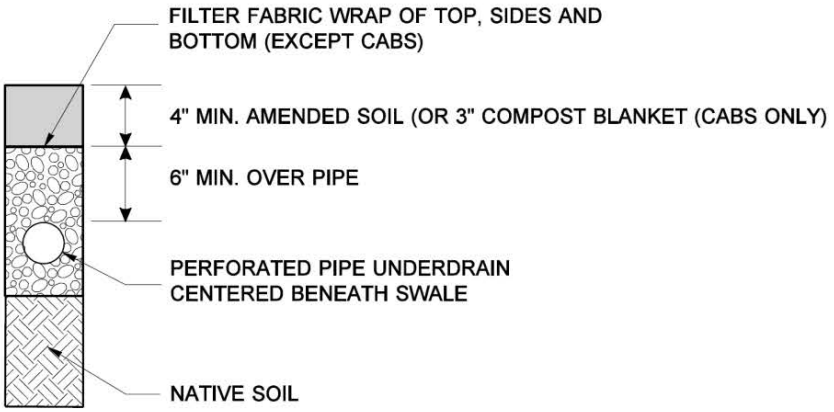
| Design Parameter | Basic Biofiltration Swale | Wet Biofiltration Swale | Continuous Inflow Biofiltration Swale |
|---|---|---|---|
| Longitudinal slope | 0.015–0.050[1] feet per foot | 0.015 feet or less per foot | Same as basic swale |
| Maximum velocity | 1 foot per second at $Q_{biofil}$ | Same as basic swale | Same as basic swale |
| Maximum water depth at $Q_{biofil}$, *y* | 2 inches if swale mowed frequently; 4 inches if mowed infrequently or inconsistently. For dryland grasses in eastern Washington, set depth to 3 inches. | 4 inches | Same as basic swale |
| Manning coefficient at $Q_{biofil}$ | See Table RT.04.1 | Same as basic swale | Same as basic swale |
| Bed width | 2–10 feet [2] | 2–25 feet | Same as basic swale |
| Freeboard height | 1 foot for the peak conveyance flow rate ($Q_{convey}$)[3] | Same as basic swale | Same as basic swale |
| Minimum length | 100 feet | Same as basic swale | Same as basic swale |
| Maximum side slope (for trapezoidal cross section)[4] | 3H:1V | Same as basic swale | Same as basic swale |

[1] For basic biofiltration swale on slopes less than 1.5%, install an underdrain system (see Figure RT.04.3). Underdrain backfill should be covered by at least 4 inches of amended soil or topsoil. Install the low-flow drain 6 inches deep in the soil (see Figure RT.04.4). 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. For slopes greater than 5%, install energy dissipaters.

[2] Multiple parallel swales can be constructed when the calculated swale bottom width exceeds 10 feet.

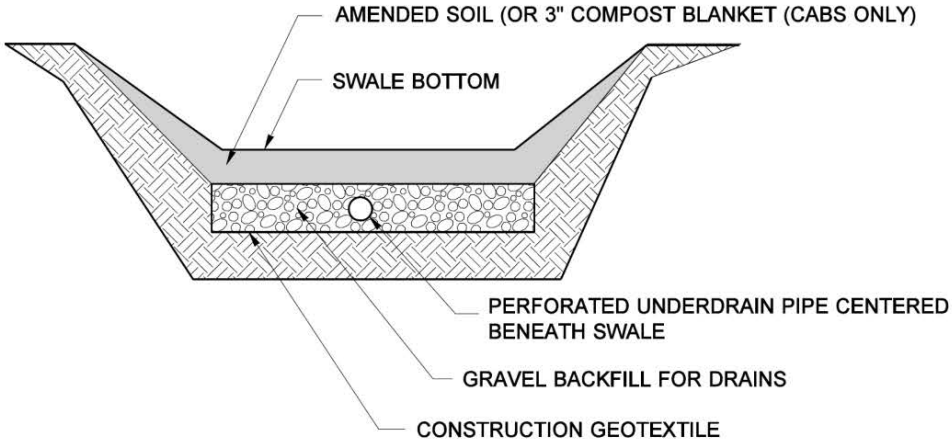
[3] See Freeboard discussion for definition of $Q_{convey}$ for eastern and western Washington.

[4] From swale bed to top of water surface at $Q_{biofil}$.




**DETAIL A**

**UNDERDRAIN FOR SLOPES < 1.5%**




**NOTE:**

UNDERDRAIN MUST INFILTRATE OR DRAIN FREELY TO AN ACCEPTABLE DISCHARGE POINT.

**SECTION**

**NTS**

BIOFILTRATION SWALE UNDERDRAIN DETAIL

THIS DRAWING IS ONLY A TEMPLATE THAT NEEDS TO BE ADJUSTED AND REVISED FOR EACH PROJECT

**Figure RT.04.3 Biofiltration swale: Underdrain detail.**

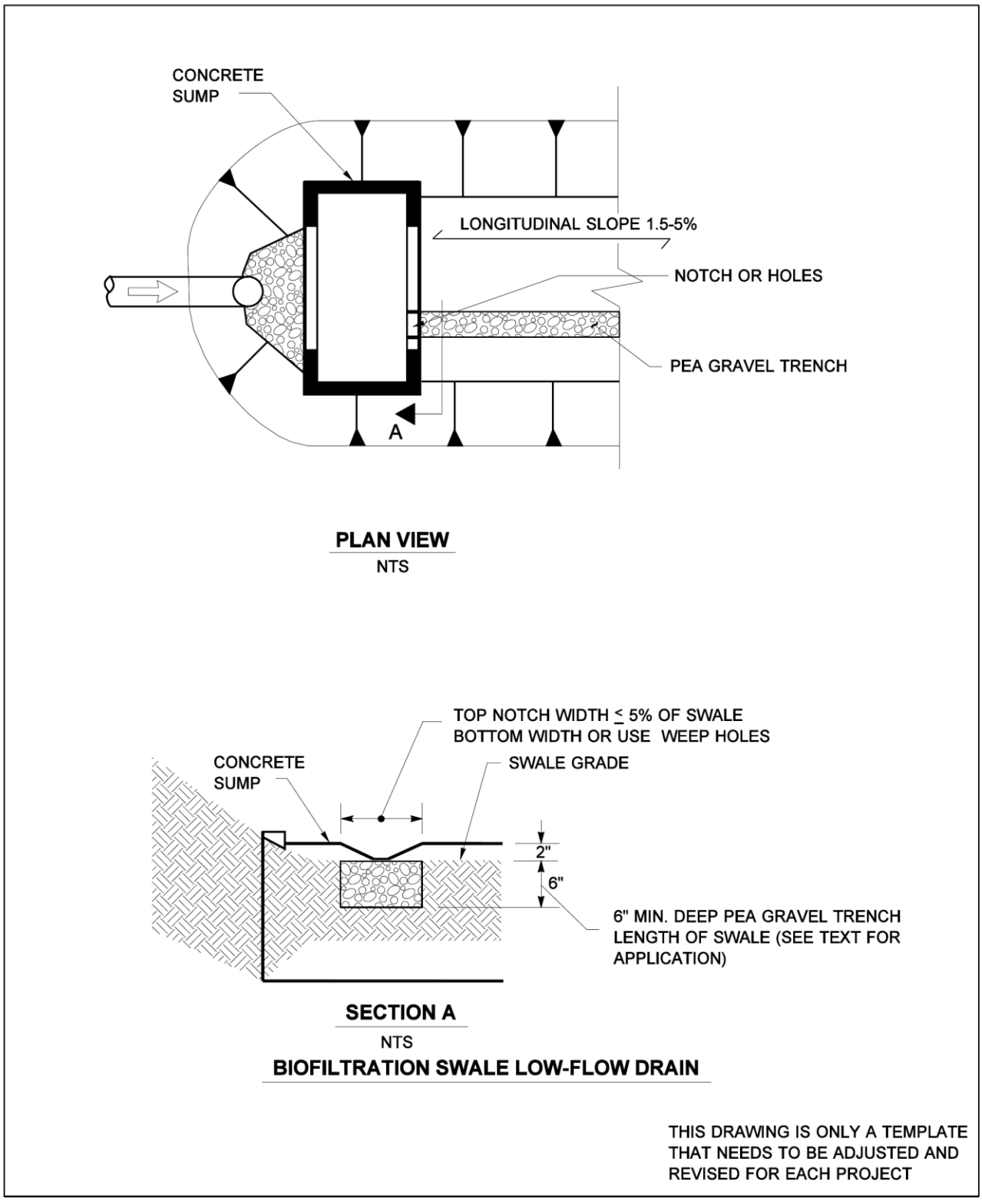



**Figure RT.04.4 Biofiltration swale: Low-flow drain detail.**

**D-3** Use Manning's equation (RT.04-1) and first approximations relating hydraulic radius and dimensions for the selected swale shape to obtain a value for the width of the biofiltration swale:

$$Q_{biofil} = \frac{1.49AR^{2/3}s^{1/2}}{n} \qquad \textbf{(RT.04-1)}$$

where: $Q_{biofil}$ = runoff treatment design flow rate (cfs)

$A$ = wetted area ($ft^2$)

$R$ = hydraulic radius (ft)

$s$ = longitudinal slope of swale (ft/ft)

$n$ = Manning's coefficient (see Table RT.04.1)

To solve for the cross-sectional shape of the swale, use one of the following methods:

**Method 1**

Solve the implicit equation $AR^{0.67} = Q_{biofil}\, n / (1.49s^{0.5})$ to determine bed width, $b$, or width of water surface, $T$ (for parabolic or triangular cross sections), for the selected cross-sectional geometry. Use Figure RT.04.5 to substitute for $A$ and $R$ for the selected cross-sectional geometry. The variables $Q_{biofil}$, $y$, $s$, and $n$ are all known values. The equation should then contain only a single unknown ($b$ or $T$).

**Method 2**

Use nomographs relating $(Q_{biofil}\, n) / (1.49s^{0.5})$ for trapezoidal channels with known side slopes ($z$) to determine $b$ for a given $y$ (see Figure RT.04.6 for $z = 3$ and Figure RT.04.7 for $z = 4$).

**Method 3**

For a trapezoidal swale that is flowing very shallow, the hydraulic radius, $R$, can be set equal to the depth of flow. Using this assumption, the equation in Method 1 can be changed to:

$$b = [(Q_{biofil}\, n) / (1.49y^{1.67}s^{0.5})] - zy$$

Note: If any of these methods produce a value for $b$ or $T$ of less than 2 feet, then set bed width to 2 feet.

**D-4** Compute $A$ at $Q_{biofil}$ by using the equations in Figure RT.04.5.

**D-5** Compute the flow velocity at $Q_{biofil}$:

$$V_{biofil} = \frac{Q_{biofil}}{A} \qquad \textbf{(RT.04-2)}$$

where: $V_{biofil}$ = flow velocity at $Q_{biofil}$ (ft/sec)

If $V_{biofil}$ > 1.0 ft/sec, increase width ($b$ or $T$) or investigate ways to reduce $Q_{WQ}$ and then repeat Steps D-3, D-4, and D-5 until $V_{biofil} \leq 1.0$ ft/sec. A velocity greater than 1.0 ft/sec was found to flatten grasses, thus reducing filtration.

**D-6** Compute the swale length, $L$ (ft):

$$L = V_{biofil}\, t\ (60\ \text{sec/min})$$

where: $t$ = hydraulic residence time (9 minutes for basic biofiltration swales)

**D-7** If there is not sufficient space for the biofiltration swale, consider the following solutions:

- Divide the site drainage to flow to multiple biofiltration swales.
- Use infiltration or dispersion to provide lower $Q_{biofil}$.
- Alter the design depth of flow if possible (see Table RT.04.2).
- Reduce the developed surface area to gain space for the biofiltration swale.
- Reduce the longitudinal slope by meandering the biofiltration swale.
- Nest the biofiltration swale within or around another stormwater BMP.

Freeboard Check (FC)

A freeboard check must be performed for the combination of highest expected flow and least vegetation coverage and height. For western Washington, the highest expected flow rate ($Q_{convey}$) is 100-year, return frequency flow using 15-minute time steps using MGSFlood or other Ecology-approved continuous simulation model. For eastern Washington, $Q_{convey}$ is the 25-year 24-hour storm (a 10-year storm is acceptable, provided that reparative maintenance will be performed following every 10-year event). The freeboard check is not necessary for biofiltration swales that are located off-line from the primary conveyance and detention system (that is, when flows in excess of $Q_{biofil}$ bypass the biofiltration swale). Off-line is the preferred configuration of biofiltration swales.

Note: Use the same units as in the biofiltration swale design steps.

**FC-1** Unless runoff at rates higher than $Q_{biofil}$ will bypass the biofiltration swale, perform a freeboard check for $Q_{convey}$.

**FC-2** Select the lowest possible roughness coefficient for the biofiltration swale (assume $n$ = 0.03).

**FC-3** Again, use the implicit equation $AR^{0.67} = Q_{convey}\, n / (1.49 s^{0.5})$ (see Figure RT.04.5) and with a known $b$ (or $T$), solve for depth, $y$. Select the lowest $y$ that provides a solution. For trapezoidal swales, Figures RT.04.6 and RT.04.7 can be used directly. (Note that in the case of a parabola, the equation must be solved implicitly for two unknowns.)

**FC-4** Ensure swale depth exceeds flow depth at $Q_{convey}$ by a minimum of 1 foot (1-foot-minimum freeboard).

| Section | Area A | Wetted perimeter P | Hydraulic radius R | Top width W | Hydraulic depth D | Section factor Z |
|---|---|---|---|---|---|---|
| Rectangle | $by$ | $b+2y$ | $\frac{by}{b+2y}$ | $b$ | $y$ | $by^{1.5}$ |
| Trapezoid | $(b+zy)y$ | $b+2y\sqrt{1+z^2}$ | $\frac{(b+zy)y}{b+2y\sqrt{1+z^2}}$ | $b+2zy$ | $\frac{(b+zy)y}{b+2zy}$ | $\frac{[(b+zy)y]^{1.5}}{\sqrt{b+2zy}}$ |
| Triangle | $zy^2$ | $2y\sqrt{1+z^2}$ | $\frac{zy}{2\sqrt{1+z^2}}$ | $2zy$ | $\frac{1}{2}y$ | $\frac{\sqrt{2}}{2}zy^{2.5}$ |
| Circle | $\frac{1}{8}(\theta - \sin\theta)d_o^2$ | $\frac{1}{2}\theta d_o$ | $\frac{1}{4}\left(1-\frac{\sin\theta}{\theta}\right)d_o$ | $\left(\sin\left(\frac{1}{2}\theta\right)d_o\right)$ or $2\sqrt{y(d-y)}$ | $\frac{1}{8}\left(\frac{\theta-\sin\theta}{\sin\frac{1}{2}\theta}\right)d_o$ | $\frac{\sqrt{2}}{32}\frac{(\theta-\sin\theta)^{1.5}}{(\sin\frac{1}{2}\theta)^{0.5}}d_o^{2.5}$ |
| Parabola | $\frac{2}{3}Ty$ | $T+\frac{8y^2}{3T}$ * | $\frac{2T^2y}{3T^2+8y^2}$ * | $\frac{3A}{2y}$ | $\frac{2}{3}y$ | $\frac{2}{9}\sqrt{6}Ty^{1.5}$ |
| Round-cornered Rectangle (y>r) | $(\frac{\pi}{2}-2)r^2+(b+2r)y$ | $(\pi-2)r+b+2y$ | $\frac{(\frac{\pi}{2}-2)r^2+(b+2r)y}{(\pi-2)r+b+2y}$ | $b+2r$ | $\frac{(\frac{\pi}{2}-2)r^2}{(b+2r)}+y$ | $\frac{[(\frac{\pi}{2}-2)r^2+(b+2r)y]^{1.5}}{\sqrt{b+2y}}$ |
| Round-bottomed Triangle | $\frac{T^2}{4z}-\frac{r^2}{z}(1-z\cot^{-1}z)$ | $\frac{T}{z}\sqrt{1+z^2}-\frac{2r}{z}(1-z\cot^{-1}z)$ | $\frac{A}{P}$ | $2[z(y-r)+r\sqrt{1+z^2}]$ | $\frac{A}{T}$ | $A\sqrt{\frac{A}{T}}$ |

*Satisfactory approximation for the interval $0<x<1$, where $x=4y/T$. When $x>1$, use the exact expression $P=(T/2)\left[\sqrt{1+x^2}+\frac{1}{x}\ln\left(x+\sqrt{1+x^2}\right)\right]$

**Figure RT.04.5 Geometric elements of common cross sections.**

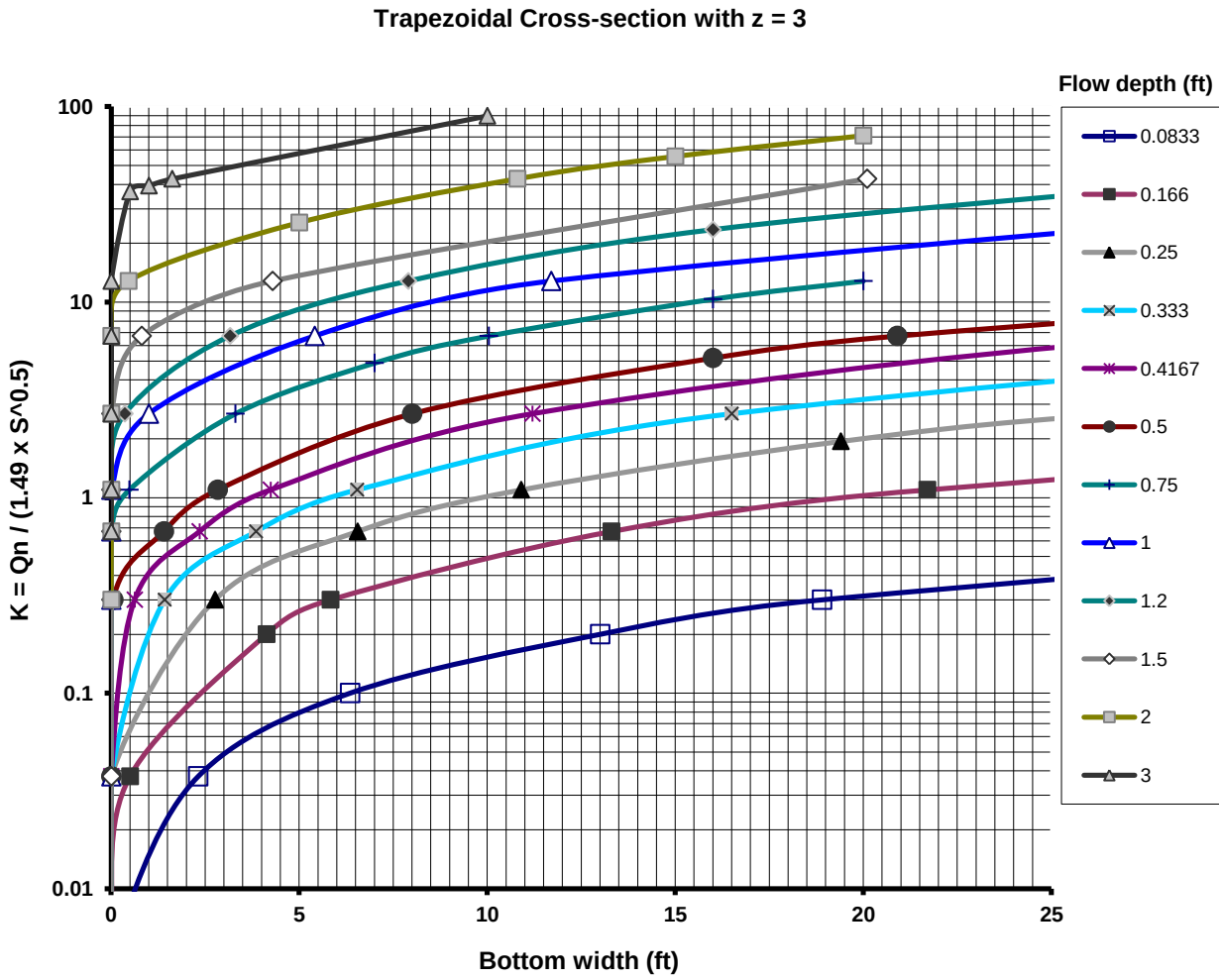



**Figure RT.04.6 Open channel flow parameter, Qn/(1.49 $s^{0.5}$), versus bottom width (b) at different flow depths (z = 3).**

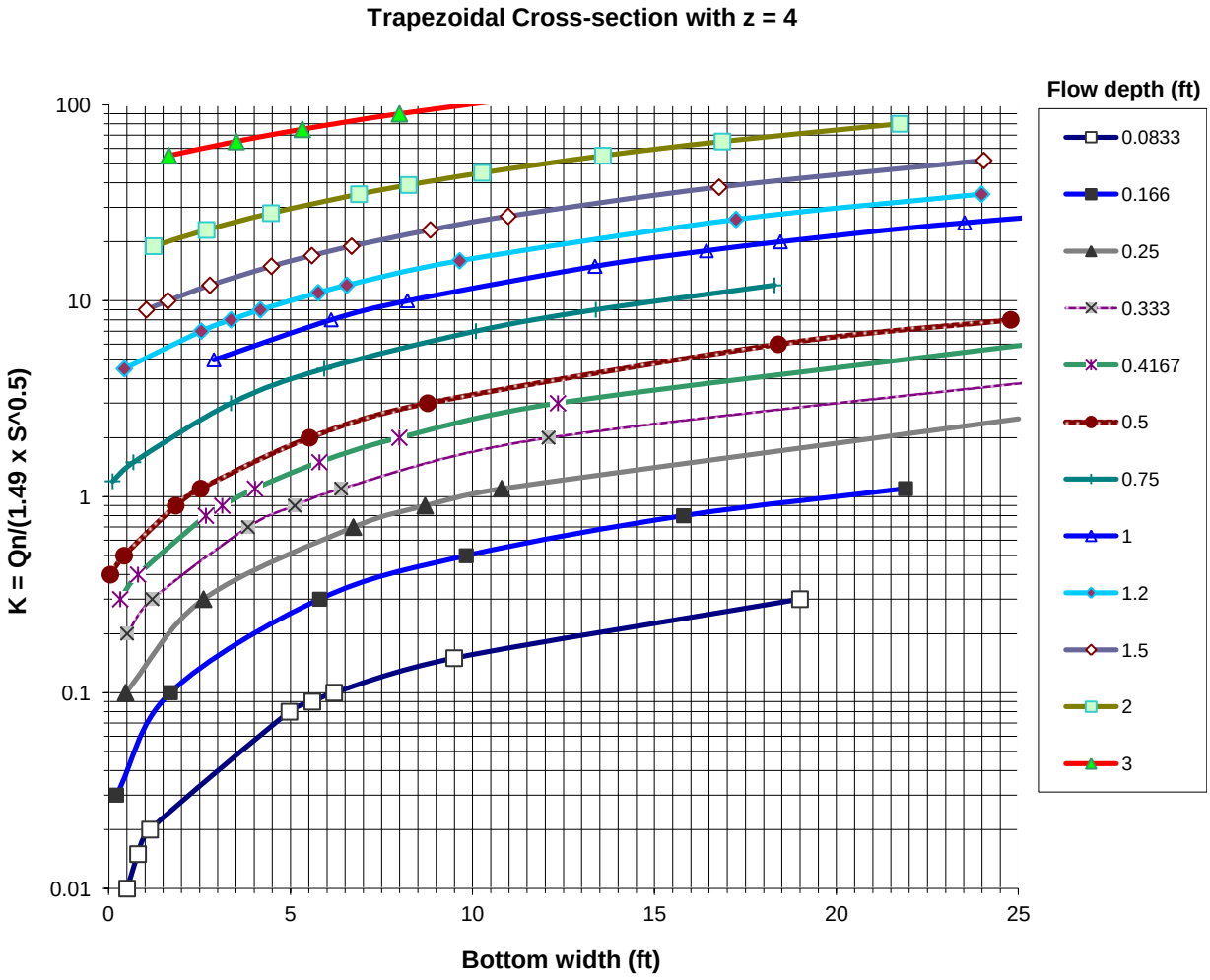



**Figure RT.04.7 Open channel flow parameter, Qn/(1.49 $s^{0.5}$), versus bottom width (b) at different flow depths (z = 4).**

**The following procedure can only be used in eastern Washington.**

*Sizing Procedure*

Preliminary Steps (P)

**P-1** Determine the runoff treatment design flow rate ($Q_{wq}$); this is also the biofiltration design flow rate ($Q_{biofil}$) (see Section 4-4.1).

**P-2** Determine the slope of the biofiltration swale (this will be somewhat dependent on where the swale is placed). The slope should be at least 1% and shall be no steeper than 5%. When slopes less than 2% are used, the need for underdrainage must be evaluated.

**P-3** Select a swale shape. Trapezoidal is the most desirable shape; however, rectangular and triangular shapes can be used. The remainder of the design process assumes that a trapezoidal shape has been selected.

**P-4** Use Manning's equation to estimate the bottom width of the biofiltration swale. Manning's equation for English units is as follows:

$$Q_{biofil} = (1.486\ AR^{0.667}s^{0.5}) / n$$

where: $Q_{biofil}$ = runoff treatment design flow rate (cfs)

$A$ = cross-sectional area of flow ($ft^2$)

$R$ = hydraulic radius of flow cross section (ft)

$s$ = longitudinal slope of biofiltration swale (ft/ft)

$n$ = Manning's roughness coefficient (use $n = 0.20$ for typical biofiltration swale with turf/lawn vegetation and $n = 0.30$ for biofiltration swale with less dense vegetation such as meadow or pasture)

For a trapezoid, this equation cannot be directly solved for bottom width. However, for trapezoidal channels that are flowing very shallow, the hydraulic radius can be set equal to the depth of flow. Using this assumption, the equation can be altered to:

$$B = (((n/1.486)\ Q_{biofil}) / (y^{1.667}\ s^{0.5})) - zy$$

where: $B$ = bottom width of the swale

$y$ = depth of flow

$z$ = the side slope of the biofiltration swale in the form of $z$:1

Typically, the depth of flow for turf grass is selected to be 4 inches. For dryland grasses, the depth of flow should be set to 3 inches. It can be set lower, but doing so will increase the bottom width. Sometimes when the flow rate is very low, the equation listed above will generate a negative value for B. Since it is not possible to have a negative bottom width, the bottom width should be set to 1 foot when this occurs.

Biofiltration swales are limited to a maximum bottom width of 10 feet. If the required bottom width is greater than 10 feet, parallel swales should be used in conjunction with a device that splits the flow and directs the proper amount to each swale.

**P-5** Calculate the cross-sectional area of flow for the given channel using the calculated bottom width and the selected side slopes and depth.

**P-6** Calculate the velocity of flow in the channel using:

$$V = Q_{biofil}/A$$

If $V$ is less than or equal to 1 ft/sec, the biofiltration swale will function correctly with the selected bottom width. Proceed to P-7.

If $V$ is greater than 1 ft/sec, the biofiltration swale will not function correctly. Increase the bottom width, recalculate the depth using Manning's equation, and return to P-5.

**P-7** Select a location where a biofiltration swale with the calculated width and a length of 200 feet will fit. If a length of 200 feet is not possible, the width of the biofiltration swale must be increased so that the area of the biofiltration swale is the same as if a 200-foot length had been used.

**P-8** Select a vegetation cover suitable for the site. Consult Table RT.04.1 or the local NRCS office or the County Extension Service for guidance.

**P-9** Using Manning's equation, find the depth of flow (typically $n = 0.04$ during $Q_{biofil}$). The depth of the channel shall be 1 foot deeper than the depth of flow. Check to determine that shear stresses do not cause erosion; the velocity needs to stay below 2 ft/sec.

Design Steps (D)

**D-1** Though the actual dimensions for a specific site may vary, the swale should generally have a length of 200 feet. The maximum bottom width is typically 10 feet. The depth of flow should not exceed 4 inches during the design storm. The flow velocity should not exceed 1ft/sec.

**D-2** The channel slope should be at least 1% and no greater than 5%.

**D-3** The swale can be sized as a treatment facility for $Q_{biofil}$.

**D-4** The ideal cross section of the swale should be a trapezoid. The side slopes should be no steeper than 3H:1V.

**D-5** Roadside ditches should be regarded as significant potential biofiltration sites and should be utilized for this purpose whenever possible.

**D-6** If flow is to be introduced through curb cuts, place pavement slightly above the biofiltration swale elevation. Curb cuts should be at least 12 inches wide to prevent clogging.

**D-7** Biofiltration swales must be vegetated in order to provide adequate treatment of runoff.

**D-8** It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing grasses (or other vegetation) that can withstand prolonged periods of wetting as well as prolonged dry periods (to minimize the need for irrigation). Consult the local NRCS office or the County Extension Service for specific vegetation selection recommendations.

**D-9** Biofiltration swales should generally not receive construction-stage runoff. If they do, presettling of sediments should be provided. (See BMPs 6A-2.30, Sediment Trap, and 6A-2.31, Temporary Sediment Pond, in Appendix 6A – Best Management Practices.) Such biofilters should be evaluated for the need to remove sediments and restore vegetation following construction. The maintenance of presettling basins or sumps is critical to their effectiveness as pretreatment devices.

**D-10** If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, protect graded and seeded areas with suitable erosion control measures.

## Site Design Elements

- Install level spreaders at the head of the biofiltration swale in swales 6 feet or greater in bottom width. Include sediment cleanouts at the head of the swale as needed (see Section 5-4.3.5 for level spreader options). It is recommended that swales with a bottom width in excess of 6 feet or greater have a level spreader for every 50 feet of swale length.
- Use energy dissipaters for swales on longitudinal slopes exceeding 2.5%.
- Specify that topsoil extends to at least an 8-inch depth unless an underdrain system is needed (see Table RT.04.2).
- To improve infiltration on longitudinal slopes less than 1.5%, ensure the swale bed material contains a sand percentage greater than 70% (greater than 70% by weight retained on the No. 40 sieve) before organic amendments are added.
- If groundwater contamination is a concern, seal the bed or underdrain area with either a treatment liner or a low-permeability liner that is appropriate for site conditions. (See Section 5-4.3.3 for additional information on these liner types.)

### *Landscaping (Planting Considerations)*

- Consult with the Region Landscape Architect or the HQ Roadside and Site Development Section to determine plants for use in the basic biofiltration swale.
- Select fine, turf-forming grasses where moisture is appropriate for growth.
- If possible, perform final seeding of the swale during the seeding windows specified in the *Standard Specifications*. Supplemental irrigation may be required depending on seeding and planting times.
- Plant wet-tolerant species in the fall.
- Use only sod specified by the Region Landscape Architect.
- Stabilize soil areas upslope of the biofiltration swale to prevent erosion and excessive sediment deposition.
- Apply seed via hydroseeder or broadcaster.

### *Soil Amendments (for CABS)*

Refer to Section 5-4.3.2, Soil Amendments.

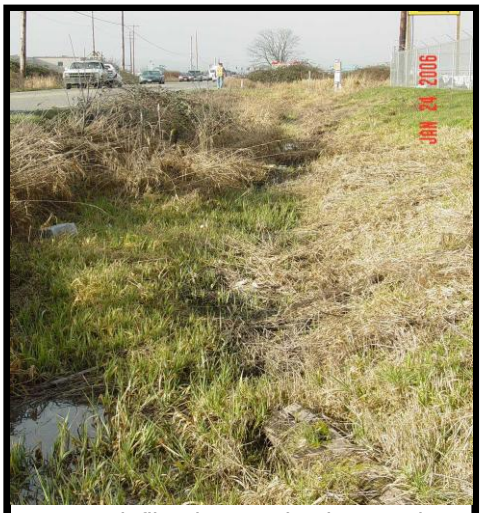
### *Construction Criteria*

- Do not put the biofiltration swale into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized.
- Keep effective erosion and sediment control measures in place until the swale vegetation is established.
- Avoid over-compaction during construction.
- Grade biofiltration swales to attain uniform longitudinal and lateral slopes.

### *Signage*

See Section 5-4.3.7 for signing requirements.

## *RT.05 – Wet Biofiltration Swale*




Wet Biofiltration Swale along I-5 in Snohomish County

**Description:** Variation of basic biofiltration swale. Vegetation is specifically selected for areas where water tables are high, or continuous base flow results in saturated soil conditions.

**Geometry Limitations**

| | |
|---|---|
| Longitudinal Slope | ≤ 1.5% |
| Max Water Depth | 4" |
| Bed Width | 2-10' |
| Min Length | 100' |
| Max Side Slopes | 3H:1V |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-20

**Capital Cost**

➲ Low to Moderate

**O & M Cost**

➲ Low to Moderate

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☑ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☑ Energy Dissipater/Level Spreader
- ☐ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☑ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☑ | ☐ | Temperature |
| ☐ | ☐ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☑ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5.

## Introduction

### *General Description*

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 base flow is likely to result in saturated soil conditions. Where saturation exceeds about two continuous weeks, typical grasses die; thus, vegetation specifically adapted to saturated soil conditions is needed. This type of vegetation in turn requires modification of several of the design parameters for the basic biofiltration swale to remove low concentrations of pollutants such as total suspended solids (TSS), heavy metals, nutrients, and petroleum hydrocarbons.

### *Applications and Limitations*

Wet biofiltration swales are applied where a basic biofiltration swale is desired but not allowed or advisable because of one or more 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, high groundwater, or base flows on the site
- Longitudinal slopes are slight (generally less than 1.5%) and ponding is likely

## Design Flow Elements

### *Flows to Be Treated*

Wet biofiltration swales must be designed to treat the runoff treatment flow rate discussed in Section 3-3.5 under Minimum Requirement 5. Hydrologic methods are presented in Sections 4-3 and 4-4.

### *Overflow or Bypass*

To accommodate flows exceeding the water quality flow rate, the following two design options are available:

- A high-flow bypass can be installed for flows greater than the runoff treatment design flow to protect wetland vegetation from damage. Unlike grass, wetland vegetation does not quickly regain an upright attitude after being flattened by high flows. New growth, usually from the base of the plant and often taking several weeks, is required for the grass to regain its upright form. The bypass may be an open channel parallel to the wet biofiltration swale.
- Alternatively, swale bottom width may be tripled to accommodate high flows. The following features must be included:

An energy dissipater and level spreader must be set at the head of the swale to ensure equal distribution of influent and reduce the potential for scour. Gravel filter berms (Standard Specification 8-01.3[9]B) must be placed every 30 feet across the full width of the swale. The minimum required swale length should not include the length occupied by gravel filter berms.

If the calculated width to convey high flows exceeds 25 feet, then a high flow channel with a bed elevation 0.5 feet above the swale depth can be constructed. The high-flow channel can be either planted or rock-lined.

## Structural Design Considerations

### *Geometry*

Use the same design approach as for basic biofiltration swales (see BMP RT.04), except add the following:

**Extended wet season flow adjustment.** If the swale is downstream of a detention pond providing flow control, multiply the treatment area (bottom width times length) of the swale (as determined by the design steps listed in BMP RT.04) by 2 and readjust the swale length or width to provide an equivalent area. Maintain a 5:1 length-to-width ratio.

*Intent: The treatment area of swales following detention ponds needs to be increased 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. Because vegetation growing in streams is often less dense, an increase in treatment area is needed to ensure equivalent pollutant removal is achieved in extended flow situations.*

**Swale geometry.** Use the same geometry specified for basic biofiltration swales (see BMP RT.04), except for the following modifications:

- The bottom width may be increased to 25 feet maximum, but a length-to-width ratio of 5:1 must be maintained (see Figure RT.05.1). No longitudinal dividing berm is needed. Note: The minimum swale length is 100 feet.
- If longitudinal slopes are greater than 2%, the wet swale must be stepped so that the slope within the stepped sections averages 2% or less. Steps may be made of retaining walls, log check dams, short riprap sections, or similar structures. Steps must be designed to prevent scour on the downstream side of the step. No underdrain or low-flow drain is required.

**Water depth and base flow.** Use the same criteria specified for basic biofiltration swales (see BMP RT.04), except that the design water depth must be 4 inches for all wetland vegetation selections and no underdrains or low-flow drains are required.

**Flow velocity, energy dissipation, and flow spreading.** Use the same criteria specified for basic biofiltration swales (see BMP RT.04), except flow spreaders are not needed.

## Site Design Elements

### *Landscaping (Planting Considerations)*

Use the same design considerations specified for basic biofiltration swales (see BMP RT.04), except for the following modifications:

- Select acceptable plants for western Washington sites from the list shown in Table RT.05.1. 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.
- A wetland seed mix may be applied by hydroseeding, but if coverage is poor, planting rootstock or nursery stock is required. Poor coverage is considered to be more than 30% bare area through the upper two-thirds of the swale after four weeks.

### *Construction Considerations*

Use the same construction considerations specified for basic biofiltration swales (see BMP RT.04).

### *Signage*

See Section 5-4.3.7 for signing requirements.

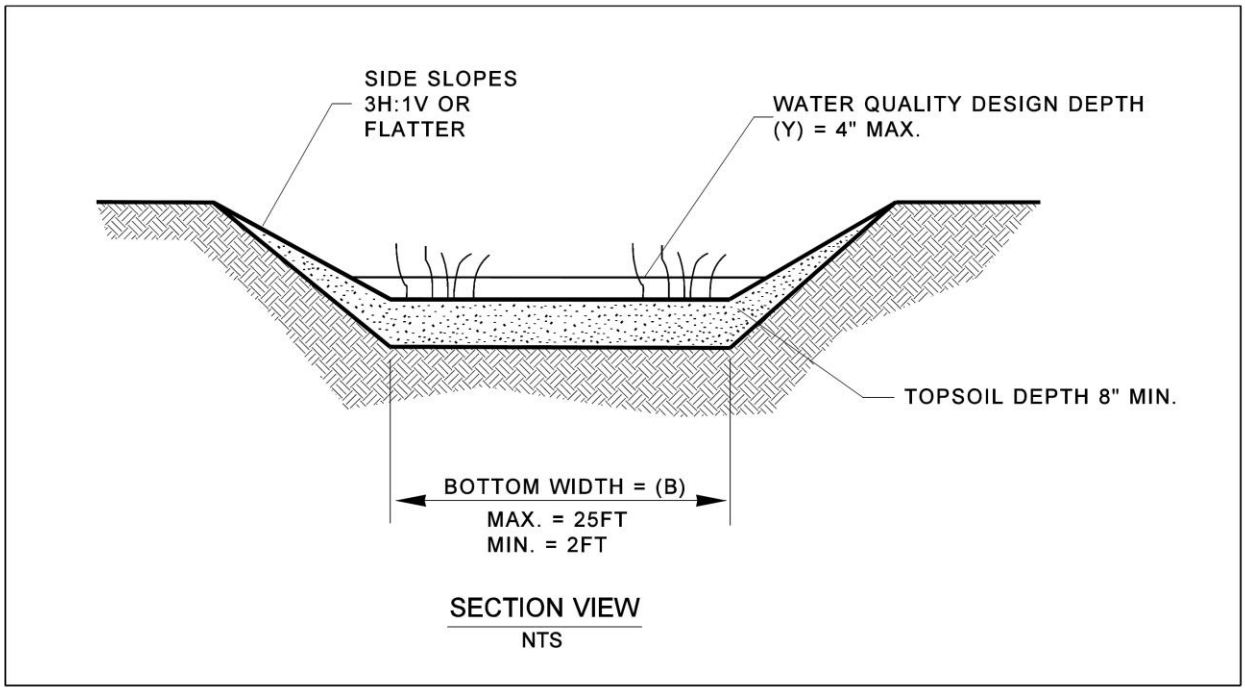



**Figure RT.05.1 Wet biofiltration swale: Cross section.**

## Table RT.05.1. Recommended plants for wet biofiltration swales in western Washington.

| Common Name | Scientific Name |
|---|---|
| Shortawn foxtail | *Alopecurus aequalis* |
| Water foxtail | *Alopecurus geniculatus* |
| Spike rush | *Eleocharis spp.* |
| Slough sedge* | *Carex obnupta* |
| Sawbeak sedge | *Carex stipata* |
| Sedge | *Carex spp.* |
| Western mannagrass | *Glyceria occidentalis* |
| Velvetgrass | *Holcus mollis* |
| Slender rush | *Juncus tenuis* |
| Watercress* | *Rorippa nasturtium-aquaticum* |
| Water parsley* | *Oenanthe sarmentosa* |
| Hardstem bulrush | *Scirpus acutus* |
| Small-fruited bulrush | *Scirpus microcarpus* |

* Good choice 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 that prevents water from filtering through the clump.

## *RT.06 – Continuous Inflow Biofiltration Swale*

Continuous Inflow Biofiltration Swale along I-5 in Snohomish County

**Description:** Variation of basic biofiltration swale. Water enters swale continuously along side slope. The basic Biofiltration design is modified by increasing swale length to achieve an equivalent average hydraulic time.

**Geometry Limitations**

| | |
|---|---|
| Max Inlet Port Flow | 10% |
| Longitudinal Slope | 1.5- 5% |
| Max Water Depth | 2-4" |
| Bed Width | 2-10' |
| Min Length | >100' |
| Max Side Slope | 3H:1V |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-20

**Capital Cost**

➲ Low to Moderate

**O & M Cost**

➲ Low to Moderate

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☑ Energy Dissipater/Level Spreader
- ☐ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☐ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☑ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5.

## Introduction

### *General Description*

In situations where water enters a biofiltration swale continuously along the side slope rather than discretely at the head, a different design approach—the *continuous inflow biofiltration swale*—is needed (see Figure RT.06.1). The basic swale design is modified by increasing swale length to achieve an equivalent average hydraulic residence time.

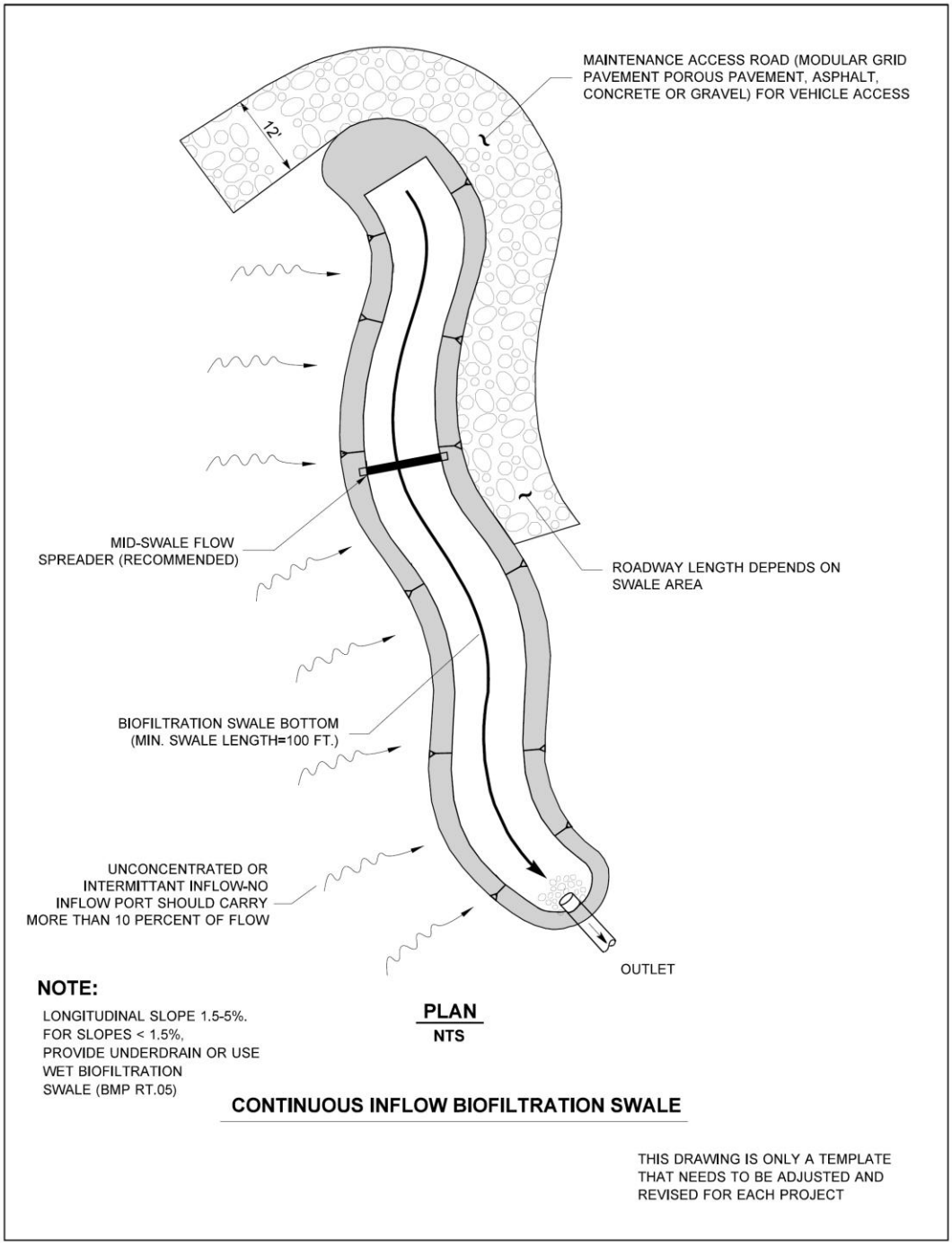



**Figure RT.06.1 Continuous inflow biofiltration swale: Plan view.**

### *Applications and Limitations*

A continuous inflow biofiltration swale is used when 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. In general, no inlet port should carry more than about 10% of the flow.

A continuous inflow swale is not appropriate where significant lateral flows enter a swale at some point downstream from the head of the swale. In this situation, the swale width and length must be recalculated from the point of confluence to the discharge point in order to provide adequate treatment for the increased flows.

## Structural Design Considerations

Use the same considerations specified for BMP RT.04 (biofiltration swale), except for the following:

- For the design flow, include runoff from the pervious side slopes draining to the swale along the entire swale length.
- If only a single design flow is used, use the flow rate at the outlet. The goal is to achieve an average residence time through the swale of 9 minutes. Assuming an even distribution of inflow into the side of the swale, double the hydraulic residence time to a minimum of 18 minutes.

Determine $Q_{biofil}$ as shown in Step P-2 of the basic biofiltration swale (see BMP RT.04) criteria.

- For continuous inflow biofiltration swales, plant interior side slopes above the runoff treatment design elevation in grass. A typical lawn seed mix or the biofiltration seed mixes are acceptable. Landscape plants or groundcovers other than grass generally should not be used 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.*

After the cross-sectional size of the biofiltration swale is determined using $Q_{biofil}$, complete the following steps. This is to account for the hydraulic residence time of flow moving through the vegetated side slopes (3H:1V or shallower and slope length >5 feet) at various points along the length of the swale.

- Break the drainage basin of the swale into areas so that no area contributes more than 20% of the flow. Include only those areas that discharge sheet flow to the vegetated side slopes and biofiltration swale.

- Determine the velocity of flows through each vegetated side slope, $V_{n,ss}$ (ft/sec), for each of the contributing areas by completing Steps 1 through 3 of the vegetated filter strip design methodology (see BMP RT.02).

- Determine the hydraulic residence time within each vegetated side slope, $t_{ss}$ (sec), for each area using:

  $$L_{n,ss}/V_{n,ss} = t_{n,ss}$$

  where: $L_{n,ss}$ = length of vegetated side slope of the n$^{th}$ swale subbasin (ft)

- Determine the weighted mean hydraulic residence time, $t_{mean,ss}$, for *all flows* passing through vegetated side slopes using:

  $$[Q_1(t_{ss,1})+Q_2(t_{ss,2})+\ldots.+Q_n(t_{ss,n})]/Q_{total,ss}= t_{mean,ss}$$

  where: $Q_n$ = flow rate for n$^{th}$ contributing area (cfs)

  $Q_{total,ss}$ = total flow that passes through all of the vegetated side slopes (cfs)

- Multiply $t_{mean,ss}$ by $R$

  where: $t_{mean,ss}$ x $R$ = $t_{adj}$

  $R$ = $Q_{total,ss}$ / $Q_{biofil}$

  $Q_{biofil}$ = total runoff treatment flow rate as determined in Step P-2 of the basic biofiltration swale (see BMP RT.04) criteria

- If the head of the swale is located downstream of the last contributing vegetated side slope section, subtract $t_{adj}$ from 540 seconds (= 9 minutes) to determine the $t_{design}$. If the swale is located along the entire toe of the contributing vegetated side slope, subtract $t_{adj}$ from 1080 seconds (= 18 minutes) to determine $t_{design}$. Note: In the latter case, the swale must be at least as long as the contributing vegetated side slopes.

- Using the downstream flow rate ($Q_{biofil}$), determine the velocity through the swale and use $t_{design}$ calculated in Step 6 to determine the total swale length required. Make any necessary adjustments to ensure the criteria in Table RT.04.2 are met.

### *Signage*

See Section 5-4.3.7 for signing requirements.

## *RT.07 – Media Filter Drain*

Media Filter Drain Along SR 167 in King County

**Description:** Linear flow-through stormwater runoff treatment device along highway side slopes, medians, borrow ditches, and other linear depressions.

**Geometry Limitations**

| | |
|---|---|
| Contributing Flow Path | ≤ 150’ |
| Embankment Slope | 2%-25% |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☑ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-20

| Capital Cost | M & O Cost |
|---|---|
| ➲ Low | ➲ Low to Moderate |

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☑ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☐ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☐ Presettling/Pretreatment
- ☑ Underdrain (Where Permitted)
- ☑ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred |
|---|---|
| ☐ | ☐ Fecal Coliform |
| ☐ | ☐ Phosphorus |
| ☐ | ☐ Nitrogen |
| ☐ | ☐ Temperature |
| ☐ | ☑ Dissolved Metals |
| ☐ | ☑ Total Suspended Solids/Turbidity |
| ☐ | ☐ Dissolved Oxygen |
| ☐ | ☐ pH |
| ☐ | ☐ Oil/Grease |
| ☐ | ☐ PAHs |
| ☐ | ☐ Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☐ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☑ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Table 5.5.10.

## Introduction

### *General Description*

The media filter drain (MFD), previously referred to as the *ecology embankment,* is a linear flow-through stormwater runoff treatment device that can be sited along highway side slopes (conventional design) and medians (dual media filter drains), borrow ditches, or other linear depressions. Cut-slope applications may also be considered. The media filter drain can be used where available right of way is limited, sheet flow from the highway surface is feasible, and lateral gradients are generally less than 25% (4H:1V). The media filter drain has a General Use Level Designation (GULD) for basic, enhanced, and phosphorus treatment. Updates/changes to the use-level designation and any design changes will be posted in the *Postpublication Updates* section of the HRM Resource Web Page.

Media filter drains (MFDs) 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 surfacing base course (CSBC). This layer of CSBC must be porous enough to allow treated flows to freely drain away from the MFD mix.

Typical MFD configurations are shown in Figures RT.07.1, RT.07.2, and RT.07.3.

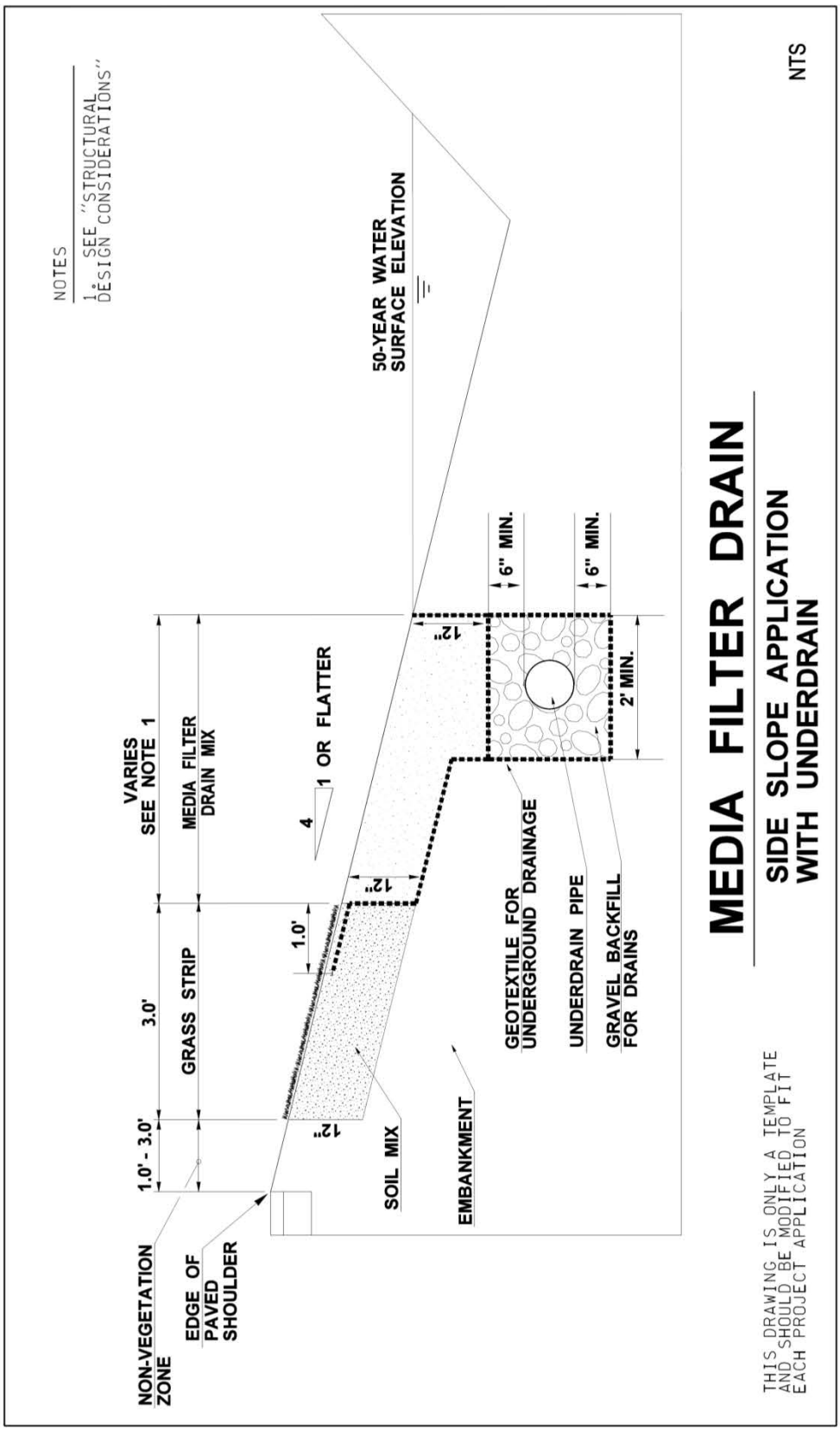



**Figure RT.07.1 Media filter drain: Side slope application with underdrain.**

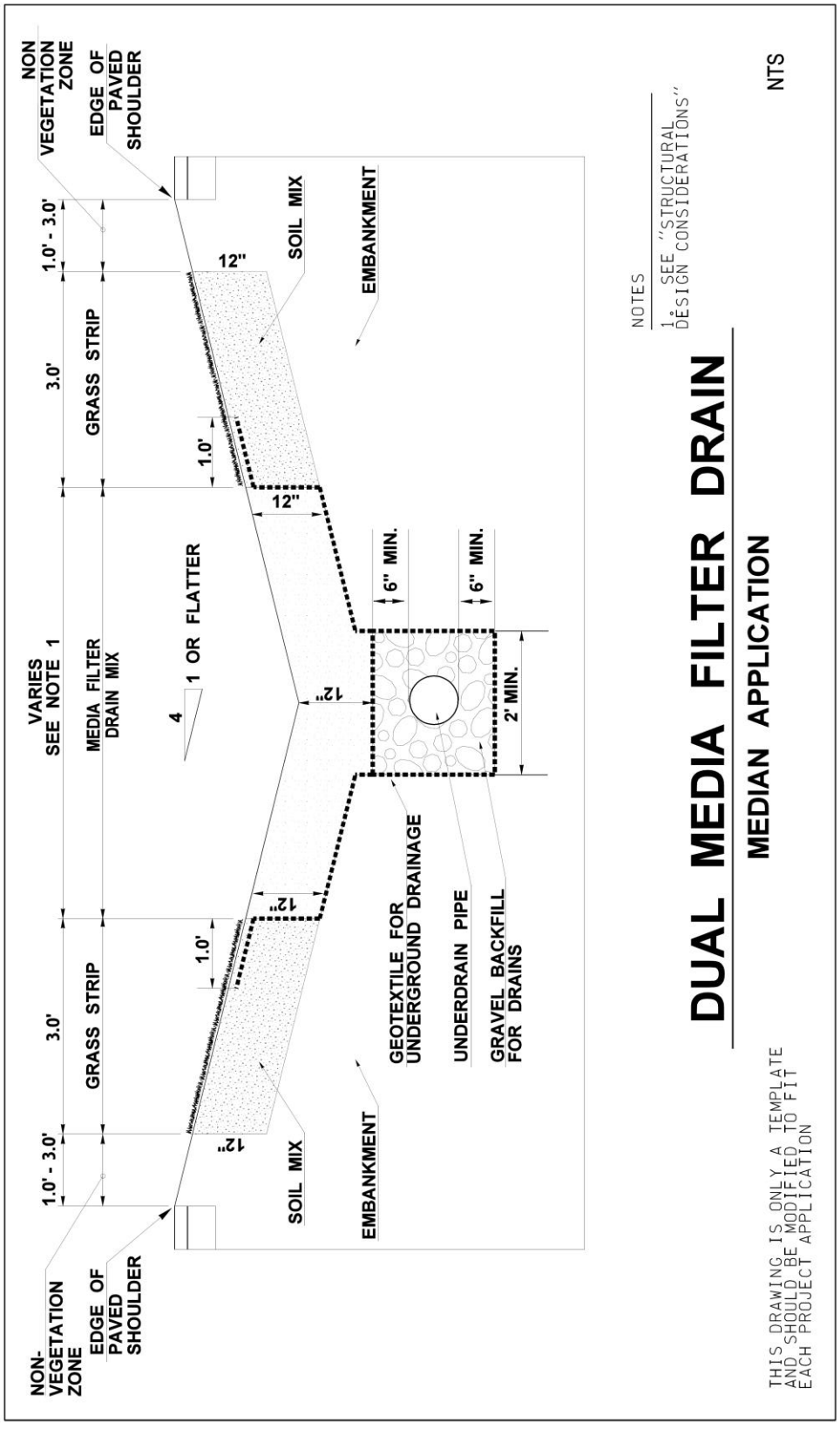



**Figure RT.07.2 Dual media filter drain: Median application.**

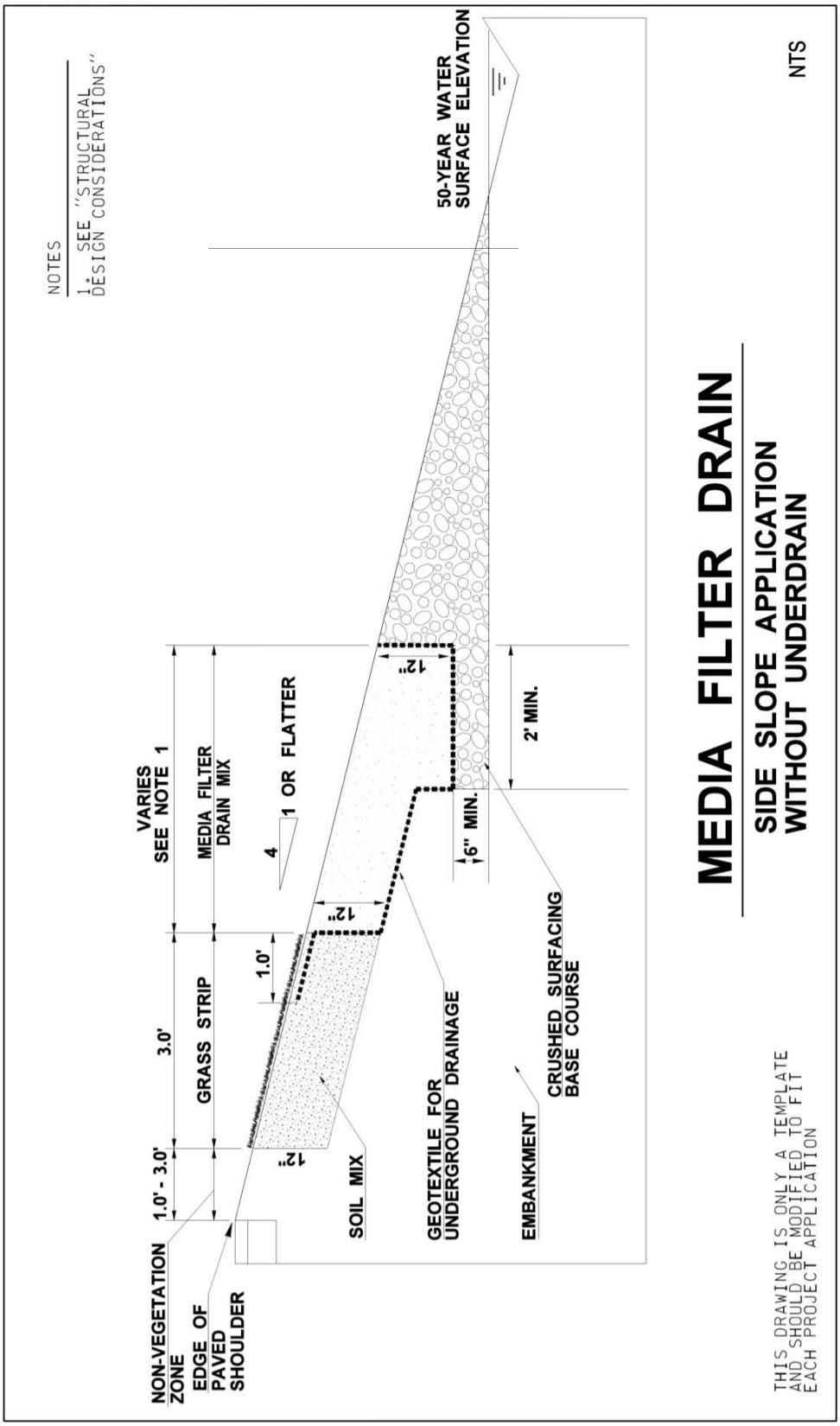



**Figure RT.07.3 Media filter drain: side slope application without underdrain.**

### *Functional Description*

The media filter drain removes suspended solids, phosphorus, and metals from highway runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration.

Stormwater runoff is conveyed to the media filter drain via sheet flow over a vegetation-free gravel zone to ensure sheet dispersion and provide some pollutant trapping. Next, 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. The runoff is then filtered through a bed of porous, alkalinity-generating granular medium—the media filter drain mix. Media filter drain mix is a fill material composed of crushed rock (sized by screening), dolomite, gypsum, and perlite. 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. Treated water drains from the media filter drain mix bed into the conveyance system below the media filter drain mix. Geotextile lines the underside of the media filter drain mix bed and the conveyance system.

The underdrain trench is an option for hydraulic conveyance of treated stormwater to a desired location, such as a downstream flow control facility or stormwater outfall. The trench's perforated underdrain pipe is a protective measure to ensure free flow through the media filter drain mix. It may be possible to omit the underdrain pipe if it can be demonstrated that the pipe is not necessary to maintain free flow through the media filter drain mix and underdrain trench.

It is critical to note that water should sheet flow across the media filter drain. Channelized flows or ditch flows running down the middle of the dual media filter drain (continuous off-site inflow) should be minimized.

### *Applications and Limitations*

In many instances, conventional runoff treatment is not feasible due to right of way constraints (such as adjoining wetlands and geotechnical considerations). The media filter drain and the dual media filter drain designs are runoff treatment options that can be sited in most right of way confined situations. In many cases, a media filter drain or a dual media filter drain can be sited without the acquisition of additional right of way needed for conventional stormwater facilities or capital-intensive expenditures for underground wet vaults.

#### *Applications*

Media Filter Drains

The media filter drain can achieve basic, phosphorus, and enhanced water quality treatment. 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:1V and longitudinal slopes no steeper than 5%. As side slopes approach 3H:1V, without design modifications, sloughing may become a problem due to friction limitations between the separation geotextile and underlying soils. The longest flow path from the contributing area delivering sheet flow to the media filter drain should not exceed 150 feet.

If there is sufficient roadway embankment width, the project office should consider placing the grass strip and media mix downslope when feasible. The project office should ensure the MFD does not intercept seeps, springs, or groundwater.

Dual Media Filter Drain for Highway Medians

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. Channelized flows or ditch flows running down the middle of the dual media filter drain (continuous off-site inflow) should be minimized.

*Limitations*

Media Filter Drains

- **Steep slopes**. Avoid construction on longitudinal slopes steeper than 5%. Avoid construction on 3H:1V lateral slopes, and preferably use less than 4H:1V slopes. 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. (For details, see *Geometry, Components* and *Sizing Criteria, Cross Section* in the Structural Design Considerations section below).

- **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 highway fill slopes adjacent to a wetland buffer. In those situations where the highway fill prism is located adjacent to wetlands, an interception trench/underdrain will need to be incorporated as a design element in the media filter drain.

- **Shallow groundwater**. Mean high water table levels at the project site need to be determined to ensure the media filter drain mix bed and the underdrain (if needed) will not become saturated by shallow groundwater.

- **Unstable slopes**. In areas where slope stability may be problematic, consult a geotechnical engineer.

- **Areas of seasonal groundwater inundations or basement flooding**. Site-specific piezometer data may be needed in areas of suspected seasonal high groundwater inundations. The hydraulic and runoff treatment performance of the dual media filter drain may be compromised due to backwater effects and lack of sufficient hydraulic gradient.

- **Wetlands**. Do not construct in wetlands and wetland buffers.

- **Narrow roadway shoulders**. In areas where there is a narrow roadway shoulder that does not allow enough room for a vehicle to fully stop or park, consider placing the MFD farther down the embankment slope. This will reduce the amount of rutting in the MFD and decrease overall maintenance repairs.

## Design Flow Elements

### *Flows to Be Treated*

The basic design concept behind the media filter drain and dual media filter drain is to fully filter all runoff through the media filter drain mix. Therefore, the infiltration capacity of the medium and drainage below needs to match or exceed the hydraulic loading rate.

## Structural Design Considerations

### *Geometry*

*Components*

No-Vegetation Zone

The no-vegetation zone (vegetation-free zone) is a shallow gravel zone located directly adjacent to the highway pavement. 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 highway surface to the BMP. The no-vegetation zone functions as a level spreader to promote sheet flow and a deposition area for coarse sediments. The no-vegetation zone should be between 1 foot and 3 feet wide. Depth will be a function of how the roadway section is built from subgrade to finish grade; the resultant cross section will typically be triangular to trapezoidal. Within these bounds, width varies depending on WSDOT maintenance spraying practices. Contact the area maintenance office for this information.

Grass Strip

The width of the grass strip is dependent on the availability of space within the highway side slope. 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 designer should consult with the Region Landscape Architect for soil mix recommendations. The designer may consider adding aggregate to the soil mix to help minimize rutting problems from errant vehicles. The soil mix should ensure grass growth for the design life of the media filter drain.

Media Filter Drain Mix Bed

The media filter drain 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 add alkalinity and ion exchange capacity to promote the precipitation and exchange of heavy metals; and the perlite improves moisture retention to promote the formation of biomass within the media filter drain mix. The combination of physical filtering, precipitation, ion exchange, and biofiltration enhances the water treatment capacity of the mix. The media filter drain mix has an estimated initial filtration rate of 50 inches per hour and a long-term filtration rate of 28 inches per hour due to siltation. With an additional safety factor, the rate used to size the length of the media filter drain should be 10 inches per hour.

Conveyance System Below Media Filter Drain Mix

The gravel underdrain trench provides hydraulic conveyance when treated runoff needs to be conveyed to a desired location such as a downstream flow control facility or stormwater outfall.

In Group C and D soils, an underdrain pipe would help to ensure free flow of the treated runoff through the media filter drain 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 underdrain trench should be a minimum of 2 feet wide for either the conventional or dual media filter drain.

The gravel underdrain trench may be eliminated 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 media filter drain mix should be kept free draining up to the 50-year storm event water surface elevation represented in the downstream ditch.

*Sizing Criteria*

Width

The width of the media filter drain mix bed is determined by the amount of contributing pavement routed to the embankment. The surface area of the media filter drain mix bed needs to be sufficiently large to fully infiltrate the runoff treatment design flow rate using the long-term filtration rate of the media filter drain mix. For design purposes, a 50% safety factor is incorporated into the long-term media filter drain mix filtration rate to accommodate variations in slope, resulting in a design filtration rate of 10 inches per hour. The media filter drain mix bed should have a bottom width of at least 2 feet in contact with the conveyance system below the media filter drain mix.

Length

In general, the length of a media filter drain or dual media filter drain is the same as the contributing pavement. Any length is acceptable as long as the surface area media filter drain mix bed is sufficient to fully infiltrate the runoff treatment design flow rate.

Cross Section

In profile, the surface of the media filter drain should preferably have a lateral slope less than 4H:1V (<25%). On steeper terrain, it may be possible to construct terraces to create a 4H:1V slope, or other engineering may be employed to ensure slope stability up to 3H:1V. 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 media filter drain mix bed. Consultation with a geotechnical engineer and the HQ Highway Runoff Unit is required.

Inflow

- Runoff is 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%. Although there is no lateral pavement slope restriction for flows going to a media filter drain, the designer should ensure flows remain as sheet flow.

Media Filter Drain Mix Bed Sizing Procedure

The media filter drain mix should be a minimum of 12 inches deep, including the section on top of the underdrain trench.

For runoff treatment, sizing the media filter drain mix bed is based on the requirement that the runoff treatment flow rate from the pavement area, $Q_{Highway,}$ cannot exceed the long-term infiltration capacity of the media filter drain, $Q_{Infiltration}$:

$$Q_{Highway} \leq Q_{Infiltration}$$

For western Washington, $Q_{Highway}$ is the flow rate at or below which 91% of the runoff volume for the developed TDA will be treated, based on a 15-minute time step (see Section 4-3.1.1), and can be determined using the water quality data feature in MGSFlood. For eastern Washington, $Q_{Highway}$ is the peak flow rate predicted for the 6-month, short-duration storm under post-developed conditions for each TDA (see Appendix 4C), and can be determined by selecting the short-duration storm option in StormShed.

The long-term infiltration capacity of the media filter drain is based on the following equation:

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

where:

$LTIR$ = Long-term infiltration rate of the media filter drain mix (use 10 inches per hour for design) (in/hr)

$L$ = Length of media filter drain (parallel to roadway) (ft)

$W$ = Width of the media filter drain mix bed (ft)

$C$ = Conversion factor of 43200 ((in/hr)/(ft/sec))

$SF$ = Safety Factor (equal to 1.0, unless unusually heavy sediment loading is expected)

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

$$W \geq \frac{Q_{Highway} * C * SF}{LTIR * L} \qquad \textbf{(RT.07-1)}$$

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 RT.07.1 was developed to simplify the design steps and should be used to establish an appropriate width.

**Table RT.07.1. Western Washington 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 RT.07.1).

Underdrain Design

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

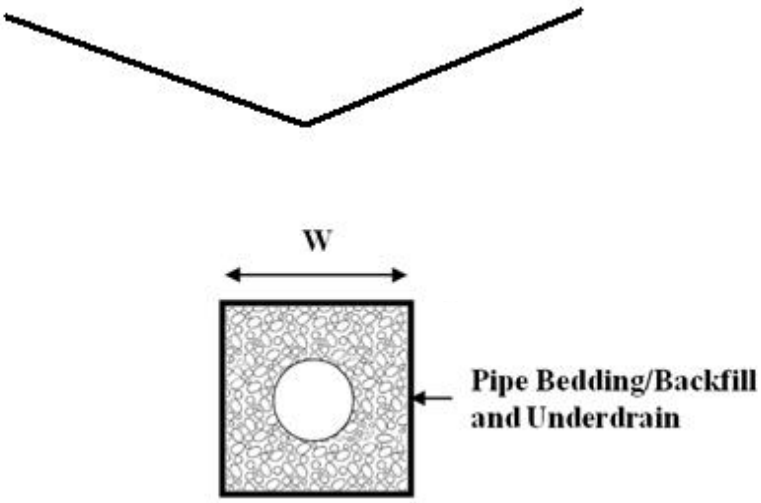



**Figure RT.07.4 Media filter drain underdrain installation.**

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 media filter drain. The design storm event used to determine the flow rate should be relevant to the purpose of the underdrain. For example, if the MFD installation is in western Washington and the underdrain will be used to convey treated runoff to a detention

BMP, size the underdrain for the 50-year storm event. (See the *Hydraulics Manual*, Figure 2-2.1, for conveyance flow rate determination.)

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

where:

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

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

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

$$Q_{\frac{MFD}{ft}} = \frac{f \times W \times 1\,ft}{ft} \times \frac{1\,ft}{12in} \times \frac{1hr}{3600\text{sec}}$$

where:

$Q_{\frac{MFD}{ft}}$ = flow rate of runoff through MFD mix layer (cfs/ft)

$W$ = width of underdrain trench (ft) – see Standard Plan B-55.20-00; the minimum width is 2 ft

$f$ = infiltration rate though the MFD mix (in/hr) = 10 in/hr

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

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

where:

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

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

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

where:

$Q_{UD}$ = estimated flow rate to the underdrain (cfs)

$W$ = width of the underdrain trench (ft) – see Standard Plan B-55.20-00; the minimum width is 2 ft

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

5. Given the underdrain design flow rate, determine the underdrain diameter. Round pipe diameters to the nearest standard pipe size and have a minimum diameter of 6 inches. For diameters that exceed 12 inches, contact either the Region or HQ Hydraulics Office.

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

where:

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

### *Materials*

*Media Filter Drain Mix*

The media filter drain mix used in the construction of media filter drains consists of the amendments listed in Table RT.07.2. Mixing and transportation must occur in a manner that ensures the materials are thoroughly mixed prior to placement and that separation does not occur during transportation or construction operations.

These materials should be used in accordance with the following *Standard Specifications*:

- Gravel Backfill for Drains, 9-03.12(4)
- Underdrain Pipe, 7-01.3(2)
- Construction Geotextile for Underground Drainage, 9-33.1

*Crushed Surfacing Base Course (CSBC)*

If the design is configured to allow the media filter drain to drain laterally into a ditch (see Figure RT.07.3), the crushed surfacing base course below the media filter drain should conform to Section 9-03.9(3) of the *Standard Specifications*.

### *Berms, Baffles, and Slopes*

See *Geometry, Components* and *Sizing Criteria, Cross Section* under Structural Design Considerations above.

## Table RT.07.2. Media filter drain mix.

| Amendment | Quantity |
|---|---|
| **Mineral aggregate: Crushed screenings 3/8-inch to #10 sieve**<br>**Aggregate for Media Filter Drain Mix**<br>Aggregate for Media Filter Drain Mix shall be manufactured from ledge rock, talus, or gravel, in accordance with Section 3-01 of the *Standard Specifications for Road, Bridge, and Municipal Construction,* and shall meet the following test requirements for quality. The use of recycled material is not permitted.<br>Los Angeles Wear, 500 Revolutions 35% max.<br>Degradation Factor 30 min.<br>Aggregate for the Media Filter Drain Mix shall conform to the following requirements for grading and quality:<br>**Sieve Size** **Percent Passing (by weight)**<br>1/2" square 100<br>3/8" square 90-100<br>U.S. No. 4 30-56<br>U.S. No. 10 0-10<br>U.S. No. 200 0-1.5<br>% fracture, by weight, min. 75<br>The fracture requirement shall be at least two fractured faces and will apply to material retained on the U.S. No. 4.<br>Aggregate for the Media Filter Drain shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50% of the surface area of any size between successive laboratory sieves. | 3 cubic yards |
| Perlite:<br>▪ Horticultural grade, free of any toxic materials)<br>▪ 0-30% passing US No. 18 Sieve<br>▪ 0-10% passing US No. 30 Sieve | 1 cubic yard per 3 cubic yards of mineral aggregate |
| Dolomite: CaMg(CO3)2 (calcium magnesium carbonate)<br>▪ Agricultural grade, free of any toxic materials)<br>▪ 100% passing US No. 8 Sieve<br>▪ 0% passing US No. 16 Sieve | 10 pounds per cubic yard of perlite |
| Gypsum: Noncalcined, agricultural gypsum CaSO4•2H2O<br>(hydrated calcium sulfate)<br>▪ Agricultural grade, free of any toxic materials)<br>▪ 100% passing US No. 8 Sieve<br>▪ 0% passing US No. 16 Sieve | 1.5 pounds per cubic yard of perlite |

## Site Design Elements

### *Landscaping (Planting Considerations)*

Landscaping for the grass strip is the same as for biofiltration swales (see BMP RT.04) unless otherwise specified in the special provisions for the project's construction documents.

### *Operations and Maintenance*

Maintenance will consist of routine roadside management. While herbicides will not be applied directly over the media filter drain, it may be necessary to periodically control noxious weeds with herbicides in areas around the media filter drain as part of WSDOT's roadside management program. The use of pesticides may be prohibited if the media filter drain is in a critical aquifer recharge area for drinking water supplies. The designer should check with the local area water purveyor or local health department. Areas of the media filter drain that show signs of physical damage will be replaced by local maintenance staff in consultation with region hydraulics/water quality staff.

### *Construction Criteria*

- Keep effective erosion and sediment control measures in place until grass strip is established.
- Do not allow vehicles or traffic on the MFD to minimize rutting and maintenance repairs.

### *Signage*

Refer to Section 5-4.3.7 for signing requirements. Additionally, if the media filter drain is in a critical aquifer recharge area for drinking water supplies, provide signage prohibiting the use of pesticides.

## *RT.08 – Bioretention Area*

Bioretention Area along SR 99 in King County

**Description:** Bioretention areas (also known as rain gardens) are shallow landscaped depressions that use a designed soil mix and plants to provide runoff treatments and flow control.

**Geometry Limitations**

| | |
|---|---|
| Ponding Depth | 12" Max |
| Pool Drawdown | 24 Hours |
| Groundwater Clearance | 1-3' Min |
| Interior Sidewalls | 2H-1V |
| Soil Depth | 18" Min |

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-20

| Capital Cost | O&M Cost |
|---|---|
| ➲ Moderate | ➲ Moderate |

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☑ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☑ Presettling/Pretreatment
- ☑ Underdrain (where required)
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☐ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads
- ☐ Vactor Truck Access
- ☐ Mowing Considerations
- ☐ Valve Access
- ☑ Specialized Training Requirements

**Additional Considerations:** See Sections 5-3.6.1 and 5.5.

## Introduction

### *General Description*

For guidelines and criteria on the design of bioretention areas, refer to Appendix C of Volume III of Ecology's *Stormwater Management Manual for Western Washington* (SMMWW) and the Puget Sound Action Team's *Low Impact Development Technical Guidance Manual for Puget Sound.*

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

## 5-4.1.4 Wet Pool BMPs

### *RT.12 – Wet Pond*

Dual-Celled Wet Pond Along I-5 in Clark County

**Description:** Stormwater pond that retains a permanent pool of water (wet pool), at least during the wet season.

**Geometry Limitations**

| | |
|---|---|
| Interior Slopes | 3H:1V Max |
| Exterior Slopes | 2H:1V Max |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☑ Phosphorus
  - ☑ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 20-50

**Capital Cost**

➲ Moderate to High

**O & M Cost**

➲ Low to Moderate

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☑ Inlet and Outlet Spacing
- ☑ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☑ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☑ | ☐ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☑ | ☐ | Temperature |
| ☐ | ☐ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☑ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Table 5.5.13.

## Introduction

### *General Description*

A *wet pond* is a constructed stormwater pond that retains a permanent pool of water (wet pool), at least during the wet season. The volume of the wet pool is related to the effectiveness of 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. Figures RT.12.1 and RT.12.2 illustrate a typical wet pond BMP.

### *Applications and Limitations*

A wet pond BMP must be an on-line facility receiving runoff from only new impervious areas or equivalent areas. If a decision has been made to treat runoff from existing impervious surfaces per the retrofit instructions in Section 3-4, then the wet pond BMP would be an on-line facility receiving runoff from the new plus existing impervious areas or equivalent areas.

Wet ponds can be designed in two sizes: basic and large (see Table 3-1). Basic wet ponds are approved basic runoff treatment BMPs. Large wet ponds are designed for higher levels of pollutant removal and are an appropriate treatment BMP for phosphorus control. It is recommended that all runoff treatment BMPs that use permanent wet pools use facility liners. Additional information can be found in Section 5-4.3.3.

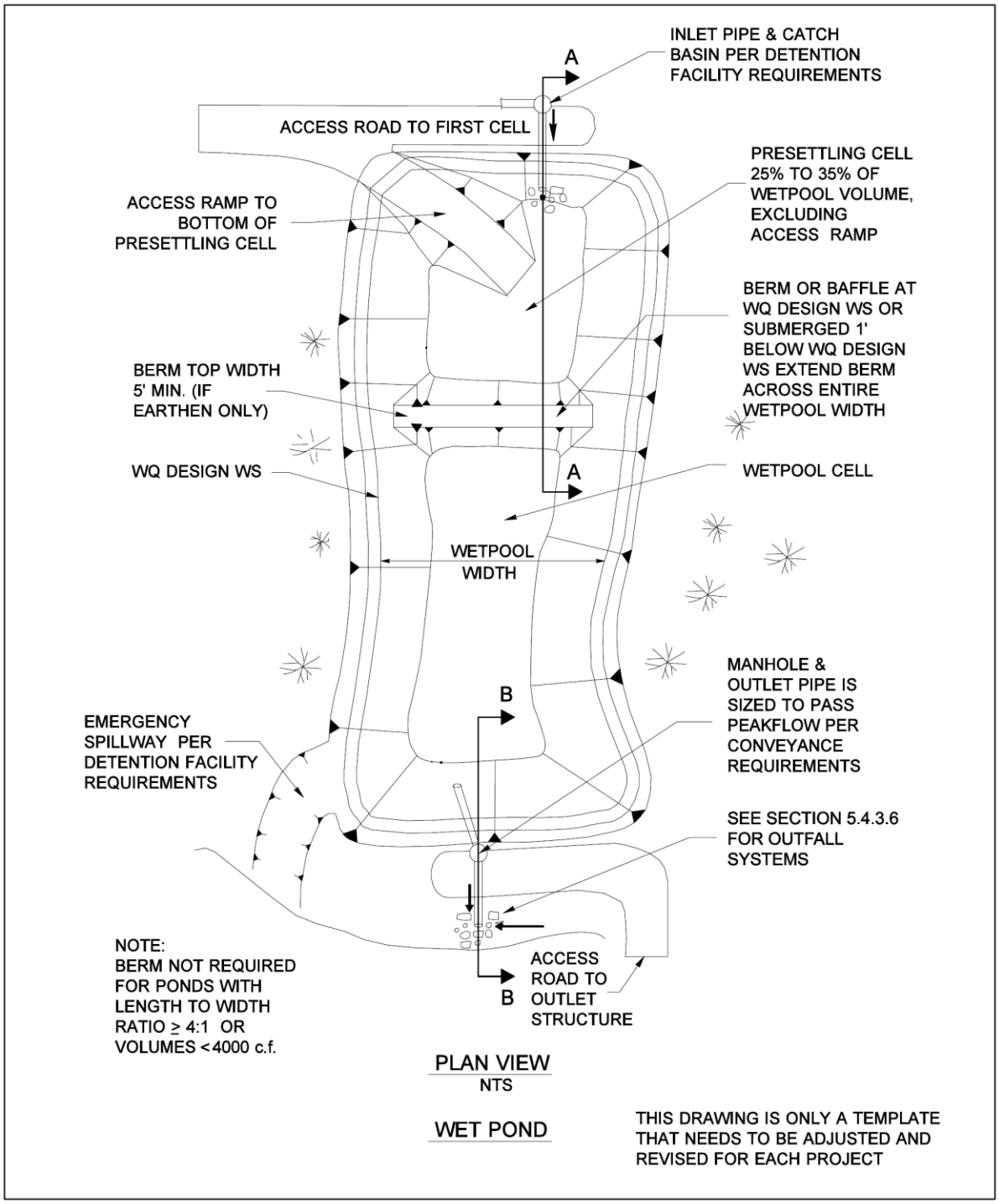



**Figure RT.12.1 Wet pond: Plan view.**

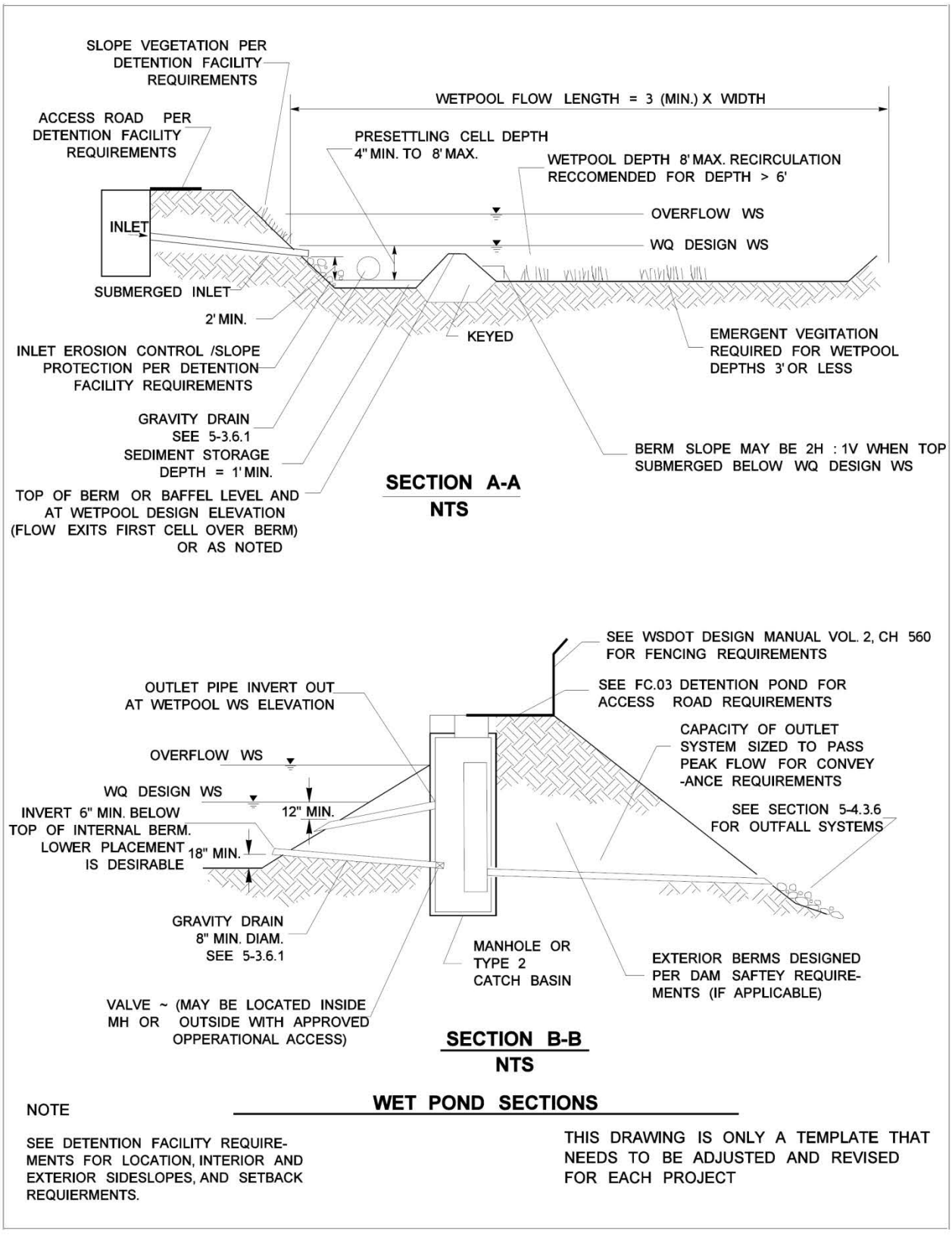



**Figure RT.12.2 Wet pond: Cross section.**

Refer to BMP CO.01 (Combined Wet/Detention Pond) if the pond is to be used for flow control in addition to runoff treatment.

## Design Flow Elements

### *Flows to Be Treated*

Basic wet ponds are designed to treat the runoff treatment volume described in Section 3-3.5 under Minimum Requirement 5. Large wet ponds are designed to treat a volume 1.5 times greater than the runoff treatment volume. Hydrologic methods are presented in Sections 4-3 and 4-4.

### *Overflow or Bypass*

The overflow criteria for single-purpose (treatment only, not combined with flow control) wet ponds are as follows:

- An open top standpipe riser in the control structure satisfies the requirement for primary overflow design (see Figure RT.12.2)
- The top of the riser should be set at the water quality design water surface elevation
- The primary overflow should be sized to pass the 100-year flow

### *Emergency Overflow Spillway*

An emergency spillway or structure must be provided and designed according to the requirements for detention ponds (see BMP FC.03). The bottom of the emergency overflow spillway must be set at the design water surface elevation (see Figure FC.03.3).

## Structural Design Considerations

### *Geometry*

*Design Criteria*

- The wet pond is divided into a minimum of two cells separated by a baffle or berm. The first cell must contain between 25% and 35% of the total wet pond volume. The baffle or berm volume does not count as part of the total wet pond 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; in a wet vault, it connects 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 the local jurisdiction.
- Sediment storage is provided in the first cell. The minimum depth of the sediment storage must be 1 foot. A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation or an alternative gauging method should be used.

- The minimum depth of the first cell must 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 must not exceed 8 feet (exclusive of sediment storage in the first cell). Pool depths of 3 feet or shallower (second cell) must be planted with emergent wetland vegetation (see *Landscaping* requirements later in this section).
- Wet ponds with wet pool volumes less than or equal to 4000 cubic feet may be single-celled (no baffle or berm is required). However, it is especially important that the flow path length be maximized in single-celled wet ponds. The ratio of flow path length to width must be greater than 4:1 in single-celled wet ponds.
- All inlets must enter the first cell. If there are multiple inlets, the length-to-width ratio is based on the average flow path length for all inlets.
- The first cell may be lined in accordance with the liner recommendations contained in Section 5-4.3.3.

*Sizing Procedure*

Design Steps (D)

**D-1** Identify the required wet pool volume ($Vol_{wq}$). For options to determine this volume using continuous runoff models, see Chapter 4. For large wet ponds, the wet pool volume is 1.5 times the water quality volume.

**D-2** Estimate wet pool dimensions satisfying the following design criterion:

$$Vol_{wq} = [h_1(A_{t1} + A_{b1}) / 2] + [h_2(A_{t2} + A_{b2}) / 2] + \ldots\ldots + [h_n(A_{tn} + A_{bn}) / 2]$$

where: $A_{tn}$ = top area of wet pool surface in cell n ($ft^2$)

$A_{bn}$ = bottom area of wet pool surface in cell n ($ft^2$)

$h_n$ = depth of wet pool in cell n (above top of sediment storage) (ft)

**D-3** Design pond outlet pipe and determine primary overflow water surface. (See the *Hydraulics Manual* for design of pond outlet pipe and method to determine primary overflow water surface.)

*Inlet and Outlet*

For details on the following requirements, see Figures RT.12.1 and RT.12.2.

- Inlets and outlets must be placed to maximize the flow path through the facility. The ratio of flow path length to width from the inlet to the outlet must 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 is calculated as follows: width = (average top width + average bottom width)/2.

- The inlet to the wet pond must be submerged, with the inlet pipe invert a minimum of 2 feet from the pond bottom (not including the 1-foot-minimum sediment storage). The top of the inlet pipe should be submerged at least 1 foot below the runoff treatment design water surface if possible. The designer shall compute the hydraulic grade line (HGL) of the inlet pipe to verify that backwater conditions are acceptable. (See the *Hydraulics Manual* for computing an HGL.)

  *Intent: The inlet is submerged to dissipate the 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 must be provided. Either a Type 2 catch basin (see the WSDOT *Standard Plans for Road, Bridge, and Municipal Construction [Standard Plans]*) or a manhole with a cone grate (birdcage) may be used. No sump is required in the outlet structure for wet ponds not providing detention storage. The outlet structure receives flow from the pond outlet pipe. The birdcage opening provides an overflow route should the pond outlet pipe become clogged.

- The pond outlet pipe (from the pond into the outlet structure) must be back-sloped, or have a turn-down elbow, and extend 1 foot below the runoff treatment 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 traps oils and floatables in the wet pond.

- The pond outlet pipe must be sized, at a minimum, to pass the runoff treatment design flow. Note: The highest invert of the outlet pipe must be set to the runoff treatment design water surface elevation.

- Alternative methods to dissipate energy at the end of the outlet pipe, such as a dissipater tee, should be considered to reduce the need for extensive riprap.

### *Materials*

- All metal parts must be corrosion-resistant. Galvanized materials should not be used unless unavoidable.

  *Intent: Galvanized metal contributes zinc to stormwater, sometimes in very high concentrations.*

### *Berms, Baffles, and Slopes*

- A berm or baffle must 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 high, the berm must be constructed by excavating a key trench equal to 50% of the embankment cross-sectional height and width. A geotechnical engineer may waive this requirement for specific site conditions. A geotechnical analysis must address situations in which one of the two cells is empty while the other remains full of water.

- The top of the berm may be at the runoff treatment design water surface or submerged 1 foot below this surface. If the top of the berm is at the runoff treatment design water surface, berm side slopes should be 3H:1V. Berm side slopes may be steeper (up to 2H:1V) if the berm is submerged 1 foot. Earthen berms should have a minimum top width of 5 feet.

  *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 backslope 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.

- Criteria for wet pond side slopes are as follows:

  - Interior side slopes must be no steeper than 3H:1V. Steeper side slopes will contain the width or thickness of emergent vegetation leading to higher density. Dense emergent vegetation causes the following problems: (1) it provides predator-free shoreline habitats for mosquito production, and (2) it reduces or eliminates access to the pond for routine inspections and maintenance.

  - Exterior side slopes must be no steeper than 2H:1V.

  - Slopes should be no steeper than 4H:1V if they are to be mowed.

  - Pond sides may be retaining walls, provided that a fence is situated along the top of the wall and at least 25% of the pond perimeter is a vegetated side slope no steeper than 3H:1V.

  - The toe of the exterior slope must be no closer than 5 feet from the right of way line.

### *Embankments*

- Embankments that impound water must comply with the Washington dam safety regulations (WAC 173-175). 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 discussion in BMP FC.03, Detention Pond.)

- The berm embankment must be constructed in accordance with Section 2-03.3(14)C, Method C, of the *Standard Specifications*.

- The berm embankment must be constructed of material consisting of a minimum of 30% clay, a maximum of 60% sand, a maximum of 60% silt, and negligible gravel and cobble.
- To prevent undermining, installation of a perimeter cutoff trench underneath or near embankments should be considered.
- Antiseepage collars must be placed on outflow pipes in berm embankments impounding water deeper than 8 feet at the runoff treatment design water surface. Antiseepage collars may also be necessary in other situations.

## Site Design Elements

### *Setback Requirements*

- Wet ponds must be a minimum of 5 feet from any property line or vegetative buffer. This distance may need to be increased based on the permit requirements of the local jurisdiction.
- Wet ponds must be 100 feet from any septic tank or drain field (except wet vaults must be a minimum of 20 feet).
- The designer should request from the WSDOT Materials Lab a geotechnical report for the project that evaluates any potential structural site instability due to extended subgrade saturation or head loading of the permeable layer. This includes the potential impacts to downgradient properties, especially on hills with known side-hill seeps. The report should address the adequacy of the proposed wet pond locations and recommend the necessary setbacks from any steep slopes and building foundations.

### *Landscaping (Planting Considerations)*

Planting requirements for detention ponds (see BMP FC.03) also apply to wet ponds.

- The cells in large wet ponds intended for phosphorus control should not be planted because the plants 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 must be planted with emergent wetland vegetation. This results in habitat for natural predators of mosquitoes such as dragonflies, birds, fish, and frogs. (See Table RT.12.1 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 in the wet pond and typically escape to other wetland areas where they do the same. They also create dense emergent vegetation that can provide a safe haven for mosquito larvae.
- Vegetation that forms floating mats should not be planted because the mats protect mosquito larvae.

- A variety of plant species should be planted to encourage a diversity of mosquito predators. This variety can also make the overall predator population more robust to withstand environmental changes to the facility.
- If the wet pond discharges to a phosphorus-sensitive lake or wetland, shrubs that form a dense cover should be planted on slopes above the runoff treatment 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*), and Pacific yew (*Taxus brevifolia*).

### *Fencing*

Pond walls may be retaining walls as long as a fence is provided along the top of the wall and at least 25% of the pond perimeter will have a slope of 3H:1V or flatter. (See the *Design Manual* for additional fencing requirements.)

### *General Maintenance Requirements*

- For general maintenance requirements for wet ponds, see Section 5-3.6.1.

**Table RT.12.1. Emergent wetland plant species recommended for wet ponds.**

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

Primary sources: Metro 1990; Hortus Northwest 1991; Hitchcock and Cronquist 1973.

[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.

Note: The recommendations in Table RT.12.1 are for western Washington only. Consult with a landscape architect to adapt this information for eastern Washington.

### *Recommended Design Features*

The following design features should be incorporated into the wet pond design where site conditions allow:

- For wet pool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer. A fountain or aerator may be used to prevent stagnation and low-dissolved-oxygen conditions. Alternatively, a small amount of base flow could be directed to the pond to maintain circulation and reduce the potential for low oxygen conditions during late summer.

- Conifer or columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating, except that no trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety. 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: Conifer trees or shrubs are preferred to avoid problems associated with leaf drop. Columnar deciduous trees (such as hornbeam and 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. Regardless of the number of inlets, the flow path length between inlet and outlet should be maximized.

- The access and maintenance road could be extended along the full length of the wet pond to function as a vegetated filter strip (see BMP RT.02) if finely ground bark, wood chips, or permeable surfacing is placed over the road surface to reduce runoff.

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

- Provide side slopes that are sufficiently gentle (3H:1V or flatter) to avoid the need for fencing. Gentler slopes typically allow a facility to better blend into its surroundings.

- Use sinuous or irregularly shaped ponds to create a more naturalistic landscape.

- Provide visual enhancement with clusters of trees and shrubs. On most pond sites, it is important to amend the soil before planting because ponds are typically placed well below the native soil horizon in very poor soils. Make sure dam safety restrictions against planting do not apply.

- Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

### *Construction Criteria*

- Sediment that has accumulated in the pond must be removed after construction in the drainage area of the pond is complete unless used for a liner (see below).

- Sediment accumulations in the pond at the end of construction may be used as a liner in excessively drained wet pond soils if the sediment meets the criteria for low-permeability or treatment liners (see Section 5-4.3.2). Sediment used for a soil liner must be graded to provide uniform coverage and thickness. Note: Sediment accumulated from construction and left in the pond for a liner must not reduce the volume of the wet pond below its design capacity; therefore, the pond should be overexcavated initially.

### *Signage*

- Refer to Section 5-4.3.7 for signing requirements.

## *CO.01 – Combined Wet/Detention Pond*

Combination Wet/Detention Pond Along SR 500 in Clark County

**Description:** Combination detention and runoff treatment wet pond. Looks like a detention facility, but has a permanent pool of water as well. Two sizes: basic and large.

**Geometry Limitations**

| | |
|---|---|
| Interior Side Slopes | 3H:1V Max |
| Exterior Side Slopes | 2H:1V Max |

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☑ Phosphorus (Large Only)
  - ☑ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 20-50

| Capitol Cost | O & M Cost |
|---|---|
| ➲ Moderate | ➲ Low to Moderate |

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☑ Inlet and Outlet Spacing
- ☑ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☑ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☑ | ☐ | Fecal Coliform |
| ☐ | ☑ | Phosphorus (Large Only) |
| ☐ | ☐ | Nitrogen |
| ☑ | ☐ | Temperature |
| ☐ | ☐ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☑ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5.

## Introduction

### *General Description*

A *combined detention and runoff treatment wet pond* facility has the appearance of a detention facility, but contains a permanent pool of water as well. The following design procedures, requirements, and recommendations cover differences in the design of the stand-alone runoff treatment facility when combined with detention storage.

There are two sizes of the combined wet pond: basic and large. The facility sizes (basic and large) are related to the pollutant-removal goals.

### *Applications and Limitations*

Combined detention and runoff treatment facilities are very efficient for sites that also have flow control requirements but are not conducive to dispersion or infiltration. The runoff treatment BMP may often be placed beneath detention storage without increasing the overall facility surface area. However, the fluctuating water surface of the live storage creates unique challenges for plant growth and for aesthetics.

The basis for pollutant removal in combined facilities is the same as that for stand-alone runoff treatment 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 the wet pool volume is sized. For the combined detention/stormwater wetland (see BMP CO.02), 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 must be provided above the seasonal high water table. It is recommended that all runoff treatment BMPs that use permanent wet pools use facility liners. (See Section 5-4.3.3 for additional information.)

Typical design details and concepts for a combined detention and wet pond are shown in Figures CO.01.1 and CO.01.2. The detention portion of the facility must meet the design criteria and sizing procedures set forth in BMP FC.03, Detention Pond.

## Design Flow Elements

### *Flows to Be Treated*

Basic combined wet/detention ponds are designed to treat the runoff treatment volume and detain flows according to the criteria described in Sections 3-3.5 and 3-3.6 under Minimum Requirements 5 and 6, respectively. Large combined wet/detention ponds are designed to treat 1.5 times the runoff treatment volume. Hydrologic methods are presented in Sections 4-3 and 4-4.

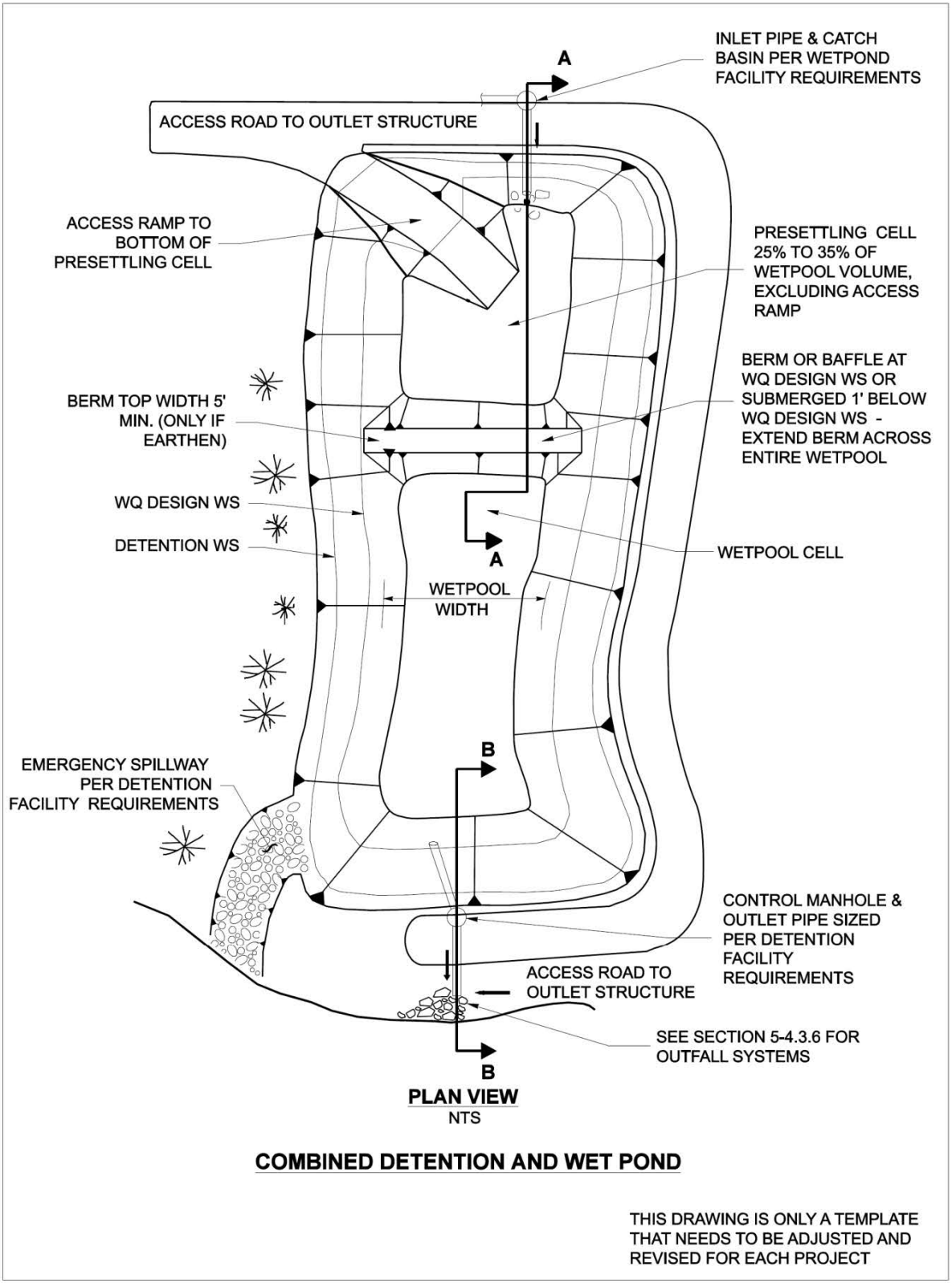



**Figure CO.01.1 Combined detention and wet pond: Plan view.**

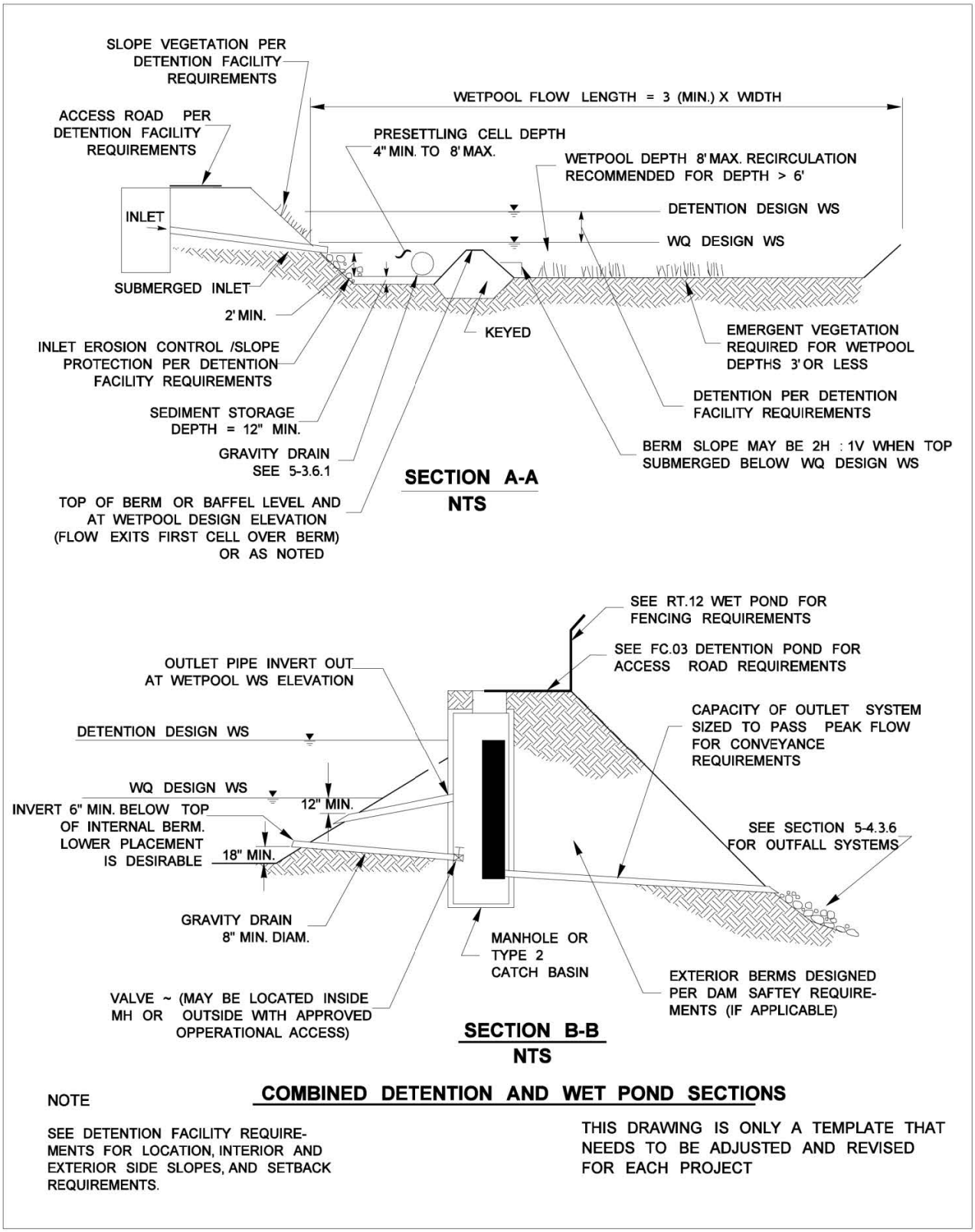



**Figure CO.01.2 Combined detention and wet pond: Cross sections.**

## Structural Design Considerations

### *Geometry*

The geometry criteria for wet ponds (see BMP RT.12) apply, with the following modifications and clarifications:

- The permanent pool may be made shallower to take up most of the pond bottom, or it may be deeper and positioned to take up only a limited portion of the bottom. Wet pond criteria governing water depth, however, must still be met. (See Figure CO.01.3 for two possibilities for wet pool cell placement.)

  *Intent: This flexibility in positioning cells allows for multiple-use options in live storage areas during the drier months.*

- The minimum sediment storage depth in the first cell is 1 foot. The 6 inches of sediment storage required for a detention pond does 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.
- The wet pool and sediment storage volumes are not included in the required detention volume.

*Sizing Procedure*

The sizing procedure for combined detention and wet ponds is identical to that outlined for wet ponds (see BMP RT.12) and detention ponds (see BMP FC.03).

*Inlet and Outlet*

The inlet and outlet criteria for wet ponds (see BMP RT.12) 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 must be designed according to the requirements for detention ponds (see BMP FC.03).

### *Berms, Baffles, and Slopes*

Criteria are the same as for wet ponds (see BMP RT.12).

## Groundwater Issues

Live storage requirements are the same as for detention ponds (see BMP FC.03). This does not apply to the wet pond dead storage component.

## Site Design Elements

### *General Maintenance Requirements and Setbacks*

Criteria are the same as for wet ponds (see BMP RT.12).

### *Planting Requirements*

Criteria are the same as for wet ponds (see BMP RT.12).

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

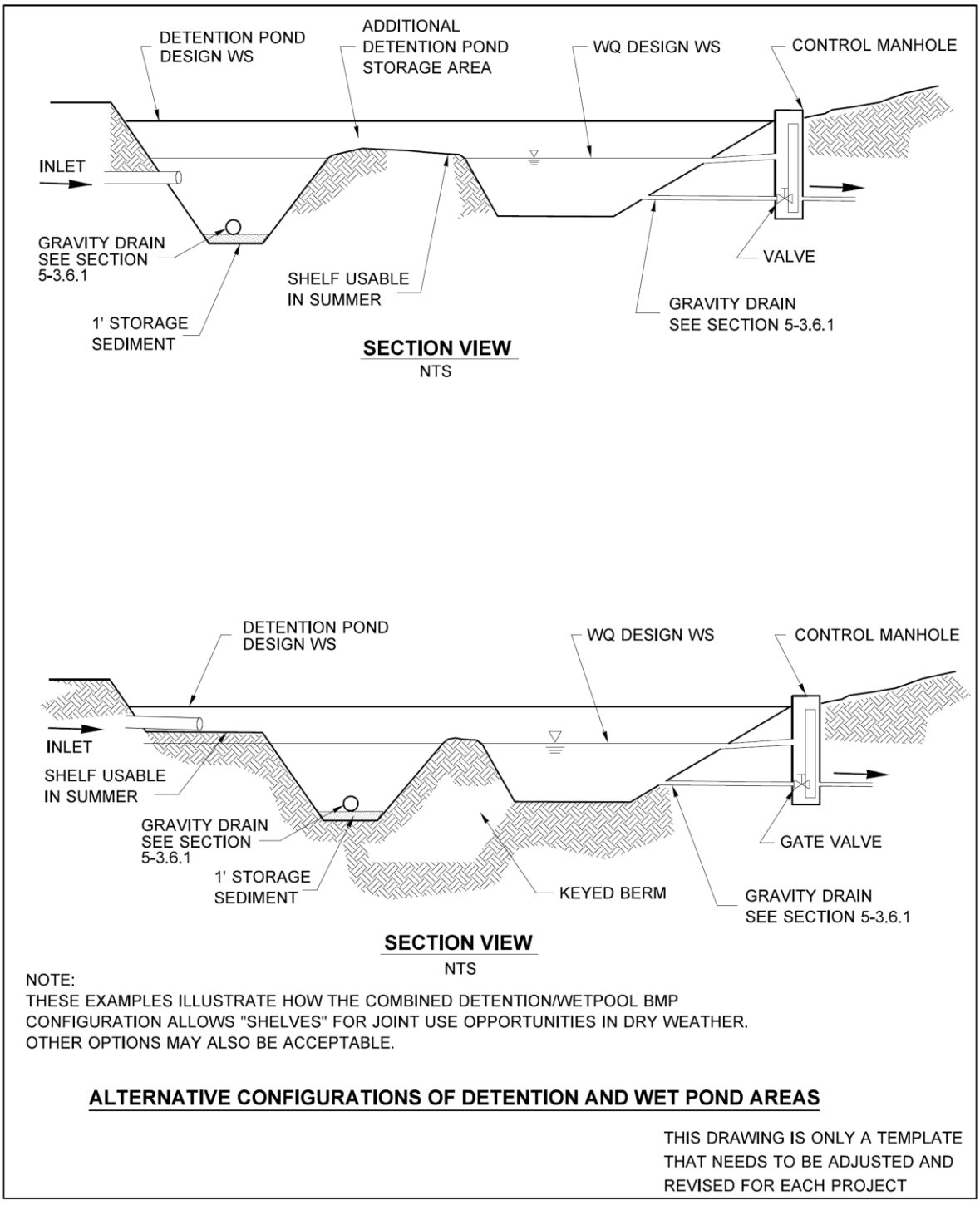



**Figure CO.01.3 Alternative configurations of detention and wet pond areas.**

## *RT.13 – Constructed Stormwater Treatment Wetland*

Constructed Stormwater Wetland on SR 539 Near Wiser Lake

**Description:** Shallow constructed wetlands. Designed to treat stormwater through settling, filtering, and biological processes associated with aquatic plants. Over time, pollutants concentrate in the sediment.

**Geometry Limitations**

| | |
|---|---|
| Wetland Cell Depth | 1.5' Max |
| Interior Slopes | 3H:1V Max |
| Exterior Slopes | 2H:1V Max |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 20-50

**Capital Cost**

➲ Moderate to High

**O & M Cost**

➲ Moderate

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☐ Landscaping/Planting
- ☑ Wetland Planting and Plant Establishment
- ☑ Inlet and Outlet Spacing
- ☐ Overflow
- ☑ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☑ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☑ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☑ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☑ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☑ Valve Access
- ☐ Specialized Equipment
- ☑ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Table 5.5.2.

## Introduction

### *General Description*

*Stormwater treatment wetlands* are shallow constructed wetlands designed to treat stormwater through settling, filtering, and the biological processes associated with emergent aquatic plants. Stormwater treatment wetlands, like wet ponds, are used to capture and transform pollutants. Over time, these pollutants concentrate in the sediment.

Instead of treating stormwater runoff, some wetlands are constructed to replace or mitigate impacts when natural wetlands are filled or impacted by development (mitigation wetlands). Natural wetlands and mitigation wetlands cannot be used to treat stormwater.

### *Applications and Limitations*

As an enhanced treatment BMP, stormwater wetlands can be considered for roadways where metal removal is a concern. Stormwater wetlands occupy roughly the same surface area as wet ponds, but they have the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is an adequate supply of water for most of the year. Careful planning is needed to ensure sufficient water is retained to sustain good wetland plant growth. Because water depths in stormwater wetlands are shallower than in wet ponds, water loss by evaporation is an important concern. Stormwater wetlands are a good runoff treatment facility choice in areas where groundwater levels are high in the winter.

## Design Flow Elements

### *Flows to Be Treated*

Constructed stormwater treatment wetlands are designed to treat the runoff treatment volume ($Vol_{WQ}$) described in Section 3-3.5 under Minimum Requirement 5. Hydrologic methods are presented in Sections 4-3 and 4-4.

### *Overflow or Bypass*

The overflow criteria for single-purpose wetlands (treatment only, not combined with flow control) follow the same criteria for wet ponds (see BMP RT.12).

### *Emergency Overflow Spillway*

- An emergency spillway must be provided and designed according to the requirements for detention ponds (see BMP FC.03).
- Bioengineered stabilization measures should be provided at the end of the outlet pipe and spillway to minimize the need for riprap and to increase aesthetics.

## Structural Design Considerations

### *Geometry*

*Design Criteria*

- Stormwater wetlands must consist of two cells: presettling cell and wetland cell.
- The presettling cell must contain approximately 33% of the wet pool volume.

- The depth of the presettling cell must be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage.
- The presettling cell must provide 1 foot of sediment storage.
- The wetland cell must not exceed a water depth of about 1.5 feet (plus or minus 3 inches).

*Sizing Procedure*

**Step 1** Specify the depth of the presettling cell (Dpc ft). (See Criterion 3 in the *Design Criteria* listed above.)

**Step 2** Determine the volume of the presettling cell (Vpc $ft^3$) by using criterion 2 in the *Design Criteria* listed above. Vpc = Vtotal x 0.33. Vtotal is the total runoff treatment wetpool volume obtained in MGSFlood. Refer to Table 3-3 and Table 3-4 to determine the sizing of the runoff treatment wetpool volume (Vtotal). If Vtotal is less than 9,410 $ft^3$, the designer must consult region hydraulic staff due to possible constructibility issues with the presettling cell. For combined treatment stormwater wetland/detention ponds, the first (presettling) cell shall be sized as required to meet the 4-foot minimum wetpool depth and volume.

**Step 3** Determine the surface area of the presettling cell (Apc $ft^2$) of the stormwater wetland using the presettling cell volume and depth. Apc = Vpc / Dpc.

**Step 4** Calculate the surface area of the stormwater wetland. The surface area of the entire wetland (Atotal $ft^2$) must be the same as the top area of a wet pond sized for the same site conditions. The surface area of the entire stormwater wetland is the runoff treatment wetpool volume divided by the wetpool water depth (use 3 feet). Atotal = Vtotal / 3 ft. *The intent of using the wetpool depth is to keep the surface area of a stormwater wetland roughly equivalent to a wet pond.* However, *the depth of the wetland cell is limited to1.5 feet.*

**Step 5** Determine the surface area of the wetland cell (Awc $ft^2$). Subtract the surface area of the presettling cell from the total wetland surface area (Atotal). Awc = Atotal – Apc. The second wetland cell shall have a minimum surface area of 1,950 $ft^2$.

One example for grading the bottom of the wetland cell is shown in Figure RT.13.1. The wetland cell is graded to a typical depth of 1.5 feet with a slight, even slope from the upstream to the downstream edge of the wetland cell. The wetland cell depth shall not exceed 1.5 feet.

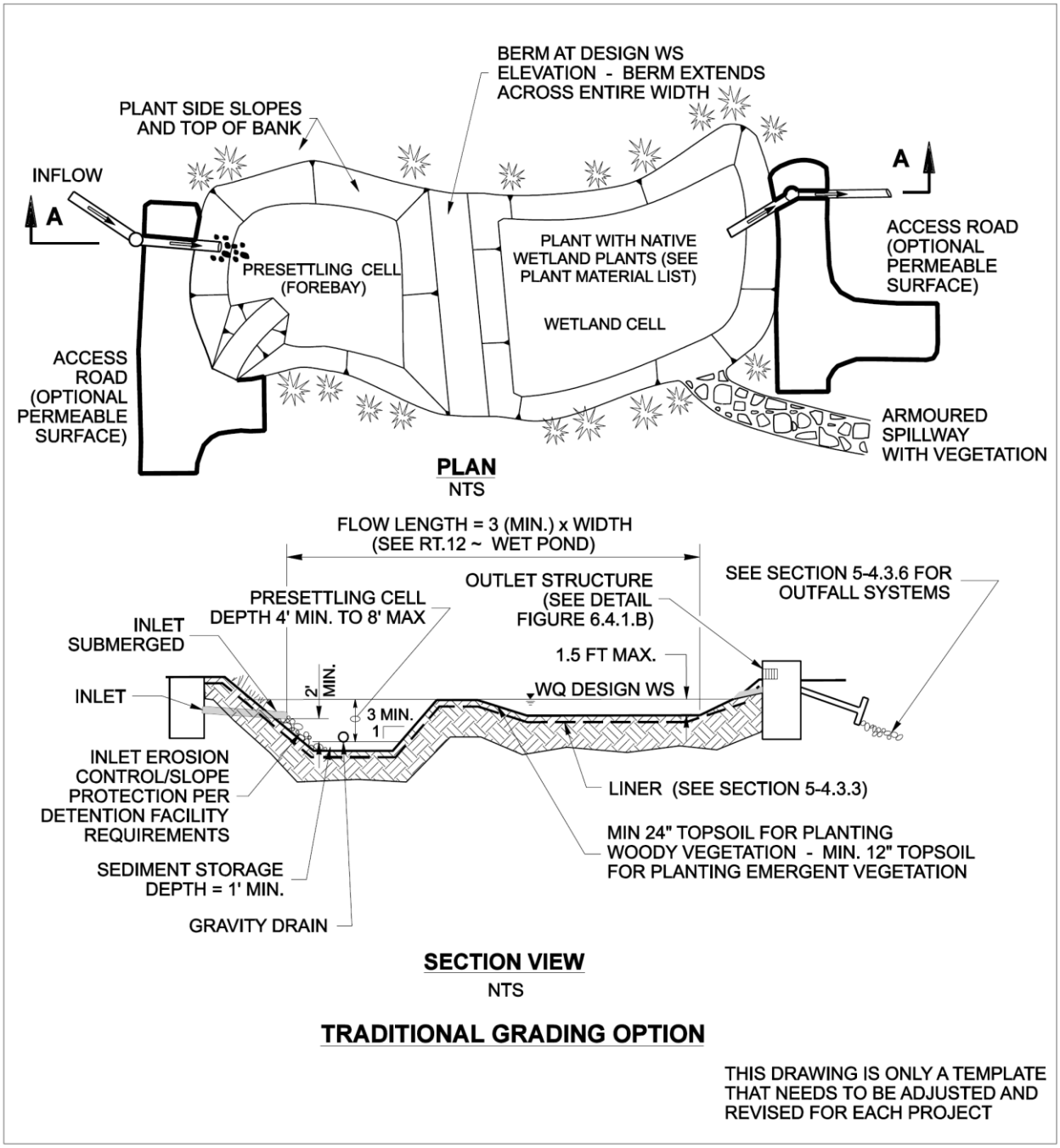



**Figure RT.13.1 Constructed wetlands for stormwater treatment – traditional grading option.**

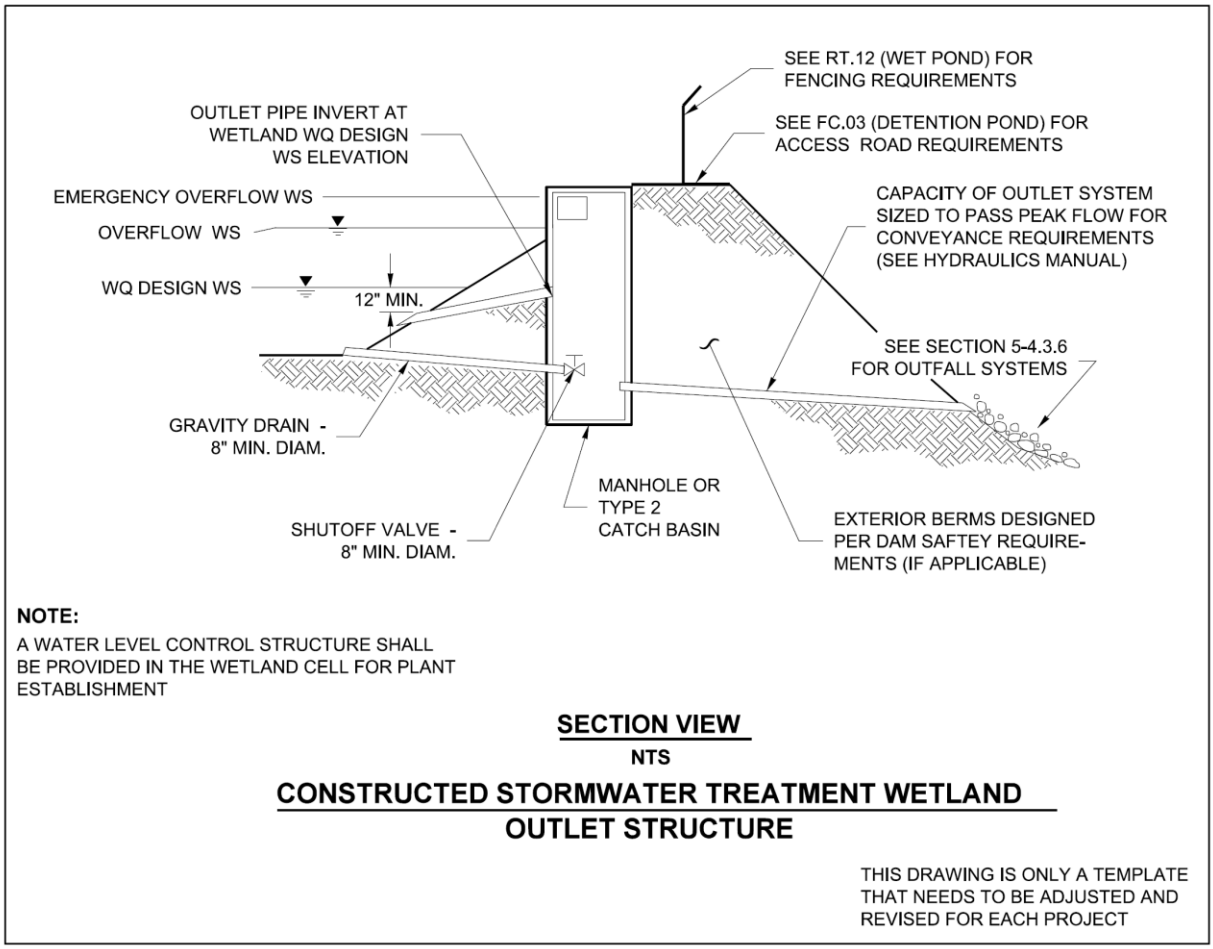



**Figure RT.13.2 Constructed stormwater treatment wetland outlet structure.**

### *Inlet and Outlet*

An inlet to the presettling cell and outlet from the wetland cell must be provided according to the requirements described in Section 5-4.1.4, Wet Ponds.

### *Dewatering and Water Level Control*

The presettling cell shall be configured with a gravity drain for dewatering. The wetland cell shall be configured with a gravity drain for dewatering and a water level control structure. Refer to Section 5-3.6.1 for information regarding gravity drains. The following replaces or supplements the guidance in Section 5-3.6.1:

- The gravity drain should be sized one size larger than the calculated diameter, with a minimum 8-inch diameter.
- For the wetland cell, the drain's invert should be located at the bottom of the wetland cell and sloped toward the outlet structure where the shut-off valve is located (see Figure RT.13.2).

- A water level control structure (which could be a gravity drain in the wetland cell) shall also be provided capable of adjusting the water level through all expected water levels in the wetland cell. The primary purpose of this structure is to adjust the water level during plant establishment. The water level control structure maybe removed after plants have reached the minimum cover for system start up.

***Berms, Baffles, and Slopes***

- The berm separating the two cells must be shaped so that its downstream side gradually slopes to form the second shallow wetland cell (see the section view on Figure RT.13.1).
- The top of the berm must be either at the runoff treatment design water surface or submerged 1 foot below this surface, as for wet ponds. Correspondingly, the side slopes of the berm must meet the following criteria:
- For safety reasons the berm should not be greater than 3H**:**1V, just as the wetland banks should not be greater than 3H**:**1V if the wetland is not fenced**.**

***Liners***

Both the presettling and wetland cell shall be lined with a low-permeability liner as described in Section 5-4.3.3. A treatment liner may be used if the soil permeability can retain sufficient water to support wetland plants. Sufficient water means that the top 1 foot of soil is saturated for a minimum of 30 days during the growing season. This shall be demonstrated by:

1. Performing a wetland hydroperiod analysis using MGSFlood or other methods as described in Appendix D of Volume 1 of the *Ecology Stormwater Management Manual for Western Washington*. Section 4-5 describes the methods for estimating infiltration and groundwater monitoring requirements.
2. Receiving approval from the Multidisciplinary Team as described below.

Buoyancy checks and counterweight may be necessary depending on groundwater conditions.

***Groundwater and Infiltration Rates***

Groundwater shall be monitored as described in Section 4-5.3, except the monitoring season shall extend to one year. Monitoring test holes shall be located as described for infiltration ponds. Infiltration rates shall be determined following the Detailed Approach defined in Section 4-5.3.1 without the correction factors.

## Site Design Elements

***Setback Requirements***

- Stormwater treatment wetlands must be a minimum of 5 feet from any property line or vegetative buffer. This distance may need to be increased based on the permit requirements of the local jurisdiction.
- Stormwater treatment wetlands must be 100 feet from any septic tank or drain field, except wet vaults, which must be a minimum of 20 feet.

- The designer should request from the WSDOT Materials Lab a geotechnical report for the project that evaluates any potential structural site instability due to extended subgrade saturation and/or head loading of the permeable layer. This includes the potential impacts to downgradient properties, especially on hills with known side-hill seeps. The report should address the adequacy of the proposed stormwater treatment wetland locations and recommend the necessary setbacks from any steep slopes and building foundations.

### *Multidisciplinary Team*

A Multidisciplinary Team is required to provide the breadth of knowledge and experience necessary to successfully design and construct a stormwater wetland. Approval by all members of the team is required starting with design and ending with the final inspection and acceptance of the constructed stormwater wetland. The team must be indentified at the beginning of the design phase and have the following technical skills represented: HRM Certified Stormwater Engineer, Materials Engineer, Design Office Representative (during design), Construction Office Representative (during construction), and Landscape Architect. The Landscape Architect shall be experienced in specifying constructed stormwater treatment wetland plants and plant establishment, and, if not, the Landscape Architect should consult with a wetland biologist who is knowledgeable in wetland plant inundation depths.

### *Wetland Landscaping and Plant Establishment*

When used for stormwater treatment, stormwater wetlands incorporate some of the same design features as wet ponds. However, instead of gravity settling being the dominant treatment process, pollutant removal by aquatic vegetation (and the microbial community associated with that vegetation) becomes the dominant treatment process. Thus, water volume is not the dominant design criterion for stormwater wetlands—rather, factors that affect plant vigor and biomass are the primary concerns.

The wetland cells must be planted with emergent wetland plants following the recommendations given in Table RT.13.1 and those of a landscape architect. Plants listed in the table are for western Washington. Local knowledge should be used to adapt this information for eastern Washington and requires approval of the team Landscape Architect. Local wetlands should be used as reference wetlands to develop the plant lists and growing depths.

**Table RT.13.1. Plants and water depths for western Washington[2] stormwater detention ponds.**

| Species[1] | Common Name | Design Water Depth[3] |
|---|---|---|
| **Shrubs** | | |
| *Cornus sericea* | Red osier dogwood | 2 inches |
| *Salix* species | Willows | 4 inches |
| *Spiraea douglasii* | Hardhack | 6 inches |
| **Emergents** | | |
| *Carex obnupta* | Slough sedge | 3 inches |
| *Juncus effuses ssp. pacificus* | Soft rush | 4 inches |
| *Scirpus microcarpus* | Small-fruited bulrush | 3 inches |
| *Schoenoplectus (Scirpus) acutus* | Hardstem bulrush, tule | 18 inches |
| *Schoenoplectus (Scirpus)tabernaemontani)* | Softstem bulrush, tule | 18 inches |

Primary sources: Azous & Horner, 2001, Cooke, 2005, modified by WSDOT staff.

1. Other species may be appropriate depending on location and site conditions and will require Region Landscape Architect approval as well.
2. Plant species, growing season, and other details will need to be adjusted for eastern Washington and the mountains.
3. Water levels must be controlled during plant establishment as described in the Soil Preparation section. Tops of plants must be above highest water level. May need larger plants and temporary summer irrigation to accelerate full operation of facility.

Note: Cattails (Typha latifolia) are not recommended. They tend to crowd out other species in constructed wetlands, as well as escape to natural wetlands where they do the same. In addition, the shoots die back each fall, resulting in oxygen depletion in the treatment wetland unless they are removed.

### *Soil Amendments and Protection*

The method of construction for soil/landscape systems can affect natural selection of specific plant species. Consult a landscape architect, soil restoration specialist, or wetland soil scientist for site-specific soil amendment recommendations. The formulation should encourage desired species and discourage undesired species. Soils should be stabilized with permanent or temporary cover to prevent washout due to storm flows.

### *Maintaining Optimum Soil Moisture*

Successful constructed stormwater wetlands rely on thick and vigorous plant communities. Establishing the plant communities depends on maintaining the optimal soil moisture throughout the growing season. There are many ways of doing this depending on the site and availability of water.

This section describes the principle of maintaining the soil moisture necessary to achieve full wetland operation where plant cover is at least 60% to 80%. The contractor should consider this principle to develop a Water Management Plan that describes an irrigation source for the plant establishment period as well as water level control. The plan must be approved by the multidisciplinary team prior to planting.

Incorrect control of soil moisture is the most frequent cause of failure to establish wetland plants. Inadequate water results in desiccation of roots. Too much water causes oxygen depletion in the root zone, submergence and drowning, or flotation of plants, which results in slow growth or plant death.

To maintain adequate soil moisture during plant establishment, a reliable and adequate supply of water is needed. When feasible, a water source for plant establishment is usually the stormwater treated in the wetland. However, if stormwater is not available, another water source must be identified to maximize planting success. If irrigation is used, adequate pumps, piping, and sprinklers or hoses must be provided to allow even flow distribution.

According to Kadlec and Knight (1996), the recommended sequence for maintaining soil moisture for wetland planting starts with initial saturation of soil by sprinkling or flood irrigation. For optimal plant growth, the soil should be fully or partially saturated with water immediately before planting and should not be allowed to completely dry out any time after planting during the plant establishment period. High soil moisture must be maintained after planting for the first few weeks without creating flooded conditions for more than a few hours. The best method to maintain soil saturation without excessive flooding is to start planting at the downgradient end of the wetland and continue planting upgradient, while gradually raising water levels using the wetland outlet water level controls or gravity drain if possible. When planting is complete, water levels can be dropped or raised as needed to maintain saturated soil conditions. Sprinklers can also be used to irrigate evenly over planted areas.

After an entire cell is planted, the water should be maintained at a level that ensures all areas of the cell continue to have saturated soil conditions between waterings. This can be achieved by (1) flood-irrigating the entire cell with enough water to allow infiltration or evapotranspiration to eliminate the applied surface water within one or two days, or (2) distributing water through the inlet distribution structures or down the embankment side slopes and allowing this water to resaturate the wetland soils as it sheet-flows across the wetland to the outlet. Weirs or outlet water control gates should be removed or left open during plant establishment to prevent flooding if rainfall is high or if a sprinkler or irrigator is accidentally left running. At no time should flood irrigation result in complete submergence of aboveground portions of installed plants. Permits may be required to use water from nearby natural aquatic water bodies for temporary irrigation purposes.

As the wetland plants grow, they have an increased ability to transport oxygen to the root zone from their leaves; thus, the plants are able to withstand longer periods of flooding. However, the best technique for establishing rapid plant cover is to maintain saturated soil conditions without surface flooding. The higher soil oxygen condition resulting from the absence of floodwaters allows maximum root metabolism, effective nutrient use, and rapid development of the plants within the wetland. This soil condition should optimally be maintained until plants achieve complete cover (100%) or at least the minimum cover required for system startup (about 60% to 80%).

Design and construction should allow the design water surface to be temporarily modified to enable plant installation and establishment before the system is brought on-line. Several strategies may be available depending on the project situation, schedule, and site conditions.

- If the system must go on-line the same year it is constructed, plant the constructed wetland cell in the spring or early summer and irrigate all summer to maintain saturated soils without plant submergence or flotation until plants are sufficiently developed to operate the system in the fall.
- If the system can remain off-line all winter, plant the constructed wetland cell in the fall, monitor water conditions, and maintain saturated soils without plant submergence or flotation, by irrigating or draining as necessary, until plants are sufficiently developed to allow operation of the system the following year. Note: Wetland plants planted later in the summer or fall have their growth interrupted by cold weather and decreasing day length (Kadlec and Knight 1996).

Several methods could be used to temporarily control water levels during plant establishment, depending on project conditions.

- Build the treatment wetland before the project is started so that wetland plants are established before flows are introduced.
- Keep the treatment wetland off-line until wetland plants become established by bypassing the treatment wetland.
- Temporarily operate the drain of the treatment wetland as the outlet to maintain water surface elevations below the design water surface level.
- Plant early in the fall or late in the spring when water surface elevations are naturally lower.
- Pump out water to lower the wetland cell for planting and establishment.

A wetland treatment system can typically begin operation when plant cover is at least 60% to 80%, which may require at least three to four months of active growth. If this coverage is achieved during the first growing season after planting, the wetland system can begin operating during the ensuing fall.

### *Planting*

- **Emergent plants should only be planted when water levels are low enough to ensure plant survival** (see Standard Specification 8-02.3(8)). Generally, this is from April 1 to June 1. Planting outside this window may be acceptable using larger stock plants or if the water levels in the pond can be drained down; it requires approval by the multidisciplinary team.
- Plants shall be located at a minimum density of 3 feet on center, with 18 inches preferred.
- Seeding the wetland cell below the runoff treatment design water surface elevation is not permitted.

- Sufficient time shall be allowed in the contract for plant establishment. Typically emergent plants require one or two growing seasons and woody plants require at least three years of plant establishment.
- Seed embankment areas above the runoff treatment design water surface and below the emergency overflow water level. Areas with permanent pools that are protected from erosion need not be seeded.
- Consider planting conifer or columnar deciduous trees along the west and south sides of wetlands to reduce thermal heating—except that no trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety. (However, trees and shrubs can be planted outside the toe of the berm if there is sufficient right of way.) 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 wetland.
- Include trees and shrubs on slopes and on top of banks to increase aesthetics. If the treatment wetland discharges to a phosphorus-sensitive lake or natural wetland, shrubs that form a dense cover should be planted on slopes above the runoff treatment 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 wetland and to provide shading. Some suitable trees and shrubs include vine maple (Acer circinatum), wild cherry (Prunus emarginata), willow (Salix sp.), red osier dogwood (Cornus stolonifera), California myrtle (Myrica californica), Indian plum (Oemleria cerasiformis), and Pacific yew (Taxus brevifolia).

### *General Maintenance Requirements*

For general maintenance requirements, see Section 5-3.6.1. The following replaces or supplements the guidelines found in Section 5-3.6.1:

- A drain in the wetland cell (or cells) may also be necessary to avoid surface flooding during wetland plant installation and establishment.

### *Recommended Design Features*

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

- Provide maintenance access to shallow pool areas enhanced with emergent wetland vegetation. This allows the wetland to be accessible for vegetation maintenance without incurring safety risks.
- Provide side slopes that are sufficiently gentle to avoid the need for fencing (3H**:**1V or flatter). For slopes greater than 3H:1V, side slopes should be designed to prevent sloughing of upland landscaping into the wetland. This may include roughing the side slopes several inches deep using the teeth of the backhoe bucket prior to placing topsoil, terracing the slopes, or using compost socks along the contours to hold the topsoil in place.

- Provide visual enhancement with clusters of trees and shrubs. On most wetland sites, it is important to amend the soil before planting because wetlands are typically placed well below the native soil horizon in very poor soils. Make sure dam safety restrictions against planting do not apply.
- Consider extending the access and maintenance road along the full length of the treatment wetland. Consider placing coarse bark, wood chips, or other permeable surfacing over the road surface to reduce runoff.
- Where right of way allows, orient the wetland length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

### *Construction*

- Construction and maintenance considerations are the same as those for wet ponds (see BMP RT.12).
- To estimate the length of time needed to establish wetland plants before allowing the system to go online, see the above section, "Planting." During the plant establishment period, the constructed stormwater treatment wetland cell cannot be used for TESC activities.

### *Nuisance Control*

*Beavers*

Information on beaver control can be found at the following websites:
www1.co.snohomish.wa.us/departments/public_works/divisions/swm/services/landowners/streamside/faq/faq_living_with_beavers.htm
http://www.kingcounty.gov/environment/animalsandplants/beavers/solutions.aspx

*Mosquitoes*

A recent study in California provides evidence that interspersing stands of emergent vegetation with areas of open water is effective in reducing mosquito production. Areas of relatively deep open water can decrease vegetation density and limit the accumulation of floating mats of root masses and dead vegetation. These characteristics were found to reduce mosquito refuge areas and increase mosquito predator habitat (Thullen et al., 2002).

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

## *CO.02 – Combined Stormwater Treatment Wetland/Detention Pond*

I-405 Bellvue Combined Stormwater Treatment Wetland/Detention Pond

**Description:** A wetland system that also provides extended detention of runoff during and following storm events.

**Geometry Limitations**

| | |
|---|---|
| Wetland Cell Depth | 1.5' Max |
| Interior Side Slopes | 3H:1V Max |
| Exterior Side Slopes | 2H:1V Max |

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 20-50

**Capital Cost**

➲ Low to Moderate

**O & M Cost**

➲ Moderate

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☐ Landscaping/Planting
- ☑ Wetland Planting and Plant Establishment
- ☑ Inlet and Outlet Spacing
- ☑ Overflow
- ☑ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☑ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☑ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☑ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☑ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☑ Valve Access
- ☐ Specialized Equipment
- ☑ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5.

## Introduction

### *General Description*

The *combined stormwater treatment wetland/detention pond* (see Figure CO.02.1) is best described as a wetland system that provides for the extended detention of runoff during and following storm events. This BMP is useful in areas with limited right of way where separate runoff treatment and flow control facilities are not feasible. It is recommended that all BMPs that use permanent wet pools use facility liners (see Section 5-4.3.3).

## Design Flow Elements

### *Flows to Be Treated*

The sizing procedure for the combined stormwater treatment wetland and detention pond is identical to that outlined for stormwater wetlands (see BMP RT.13) and for combined wet/detention ponds (see BMP CO.01). Follow the procedures outlined in those sections to determine the stormwater wetland size.

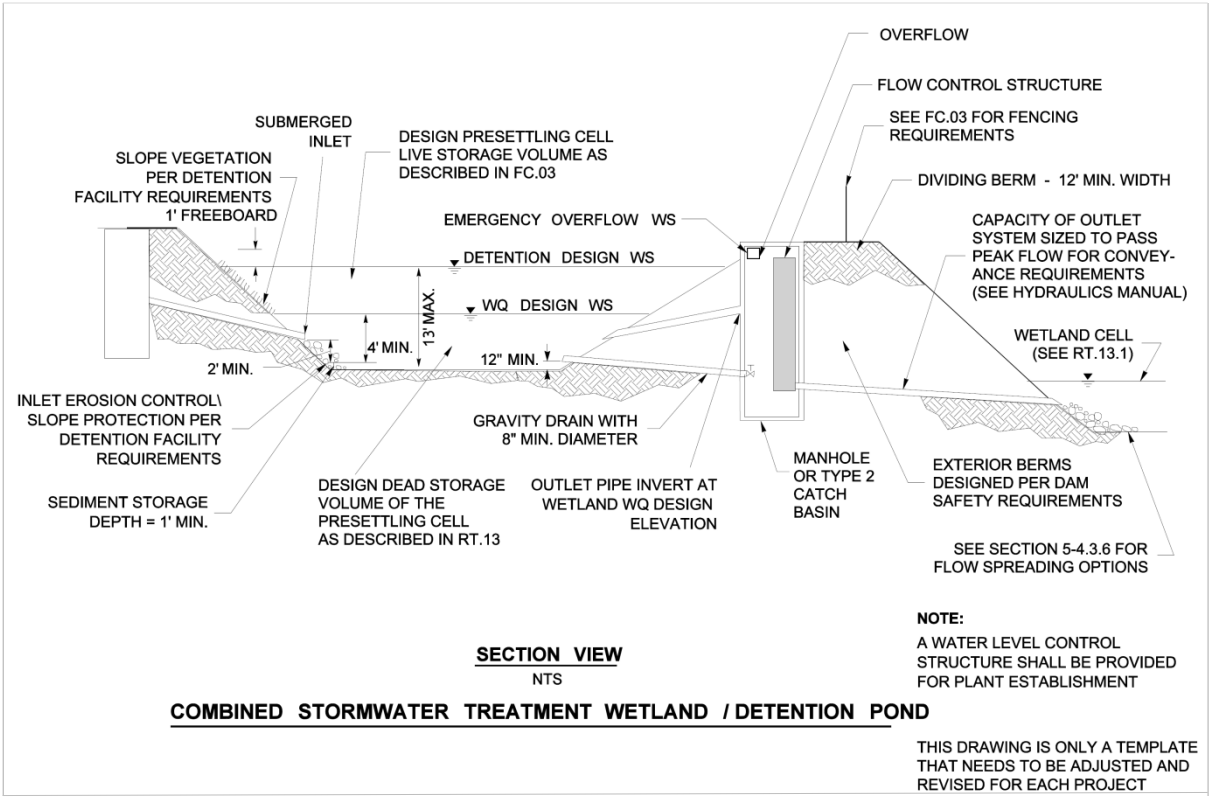



**Figure CO.02.1 Combined stormwater treatment wetland/detention pond.**

## Structural Design Considerations

The Structural Design Considerations are the same as for detention ponds (see BMP FC.03) and constructed stormwater treatment wetlands (see BMP RT.13), except for the following modifications or clarifications:

Geometry

- 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: Because 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.*

- The inlet and outlet criteria for constructed stormwater treatment wetlands (see BMP RT.13) apply, with the following modifications:

A sump must be provided in the outlet structure of combined facilities.

The detention flow restrictor and its outlet pipe must be designed according to the requirements for detention ponds (see BMP FC.03).

- The detention (live) storage shall be limited to the presettling cell. The design approach would include sizing the presettling cell depth and dead storage volume as described in Section RT.13. The remaining detention storage shall be designed to fit above the dead storage with 1 foot of freeboard. The presettling cell and dividing berm shall meet embankment and dam safety guidelines for detention ponds (the BMP FC.03).

- The outlet pipe from the flow restrictor to the wetland cell shall have a flow spreader at the outlet for the full length of the dividing berm. (See Section 5-4.3.5 for flow spreading options.)

- The primary emergency overflow structure shall be located in the first (presettling) cell of the constructed stormwater treatment wetland to collect and convey detention storage overflows directly to the pond discharge (bypassing the second wetland cell).

## Groundwater Issues

Live storage requirements are the same as for detention ponds (see BMP FC.03). This does not apply to the constructed stormwater treatment wetlands' dead storage component.

## Site Design Elements

The Site Design Elements are the same as for detention ponds (see BMP FC.03) and constructed stormwater treatment wetlands (see BMP RT.13).

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

## 5-4.1.5 Oil Control BMPs

### *RT.22 – Oil Containment Boom*

Oil Containment Boom Along I-5 in Thurston County

**Description:** Weather-resistant, hydrophobic, absorbent-filled boom. Removes hydrocarbon sheens from water.

**Geometry Limitations**

Secure boom ends to an immobile structure or metal stake with weather-resistant tape.

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment
  - ☑ Oil Control
  - ☐ Phosphorus
  - ☐ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ Check With Manufacturer

| Capital Cost | O & M Cost |
|---|---|
| ➲ Low | ➲ Low |

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☐ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☐ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☐ | Dissolved Metals |
| ☐ | ☐ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☑ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Table 5.5.2. Requires frequent replacement.

## Introduction

### *General Description*

The *oil containment boom* is a weather-resistant, hydrophobic, absorbent-filled boom for removing hydrocarbon sheens from water.

### *Applications and Limitations*

Oil containment booms can be used to remove oil from stormwater facilities to meet performance goals at locations where oil control is required, as described in Table 3-1.

Oil containment boom technology offers the following advantages over other treatment options:

- Fully functional at flow rates exceeding treatment flow criteria
- Easy and complete removal and disposal of absorbed oil
- Higher reliability because sediment clogging is avoided
- Effectiveness easily assessed due to aboveground installation
- Reduced exposure of maintenance workers to traffic and confined-space hazards
- Lower material and labor costs (6 to 17 times lower than oil/water separators, sand filters, and catch basin inserts)
- No capital improvement costs
- No additional right of way requirements or conflicts with buried structures

## Structural Design Considerations

### *Geometry*

The boom must be cylindrical, with a minimum diameter of 2 inches. It should be installed near the outlet end of the facility so that the oil has a maximum amount of time to rise to the water surface. Maximizing boom distance from inlet currents also maximizes contact time between the boom and the oil. The boom must span the entire width of ponds when they are filled to capacity. The boom must be placed so that it is in direct contact with the water across the entire water surface. In treatment ponds, the boom must be installed diagonally across the water surface to maximize contact area and contact time between hydrocarbons and the boom. When used in a vault, the boom must completely encircle the outlet structure (see Figure RT.22.1).

### *Materials*

The absorbent material must consist of high-molecular-weight polymers capable of absorbing (1) C5-C18 hydrocarbons associated with fuels, and (2) longer chain hydrocarbons with frequently attached cyclic hydrocarbon structures associated with lubricating oils.

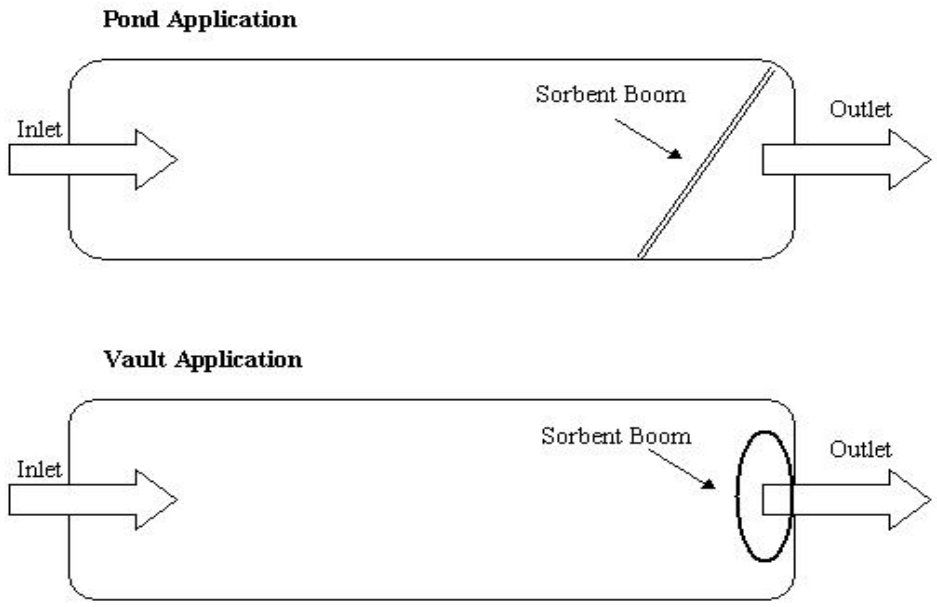



**Figure RT.22.1 Oil containment boom.**

The absorbent material must exhibit the following characteristics:

- Absorb and solidify a minimum of three times its weight in liquid hydrocarbons.
- Have sufficient buoyancy at the exhausted condition to continue to trap oil.
- Irreversibly absorb and permanently hold the hydrocarbons so that oil leachate is not released from the sorbent. U.S. EPA guidelines for solidified hazardous waste without chemical bonds being formed or broken must also be met.
- Contain a minimum of 99% active ingredient and no leachable toxicant to fish and other aquatic life. The supplier must provide appropriate information demonstrating that toxicity will not be a problem.

The absorbent boom cover fabric must meet the following criteria:

- Be fabricated of photo-resistant mesh that meets the ultraviolet (UV) stability requirement for permanent erosion control blankets in Section 9-14.5 of the *Standard Specifications*.
- Be sized to allow for the expansion of the absorbent material to hold the specified absorption volume per foot.

Additional requirements for materials related to booms include the following:

- Booms must include a weather-resistant tag to enable labeling with installation and inspection dates for tracking long-term effectiveness/maintenance activities.
- Boom ends must be configured so that they can be secured to immobile structures or metal stakes with weather-resistant rope.

### *Signage*

Refer to Section 5-4.3.7 for signing requirements. "Oil Containment Boom" should be added to the stormwater BMP sticker.

## 5-4.2 Flow Control Methods

The primary function of the BMPs listed in this section is to meet Minimum Requirement 6 (Flow Control) in Section 3-3.6.

### 5-4.2.1 Infiltration BMPs

#### *IN.01 – Bioinfiltration Pond (eastern Washington only)*

Spokane County Bioinfiltration Pond

**Description:** Combines grasses or other vegetation and soils to remove stormwater pollutants by filtration, soil sorption, and uptake by vegetative root zones. Used in eastern Washington only.

**Geometry Limitations**

| | |
|---|---|
| Bottom Slope | ≤ 1% |
| Drywell Considerations | |
| Typical Pond Depth | 1.5' |

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment
  - ☑ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-20

**Capital Cost**

➲ Low to Moderate

**O & M Cost**

➲ Low

**Additional Constraints/Requirements**

| | |
|---|---|
| ☑ 4-5 Infiltration Design Criteria | ☑ Soil Amendments/Compost |
| ☑ Setback | ☐ Energy Dissipater/Level Spreader |
| ☑ Landscaping/Planting | ☑ 5-4.3.3 Facility Liners (treatment) |
| ☐ Wetland Planting and Plant Establishment | ☑ 5-4.3.7 Signing |
| ☐ Inlet and Outlet Spacing | ☐ Fencing |
| ☐ Overflow | ☑ Presettling/Pretreatment |
| ☐ Multidisciplinary Team | ☐ Underdrain |
| ☐ WSDOT Pavement Engineer Approval | ☐ Soil Preparation |

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Table 5.5.2.

## Introduction

### *General Description*

*Bioinfiltration ponds*, also known as bioinfiltration swales or grass percolation areas, combine grasses (or other vegetation) and soils to remove stormwater pollutants by percolation into the ground. Their pollutant removal mechanisms include filtration, soil sorption, and uptake by vegetative root zones. Bioinfiltration ponds have been used in Spokane County for many years to treat urban stormwater and recharge the groundwater.

In general, bioinfiltration ponds are used for treating stormwater runoff from roofs, roads, and parking lots. Flows greater than the design treatment flow typically overflow through an appropriate conveyance system to a higher permeability (flow control) infiltration BMP such as a drywell or infiltration pond or to a surface water discharge point with flow control as necessary (see Figure IN.01.1). Note: Underground injection control (UIC) regulations apply to the drywell.

### *Applications and Limitations*

Bioinfiltration ponds can be used to meet basic and enhanced runoff treatment objectives and oil control for high-use roads (see Table 3-1). Although bioinfiltration ponds treat runoff by infiltration through soil, the infiltration capacity of these facilities is usually not sufficient to provide flow control to meet the criteria of Minimum Requirement 6 in Section 3-3.6. Unless a very large area is available for the shallow water depth required of a bioinfiltration pond, flow control must be implemented using a different facility.

Bioinfiltration ponds require moderately permeable soil for proper function. For general site suitability criteria for infiltration facilities, see BMP IN.02, Infiltration Pond. Additional criteria for runoff treatment are presented in Section 4-5.1.

### *Presettling/Pretreatment*

Pretreatment should be considered to prevent the bioinfiltration pond treatment soil from clogging. (See Section 5-4.3.1 for pretreatment design criteria.)

## Design Flow Elements

### *Flows to Be Treated*

Bioinfiltration ponds are designed as volume-based infiltration treatment facilities. The runoff volume to be treated by a bioinfiltration pond is based on hydrologic models, such as SCS or SBUH. Design storm volumes are discussed in Section 3-3.5 under Minimum Requirement 5, and hydrologic methods are presented in Section 4-5.

## Structural Design Considerations

### *Geometry*

Bioinfiltration pond sizing methods are the same as those for infiltration ponds (see BMP IN.02) designed for runoff treatment, except for the following:

- Drawdown time for the maximum ponded volume is 72 hours (maximum) following the design storm event.

- The maximum ponded level is 6 inches, prior to overflow to a drywell or other infiltrative or overflow facility.
- The pond shall be designed to contain the runoff treatment volume from the 6-month 24-hour storm, below the first 6 inches in the pond.
- The swale bottom should be flat with a longitudinal slope less than 1%.
- A concrete or riprap apron shall be provided at the curb opening to prevent vegetation from blocking the inlet.
- The treatment soil should be at least 6 inches thick with a cation exchange capacity (CEC) of at least 5 milliequivalents per 100 grams of dry soil, organic content of at least 1%, and sufficient target pollutant loading capacity (see *Criteria for Assessing the Trace Element Removal Capacity of Bio-filtration Systems*, Stan Miller, Spokane County, June 2000).
- Other combinations of treatment soil thickness, CEC, and organic content design factors may be considered if it is demonstrated that the soil and vegetation will provide a target pollutant loading capacity and performance level acceptable to the local jurisdiction.
- The treatment zone depth of 6 inches or more should contain sufficient organics and texture to ensure good vegetation growth.
- The average infiltration rate of the 6-inch-thick layer of treatment soil should not exceed 1 inch/hour for a system relying on the root zone to enhance pollutant removal. Furthermore, a maximum infiltration rate of 2.4 inches per hour is applicable and the site suitability criteria in Section 4-5.1 must also be applied.
- Native grasses, adapted grasses, or other vegetation with significant root mass should be used. For eastern Washington, grasses should be drought tolerant or irrigation should be provided.
- Pretreatment may be used to prevent clogging of the treatment soil and vegetation by debris, TSS, and oil and grease.

Identify pollutants, particularly in industrial and commercial area runoff, that could cause a violation of the Ecology groundwater quality standards (WAC 173-200). Include appropriate mitigation measures (for example, pretreatment or source control) for the pollutants.

### *Materials*

For runoff treatment, soils must meet the criteria described in BMP IN.02, Infiltration Pond, and the *Site Suitability Criteria* in Section 4-5.1.

## Groundwater Issues

Groundwater issues for bioinfiltration ponds are the same as those for infiltration ponds (see BMP IN.02).

Consider the potential impact of roadway deicers on potable water wells when siting the bioinfiltration pond. Mitigation measures must be implemented if infiltration of roadway deicers could cause a violation of groundwater quality standards.

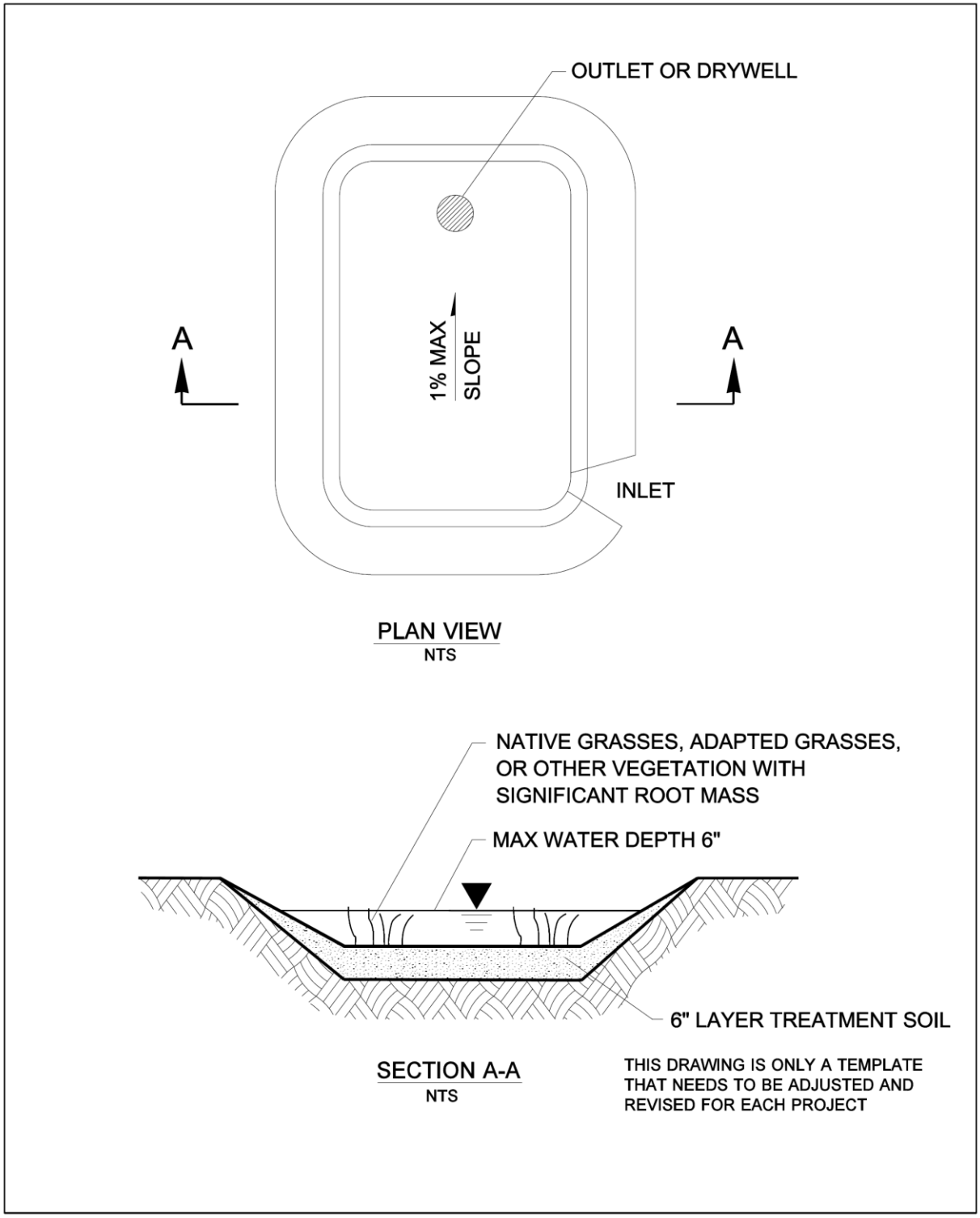



**Figure IN.01.1 Bioinfiltration pond.**

## Site Design Elements

Conduct initial excavation to within 1 foot of the final elevation of the floor of the bioinfiltration pond. Defer final excavation to the finished grade until all disturbed areas in the upgradient drainage area have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. After construction is completed, prevent sediment from entering the bioinfiltration pond by first conveying the runoff water through an appropriate pretreatment system such as a presettling basin.

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

Relatively light-tracked equipment is recommended for excavation to avoid compacting the floor of the bioinfiltration pond. Consider the use of draglines and trackhoes. The bioinfiltration pond area should be flagged or marked to keep equipment away.

### *Setback Requirements*

Setback requirements for bioinfiltration ponds are the same as those for infiltration ponds (see BMP IN.02).

### *Right of Way*

Right of way requirements for bioinfiltration ponds are the same as those for detention ponds (see BMP FC.03).

### *Landscaping (Planting Considerations)*

Use native or adapted grass species for the entire area of the bioinfiltration pond.

### *Maintenance Access Roads (Access Requirements)*

Access requirements for bioinfiltration ponds are the same as those for infiltration ponds (see BMP IN.02).

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

## *IN.02 – Infiltration Pond*

Infiltration Pond Along I-90 in Spokane County

**Description:** Used for collection, temporary storage, and infiltration of stormwater runoff to groundwater. For flow control and can be designed to provide runoff treatment.

**Geometry Limitations**

| | |
|---|---|
| Floor Slope | ≤ 3% |
| Interior Embankment | 3H:1V |
| Exterior Embankment | 2H:1V |
| Desirable Depth | 3' |
| Max Depth | 6' |
| Freeboard | 1' Min |

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment*
  - ☐ Oil Control
  - ☑ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-10

| Capital Cost | O & M Cost |
|---|---|
| ➲ Moderate | ➲ Moderate |

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria
- ☑ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☑ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☑ Fencing
- ☑ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5.

**Pretreatment must be provided with a presettling basin (RT.24) or any basin treatment BMP listed in step 7 of Figure 5.3.2.*

## Introduction

### *General Description*

*Infiltration ponds* for flow control are earthen impoundments used for the collection, temporary storage, and infiltration of incoming stormwater runoff to groundwater (see Figure IN.02.1). Infiltration ponds can also be designed to provide runoff treatment (see Section 4-5.1).

### *Applications and Limitations*

Infiltration of runoff is the preferred method of flow control. Runoff in excess of the infiltration capacity must be detained and released in compliance with the flow control requirement described in Section 3-3.6 under Minimum Requirement 6.

#### *Site Suitability Criteria*

Infiltration ponds require permeable soil conditions for proper function. For a site to be considered suitable for an infiltration pond, the design infiltration rate must be at least 0.5 inches per hour. Infiltration can still be considered in the design if the infiltration rate is less, but infiltration would be considered a secondary function in this case. Additional site suitability criteria are specified in Section 4-5.1.

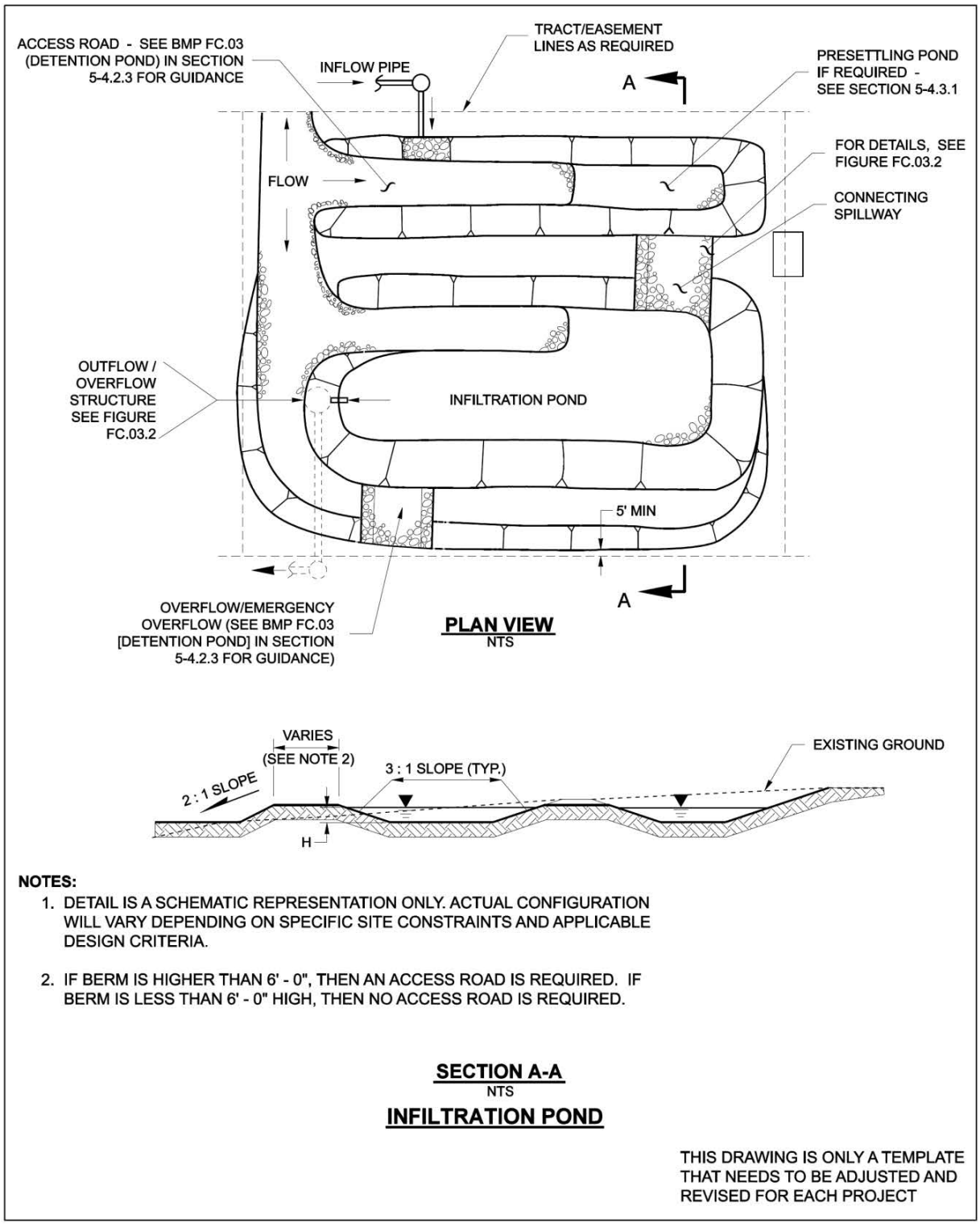



**Figure IN.02.1 Infiltration pond.**

The base of all infiltration ponds must typically be at least 5 feet above the seasonal high-water mark, bedrock (or hardpan), or other low-permeability layer. This vertical distance may be reduced to a minimum of 3 feet if the following apply:

- The groundwater mounding analysis, volumetric receptor capacity, and design of the overflow or bypass structures are judged by the designer to be adequate to prevent overtopping
- The facility meets all other criteria listed in this BMP description

### *Presettling/Pretreatment*

Infiltration ponds should follow a runoff treatment or pretreatment facility to prevent sediment buildup and clogging of the infiltrative soils. A presettling cell can be included in the infiltration pond design, as shown in Figure IN.02.1. (See BMP RT.24, Presettling/ Sedimentation Basin, for design criteria.) If an infiltration pond cannot meet the site suitability criteria for treatment, a minimum of basic treatment must be provided prior to infiltration. (See Section 5-3.4 for additional criteria.)

## Design Flow Elements

### *Flows to Be Infiltrated*

Site runoff should be infiltrated to the extent that occurred before the site was developed. Runoff in excess of the infiltration capacity must be detained and released in compliance with the flow control requirement described in Section 3-3.6 under Minimum Requirement 6. (See Section 4-5 for hydrologic analysis methods applicable to flow control for surface discharges.)

For a site to be considered suitable for an infiltration pond, the design infiltration rate must be at least 0.5 inches/hour. Infiltration can still be considered in flow control facility design if the infiltration rate is less than this, but infiltration must be considered to be a secondary function in that case. A pond must be designed to a desirable depth of 3 feet and a maximum depth of 6 feet, with a minimum freeboard of 1 foot above the design water level (1 foot above the 50-year water surface elevation for western Washington and 1 foot above the 25-year water surface elevation for eastern Washington). For a web link to examples of infiltration pond design and associated spreadsheets, see Appendix 4A. Please note that examples are separated into western Washington examples on MGSFlood and eastern Washington examples on StormShed.

- For western Washington, an infiltration flow control pond must be designed using a continuous hydrograph model to infiltrate sufficient volume so that the overflow matches the duration standard (or 100% of the runoff volume).
- For eastern Washington, an infiltration flow control pond must be designed using a single-event hydrograph model to infiltrate the runoff treatment volume out of the pond within 72 hours. An infiltration flow control pond must be designed using a single-event hydrograph model to infiltrate the 25-year storm with an overflow for the higher events or infiltrate 100% of the storm runoff volume.

### *Outlet Control Structure*

Runoff in excess of the infiltration capacity must be detained and released in compliance with the flow control requirement described in Section 3-3.6 under Minimum Requirement 6. Outlet control structure design criteria are provided in BMP FC.03, Detention Pond.

## Site Design Elements

### *Setback Requirements*

Setback requirements for infiltration vaults are the same as those for infiltration ponds (see BMP IN.02).

### *Flow Splitters*

For an infiltration pond designed to serve only as a runoff treatment facility, the pond may be located off-line by installing a flow splitter upstream of the treatment facility. The splitter must direct all flows up to the water quality design flow rate into the infiltration facility. The facility must be designed to infiltrate all water directed to it. All bypassed flow must be conveyed to a flow control facility unless it is directly discharged to an exempt water body. (See Section 5-4.3.4 for flow splitter design criteria.)

Note: Infiltration ponds designed for flow control must be located on-line.

### *Emergency Overflow Spillway*

A nonerodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow to the downstream conveyance system, as described in BMP FC.03, Detention Pond. Ponding depth, drawdown time, and storage volume are calculated from the overflow elevation.

## Structural Design Considerations

### *Geometry*

For detailed criteria on sizing infiltration facilities, see Section 4-5. Infiltration ponds must meet the following criterion:

- The slope of the floor of an infiltration pond must not exceed 3% in any direction.

*Eastern Washington*

For cold climate infiltration pond design criteria, refer to Ecology's SMMEW.

### *Embankments*

Requirements for infiltration pond embankments are the same as those for BMP FC.03, Detention Pond. In addition, the site geotechnical investigation must include:

- Stability analysis of side slopes for ponds and the potential to activate landslides in the vicinity of the facility during construction or during service.
- Seepage analysis of any berms or dams required by the facility to retain stormwater.

### *Liners*

The floor of infiltration ponds can be covered with a 6- to 12-inch layer of filter material such as coarse sand, or a suitable filter fabric liner may be used to help prevent buildup of impervious deposits on the soil surface. A nonwoven geotextile that functions sufficiently without plugging should be selected (see underground drainage geotextile specifications in Section 9-33 of the *Standard Specifications*). With this underlying geotextile, the filter layer can be readily replaced or cleaned if it becomes clogged.

## Groundwater Issues

A site is not suitable if the infiltration of stormwater may cause a violation of Ecology groundwater quality standards (see Chapter 2 for guidelines). Local jurisdictions should be consulted for applicable pollutant-removal requirements upstream of the infiltration facility and to determine whether the site overlies a sensitive groundwater recharge area, sole-source aquifer, or wellhead protection zone.

## Site Design Elements

Initial excavation should be conducted to within 1 foot of the final elevation of the infiltration pond floor. 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 ponds, as with all types of infiltration facilities, should generally not be used as temporary sediment traps during construction. If an infiltration pond 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 pond must be removed before the pond is put into service.

Low-ground-pressure equipment is recommended for excavation to avoid compacting the floor of the infiltration pond. The use of draglines and trackhoes should be considered. The infiltration area should be flagged or marked to keep equipment away.

### *Setback Requirements*

Setback requirements for infiltration ponds are generally required by local regulations, Uniform Building Code requirements, or other state regulations. The following setback criteria are provided as guidelines:

- For infiltration facilities, the designer should request from the WSDOT Materials Lab a geotechnical report for the project that evaluates any potential structural site instability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps. The report should address the adequacy of the proposed infiltration pond locations and recommend the necessary setbacks from any steep slopes and building foundations.

- Infiltration facilities should be set back at least 100 feet from drinking water wells, septic tanks or drain fields, and springs used for public drinking water supplies. Infiltration facilities upgradient of drinking water supplies and within 1-, 5-, and 10-year time of travel zones must comply with health department requirements (Washington Wellhead Protection Program, WAC 246-290-135).
- Additional setbacks must be considered if roadway deicers or herbicides are likely to be in the influent to the infiltration system.
- Infiltration facilities must be located at least 20 feet downslope and 100 feet upslope from building foundations.
- Infiltration facilities must be located at least 20 feet from a native growth protection easement (NGPE).
- Infiltration facilities must be a minimum of 5 feet from any property line and/or vegetative buffer. This distance may need to be increased based on permit conditions required by regulations of the local jurisdiction.

### *Landscaping (Planting Considerations)*

The interior of the infiltration pond, as well as surrounding berms, spoil areas, borrow areas, and other disturbed areas, should be stabilized and planted, preferably with grass. Without healthy vegetation, the surface soil pores quickly plug. The use of slow-growing, stoloniferous grasses permits long intervals between mowing. Refer to BMP FC.03, Detention Pond, for seed mixture recommendations.

### *Fencing*

Fencing requirements for an infiltration pond are identical to those of BMP FC.03, Detention Pond.

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

### *Maintenance Access Roads (Access Requirements)*

Vehicle access must be provided to maintain the forebay (presettling basin) area and not disturb vegetation or resuspend sediment.

### *Operation and Maintenance*

Infiltration ponds, as with all BMPs, must have routine inspection and maintenance designed into the life performance of the facility. (See Section 5-5 for more details.)

## *IN.03 – Infiltration Trench*

SR 539 Infiltration Trench with Vegetative Filter Strip

**Description:** Long, narrow, stone-filled trench used for collection, temporary storage, and infiltration of stormwater runoff to groundwater. Can be placed beneath parking areas, along site periphery, or other linear areas. Can be designed for runoff treatment.

**Geometry Limitations**

| | |
|---|---|
| Trench Width | 2' Min |
| Freeboard | 1' Min |
| Bottom Slope | ≤ 3% |

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment*
  - ☐ Oil Control
  - ☑ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 20-50

| Capital Cost | O & M Cost |
|---|---|
| ➲ Low | ➲ Low |

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☑ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☑ Presettling/Pretreatment
- ☑ Underdrain (where required)
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. See Table 5.5.2.

**Pretreatment must be provided with a presettling basin (RT.24) or any basin treatment BMP listed in step 7 of Figure 5.3.2.*

## Introduction

### *General Description*

*Infiltration trenches* are long, narrow, stone-filled trenches used for the collection, temporary storage, and infiltration of stormwater runoff to groundwater. They can be a useful alternative for sites with constraints that make siting an infiltration pond difficult. Infiltration trenches may be placed beneath parking areas, along the site periphery, or in other suitable linear areas. They may also be designed for runoff treatment (see Section 4-5.1). For infiltration trench concept details, see Figures IN.03.1 through IN.03.5.

### *Applications and Limitations*

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 Section 3-3.6 under Minimum Requirement 6.

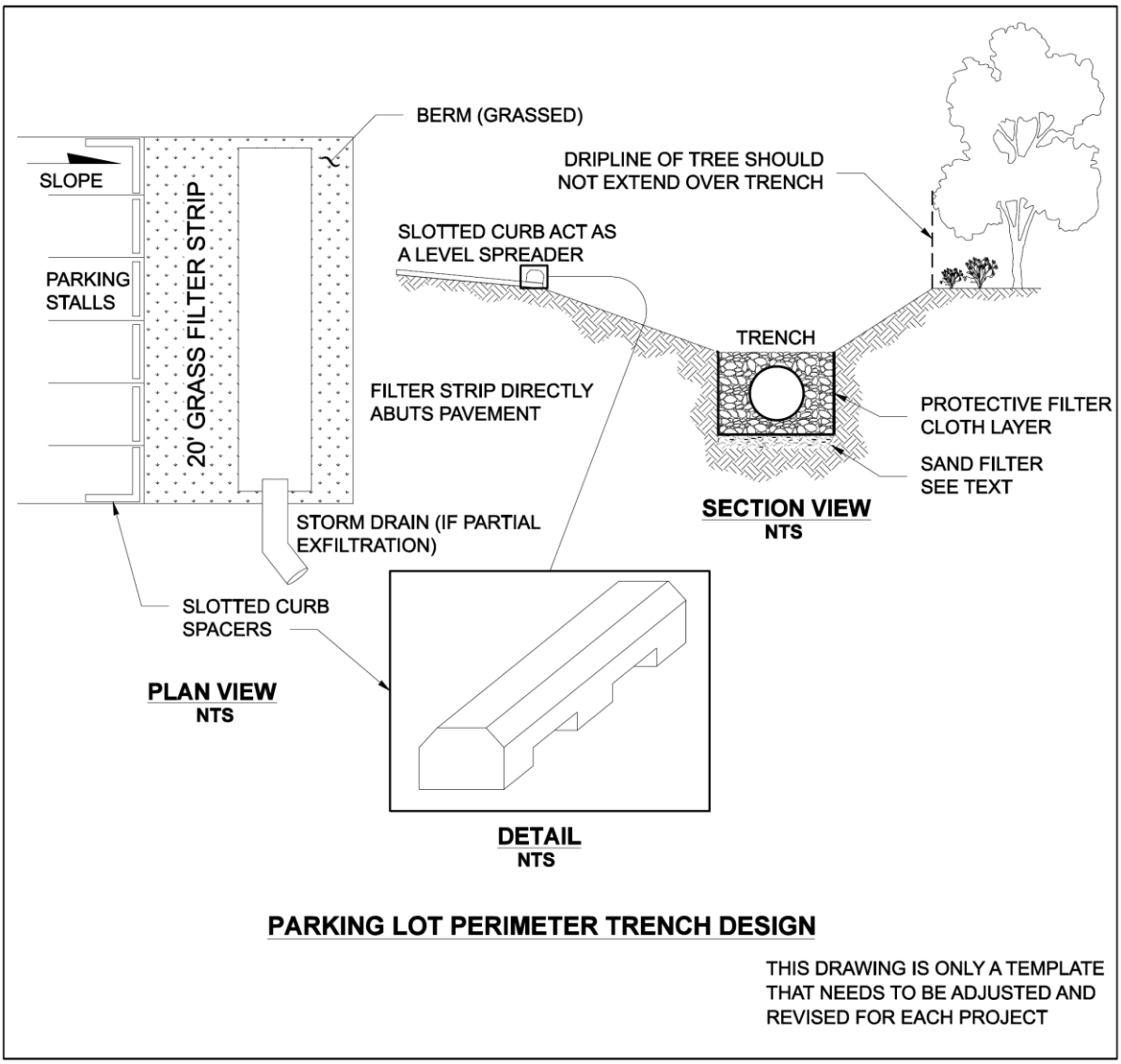
This BMP is considered a subsurface infiltration facility and its use may be subject to the rules governing Class V underground injection wells, but only if it includes the use of a perforated pipe. This type of stormwater facility must be registered through Ecology's UIC (Underground Injection Control) Program. For more information on UIC requirements, see Section 4-5.4.

*Site Suitability Criteria*

Site suitability criteria are the same as those for infiltration ponds (see BMP IN.02).

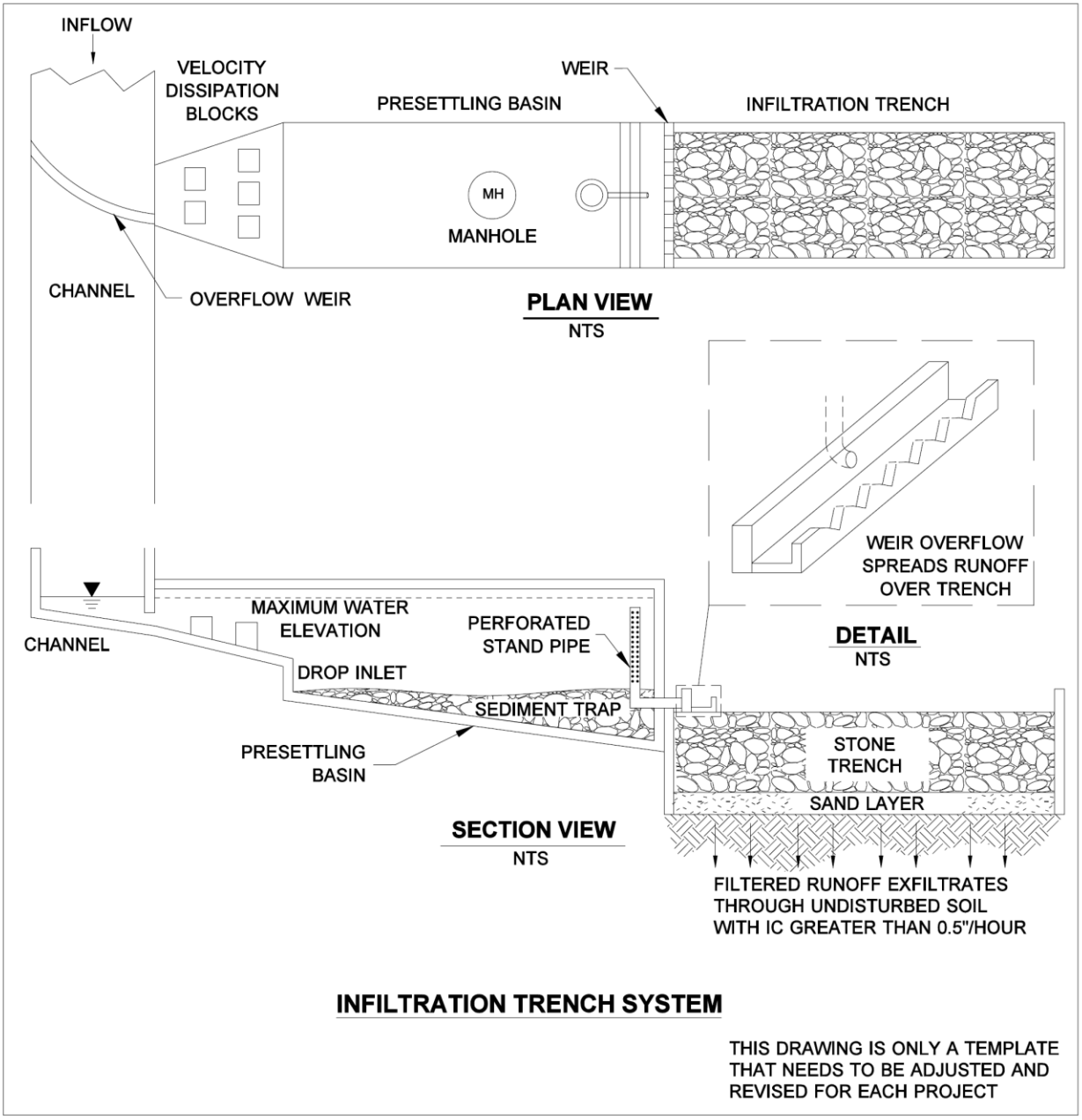
### *Presettling/Pretreatment*

Infiltration trenches should follow a runoff treatment or pretreatment facility to prevent sediment buildup and clogging of the trench. (See BMP RT.24, Presettling/Sedimentation Basin, for pretreatment design criteria.)



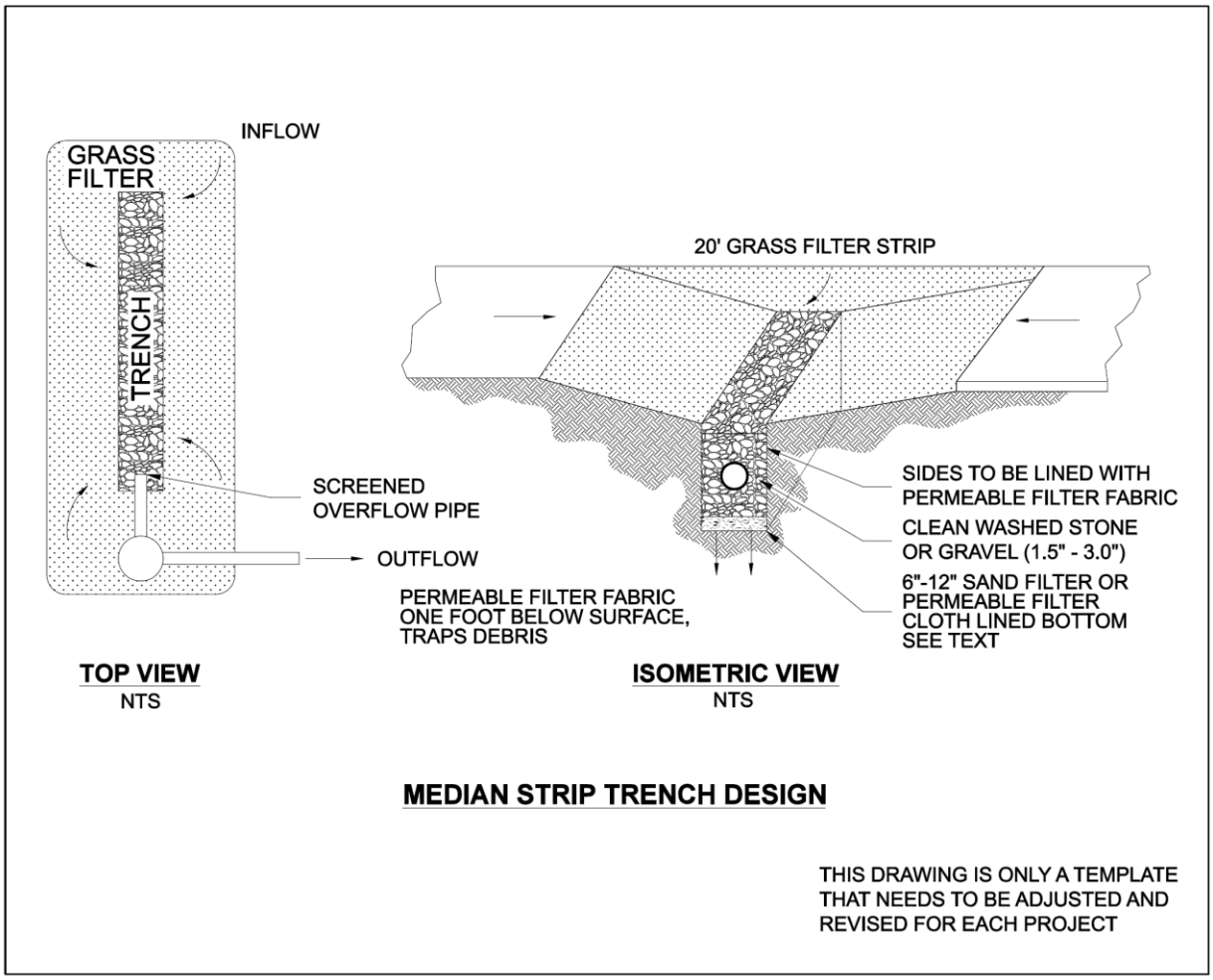

Source: Schueler.

**Figure IN.03.1 Parking lot perimeter trench design.**



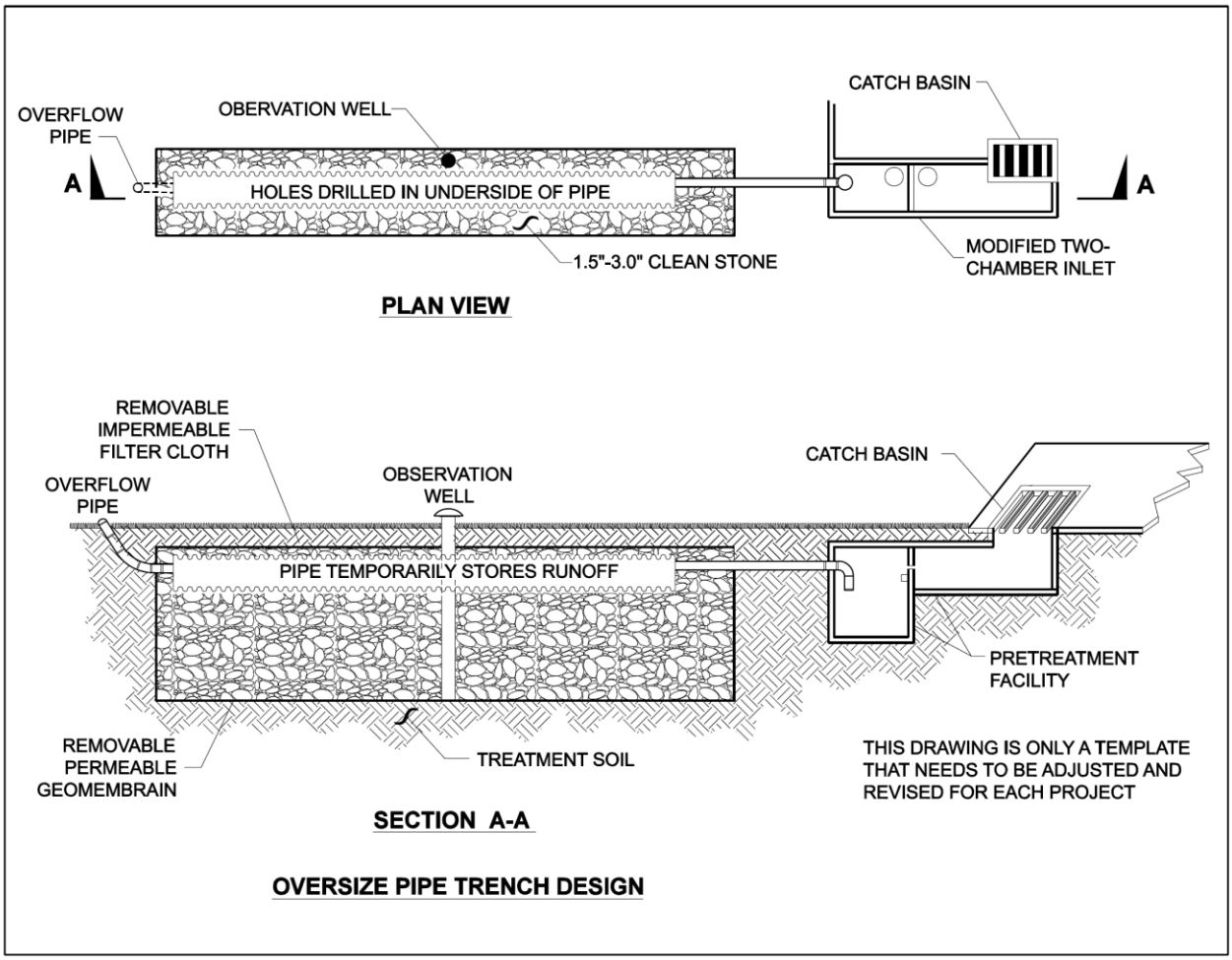

Source: Schueler.

**Figure IN.03.2 Infiltration trench system.**



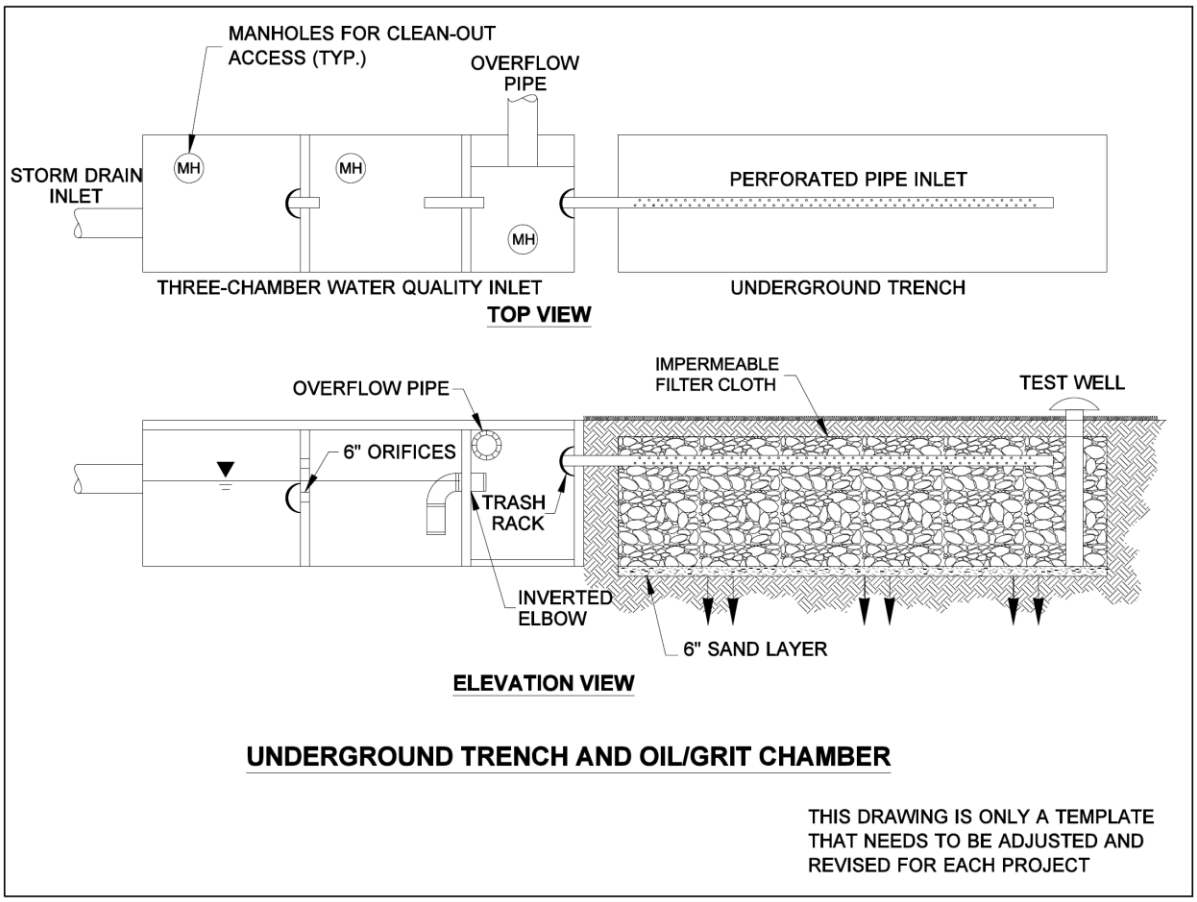

Source: Schueler.

**Figure IN.03.3 Median strip trench design.**




Source: Schueler.

**Figure IN.03.4 Oversize pipe trench design.**




Source: Schueler

**Figure IN.03.5 Underground trench and oil/grit chamber.**

## Design Flow Elements

### *Flows to Be Infiltrated*

The flows to be treated by an infiltration trench are identical to those for BMP IN.02, Infiltration Pond. (See Section 4-5.4.1, Design Procedure for Infiltration Trenches, for flow control criteria.)

### *Overflow or Bypass*

Because infiltration trenches are generally used for small drainage areas, an emergency spillway is not necessary. However, a nonerosive overflow channel leading to a stabilized watercourse should be provided.

### *Outlet Control Structure*

Outlet control structure requirements for an infiltration trench are identical to those for BMP IN.02, Infiltration Pond.

### *Flow Splitters*

Flow splitter requirements for an infiltration trench are identical to those for BMP IN.02, Infiltration Pond.

## Structural Design Considerations

### *Geometry*

Infiltration trench sizing methods are the same as those for BMP IN.02, Infiltration Pond.

### *Materials*

*Backfill Material*

The backfill material for the infiltration trench should consist of clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Void space for the aggregate should be in the range of 30% to 40%.

*Geotextile Fabric Liner*

An engineering geotextile material must encase all of the aggregate fill material, except for the top 1 foot of the trench where an aggregate surface is the final ground condition. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging. (See geotextile for underground drainage in Section 9-33 of the *Standard Specifications*.) The bottom sand or geotextile fabric shown in Figures IN.03.1 through IN.03.3 is optional.

Refer to Section 5-6, References, for publications by the Federal Highway Administration (FHWA) (1995) regarding design criteria on geotextiles in drainage applications. Also, see the National Cooperative Highway Research Program (NCHRP) (1994) for long-term performance data and background on the potential for geotextiles to clog or blind and for piping to be incorporated and how to design for these issues.

### *Observation Well*

An observation well should be installed at the lower end of the infiltration trench to check water levels, drawdown time, and sediment accumulation, and to allow for water quality monitoring. The well should consist of a perforated PVC pipe 4 to 6 inches in diameter, constructed flush with the ground elevation. For larger trenches, a 12- to 36-inch-diameter well can be installed to facilitate maintenance operations such as pumping out trapped sediment. The top of the well should be capped to discourage vandalism and tampering. (See Figure IN.03.6 for more details.)

## Groundwater Issues

Groundwater issues for an infiltration trench are identical to those for BMP IN.02, Infiltration Pond.

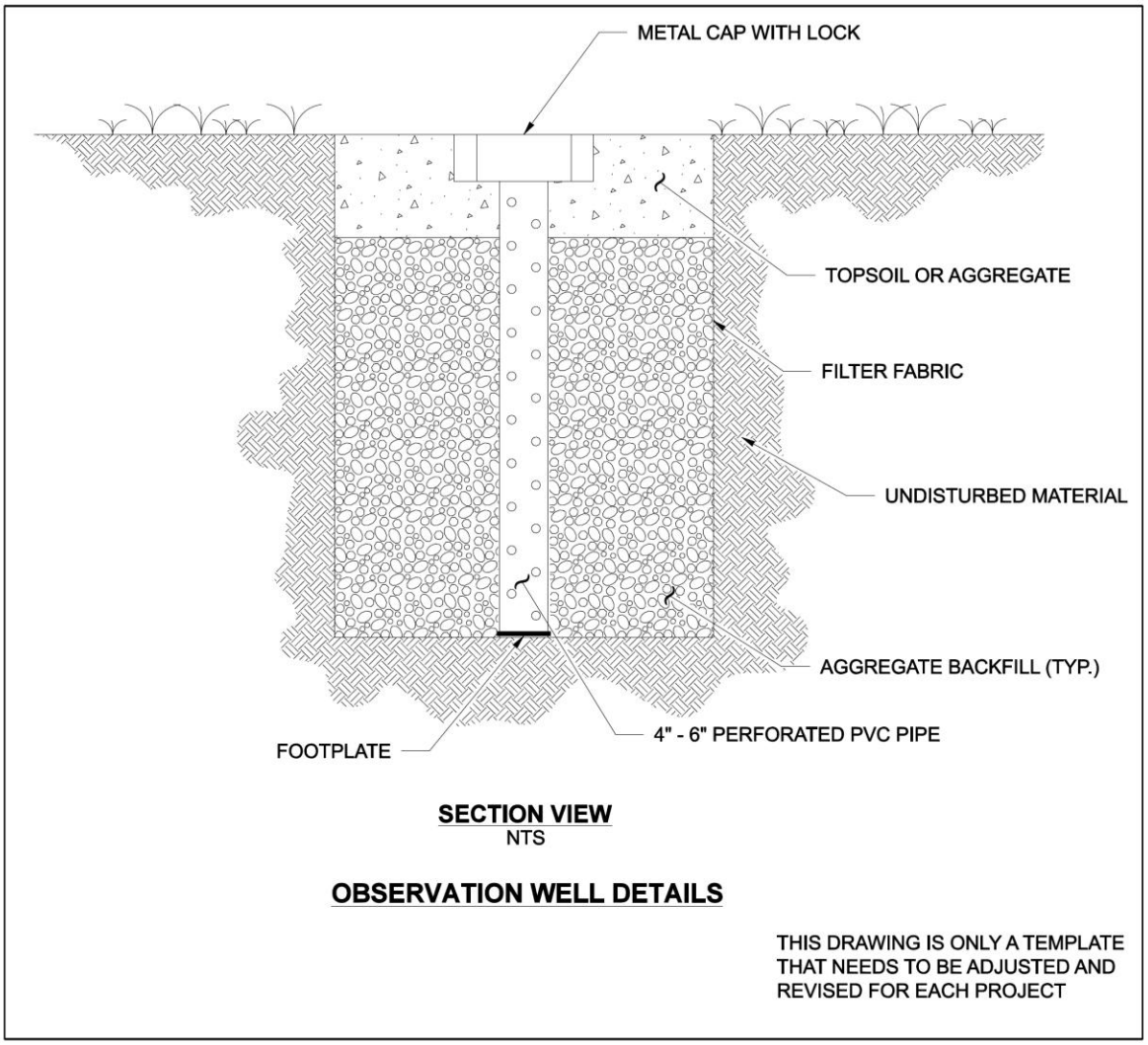
## Site Design Elements

### *Setback Requirements*

Setback requirements for an infiltration trench are identical to those for BMP IN.02, Infiltration Pond.

### *Landscaping (Planting Considerations)*

The trench bottom and sides should be stabilized with a mixture of native grasses that will also enhance water quality. The landscape architect will specify plant material.




Source: King County.

**Figure IN.03.6 Observation well detail.**

### *Maintenance Access Roads (Access Requirements)*

Because of accessibility and maintenance limitations, infiltration trenches must be carefully designed and constructed. The local jurisdiction should be contacted for additional specifications.

An access port or an open or grated top should be considered to permit access for inspections and maintenance.

### *Construction Criteria*

*Trench Preparation*

Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care should be taken to keep this material away from slopes, neighboring property, sidewalks, and streets. It is recommended that this material be covered with plastic.

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

*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, as well as settlement problems.

*Separation of Aggregate from Surrounding Soil*

Natural or fill soils must not intermix with the stone aggregate. If the stone aggregate becomes mixed with the soil, the stone aggregate must be removed and replaced with uncontaminated stone aggregate.

*Overlapping and Covering*

Following the stone aggregate placement and compaction, 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 should overlap a minimum of 2 feet over the downstream roll to provide a shingled effect.

*Voids Behind Geotextile*

Voids between the geotextile and excavation sides must be avoided. The space left by boulders or other obstacles removed 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 can 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.

Initial excavation should be conducted to within 1 foot of the final elevation of the infiltration pond floor. 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 trenches, as with all types of infiltration facilities, should generally not be used as temporary sediment traps during construction. If an infiltration trench 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 trench must be removed before the trench is put into service.

### *Operation and Maintenance*

Infiltration trenches, as with all BMPs, must have routine inspection and maintenance designed into the life performance of the facility. (See Section 5-5 for more details.)

## *IN.04 – Infiltration Vault*

Infiltration Vault along SR 303 in Kitsap County

**Description:** Bottomless underground structures used for temporary storage and infiltration of stormwater runoff to groundwater. May be modified for runoff treatment.

**Geometry Limitations**

Limit to sites where infiltration ponds cannot be located due to site constraints.

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment*
  - ☐ Oil Control
  - ☑ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-10

| Capital Cost | O & M Cost |
|---|---|
| ➲ Moderate | ➲ Moderate to High |

**Additional Constraints/Requirements**

| | |
|---|---|
| ☑ 4-5 Infiltration Design Criteria | ☐ Soil Amendments/Compost |
| ☑ Setback | ☐ Energy Dissipater/Level Spreader |
| ☐ Landscaping/Planting | ☐ 5-4.3.3 Facility Liners |
| ☐ Wetland Planting and Plant Establishment | ☑ 5-4.3.7 Signing |
| ☐ Inlet and Outlet Spacing | ☐ Fencing |
| ☑ Overflow | ☑ Presettling/Pretreatment |
| ☐ Multidisciplinary Team | ☐ Underdrain |
| ☐ WSDOT Pavement Engineer Approval | ☐ Soil Preparation |

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☑ Specialized Equipment
- ☑ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Tables 5.5.2. and 5.5.3.

*Pretreatment must be provided with a presettling basin (RT.24) or any basin treatment BMP listed in step 7 of Figure 5.3.2.

## Introduction

### *General Description*

*Infiltration vaults* are typically bottomless underground structures used for temporary storage and infiltration of stormwater runoff to groundwater. Infiltration tanks are large-diameter cylindrical structures with perforations in the base. These types of underground infiltration facilities can be a useful alternative for sites with constraints that make siting an infiltration pond difficult. They may also be modified for runoff treatment (see Section 4-5.1).

### *Applications and Limitations*

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 Section 3.3.6 under Minimum Requirement 6.

*Site Suitability Criteria*

Site suitability criteria are the same as for infiltration ponds (see BMP IN.02).

Infiltration vaults are not allowed on slopes greater than 25% (4H:1V). On slopes over 15%, a geotechnical report may be required for evaluation by a professional engineer with geotechnical expertise or a qualified geologist with jurisdiction approval. A geotechnical report may also be required if the proposed vault is located within 200 feet of the top of a steep slope or landslide hazard area.

### *Presettling/Pretreatment*

Infiltration vaults should follow a runoff treatment or pretreatment facility to prevent sediment accumulation and clogging of the basin. (See Section 5-4.3.1 for pretreatment design criteria.)

## Design Flow Elements

### *Flows to Be Infiltrated*

The flows to be disposed to groundwater by infiltration vaults are the same as those for infiltration ponds (see BMP IN.02).

### *Overflow or Bypass*

A primary overflow must be provided to bypass flows over the 100-year postdeveloped peak flow to the infiltration vault. (See BMP FC.03, Detention Pond, for overflow structure types.)

### *Outlet Control Structure*

Outlet control structure requirements for infiltration vaults are the same as those for infiltration ponds (see BMP IN.02).

### *Flow Splitters*

Flow splitter requirements for infiltration vaults are the same as those for infiltration ponds (see BMP IN.02).

## Structural Design Considerations

### *Geometry*

Infiltration vault geometric design criteria are the same as those for infiltration ponds (see BMP IN.02).

Note: If a vault is over 20 feet in width it must be designed by the HQ Bridge and Structures Office and added to the bridge inspection inventory by the Preservation Section.

### *Materials*

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.

Infiltration vaults may be constructed using material other than reinforced concrete, such as large, perforated, corrugated metal pipe (see Figure IN.04.1), 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.
- 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.
- The criteria for general design**,** materials, structural stability, buoyancy, maintenance access, access roads, and right of way are the same as those for detention tanks (see BMP FC.03), except for features needed to facilitate infiltration.

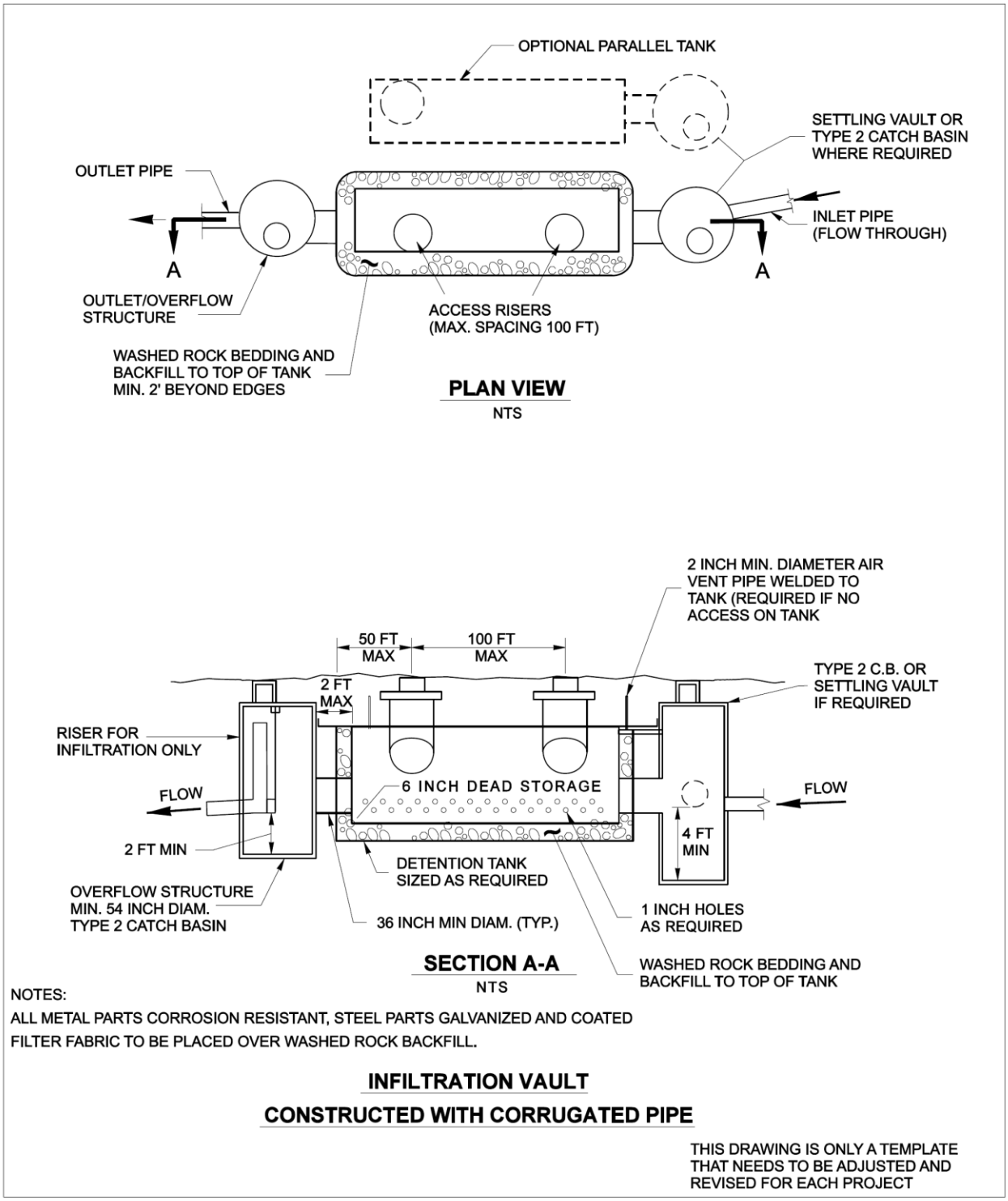



**Figure IN.04.1 Infiltration vault constructed with corrugated pipe.**

## Groundwater Issues

Groundwater issues for infiltration vaults are the same as those for infiltration ponds (see BMP IN.02).

### *Maintenance Access Roads (Access Requirements)*

For general maintenance r**eq**uirements, see Section 5-3.6.1.

### *Construction Criteria*

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

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

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

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

### *Operation and Maintenance*

Infiltration vaults, as with all BMPs, must have routine inspection and maintenance designed into the life performance of the facility. (See Section 5-5 for more details.)

## *IN.05 – Drywell*

Drywell installed along the North Spokane Corridor in Spokane

**Description:** Subsurface concrete structure that conveys stormwater runoff into the soil.

**Geometry Limitations**

Part of a larger drainage system (overflow for a bioinfiltration pond).

**BMP Function**

- ☑ Flow Control*
- ☐ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☐ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-20

| Capital Cost | O & M Cost |
|---|---|
| ➲ Low to Moderate | ➲ Low to Moderate |

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☐ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☑ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☐ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5.

*Drywells are intended for use with a flow control facility and should not be used as a stand-alone BMP.

## Introduction

### *General Description*

*Drywells* are subsurface concrete structures, typically precast, that convey stormwater runoff into the soil matrix. They can be used as stand-alone structures or as part of a larger drainage system (for example, the overflow for a bioinfiltration pond).

### *Applications and Limitations*

Drywells may be used for flow control where runoff treatment is not required, for flows greater than the runoff treatment design storm, or where runoff is treated before it is discharged. (See Tables 4-8 and 4-9 in Section 4-5.4 for determining when treatment is required prior to infiltration.)

This BMP is considered a subsurface infiltration facility and its use would be subject to the rules governing Class V underground injection wells. This type of stormwater facility must be registered through Ecology's UIC (Underground Injection Control) Program. For more information on UIC requirements, see Section 4-5.4.

Uncontaminated or properly treated stormwater must be discharged to drywells in accordance with Ecology's UIC Program (WAC 173-218).

### *Presettling/Pretreatment*

Treatment for removal of total suspended solids (TSS), oil, and soluble pollutants may be necessary before the stormwater is conveyed to a drywell. Companion practices, such as street sweeping and catch basin inserts, can provide additional benefits and reduce the cleaning and maintenance needs for the infiltration facility.

## Design Flow Elements

Inflow to infiltration facilities is calculated according to the methods described in Chapter 4. The storage volume in the detention facility above the drywell is used to detain runoff prior to infiltration. The infiltration rate is used in conjunction with the size of the storage area to design the facility. To prevent the onset of anaerobic conditions, the infiltration facility must be designed to drain completely 72 hours after the flow to it has stopped.

In general, an infiltration facility should have two discharge modes. The primary mode of discharge is infiltration into the ground. However, when the infiltration capacity of the facility is reached, a secondary discharge mode is needed to prevent overflow. Overflows from an infiltration facility must comply with Minimum Requirement 6 in Section 3-3.6.

### *Flows to Be Infiltrated*

The flows to be disposed to groundwater by drywells are the same as those for infiltration ponds (see BMP IN.02).

### *Overflow or Bypass*

A primary overflow must be provided to bypass the 100-year postdeveloped peak flow over or around the flow restrictor system.

## Structural Design Considerations

### *Geometry*

The *Standard Plans* show typical details for drywell systems. These systems are designed as specified below.

- Drywell bottoms should be a minimum of 5 feet above seasonal high ground-water level or impermeable soil layers. Refer to the *Setback Requirements* below.
- Typically, drywells are 48 inches (minimum) in diameter and are approximately 5 to 10 feet (or more) deep.
- Filter fabric (geotextile) may need to be placed on top of the drain rock and on trench or drywell sides before the drywell is backfilled to prevent migration of fines into the drain rock, depending on local soil conditions and local jurisdiction requirements.
- Drywells should be spaced no closer than 30 feet center to center or twice the structure depth in free-flowing soils, whichever is greater.
- Drywells should not be built on slopes greater than 25% (4H:1V).
- Drywells may not be placed on or above a landslide hazard area or slopes greater than 15% without evaluation by a professional engineer with geotechnical expertise, or a qualified geologist, and approval by the local jurisdiction.

## Groundwater Issues

A site is not suitable if the infiltration of stormwater may cause a violation of Ecology ground- water quality standards. Local jurisdictions should be consulted for applicable pollutant removal requirements upstream of the infiltration facility and to determine whether the site is located in an aquifer-sensitive area, sole-source aquifer, or a wellhead protection zone.

A drywell may be considered for runoff collection from those areas requiring oil control (see Table 3-1). For such applications, sufficient pollutant removal, including oil removal, must be provided upstream of the infiltration facility to prevent violations of groundwater quality standards and adverse effects on the infiltration facility.

### *Vadose Zone Requirements*

As mentioned under *Geometry*, the base of all infiltration systems should be at least 5 feet above the seasonal high-water level, bedrock (or hardpan), or other low-permeability layer. The base of the facility may be within 3 feet if the groundwater mounding analysis, volumetric receptor capacity, and design of the overflow or bypass structures are judged by the designer to be adequate to prevent overtopping and meet the site suitability criteria.

The designer should investigate whether the soil under the proposed infiltration facility contains contaminants that could be transported by infiltration from the facility. If so, measures should be taken for remediation of the site before the facility is constructed or an alternative location should be chosen. The designer should also determine whether the soil beneath the proposed infiltration facility is unstable due to improper placement of fill, subsurface geologic features, or other reasons. If so, further investigation and planning should be undertaken before siting the facility.

## Site Design Elements

### *Setback Requirements*

Setback requirements for drywells are the same as those for infiltration ponds (see BMP IN.02).

### *Signage*

Refer to Section 5-4.3.7 for signing requirements

## *IN.06 – Permeable Pavement Surfaces*

Test Section of Pervious Pavement at Anacortes Ferry Terminal

**Description:** The pervious concrete or asphalt pavement surface is an open-graded mix placed in a manner that results in a high degree of interstitial spaces or voids within the cemented aggregate. This technique allows runoff to infiltrate through to the subsoils.

**Geometry Limitations**

Limited to pedestrians and light to medium-load parking areas.

**BMP Function***

- ☑ Flow Control
- ☑ Runoff Treatment
  - ☑ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

*Currently, this BMP cannot be considered a stand-alone runoff treatment or flow control BMP. However, when used as part of a project surface, it can reduce the total runoff, thereby providing an overall reduction to the size and placement of other acceptable runoff treatment and flow control BMPs.

**Effective Life (Years)**

➲ --

| Capital Cost | O & M Cost |
|---|---|
| ➲ Medium | ➲ High |

**Additional Constraints/Requirements**

- ☑ 4-5 Infiltration Design Criteria
- ☐ Setback
- ☐ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☑ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☐ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☐ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☐ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☑ Specialized Equipment
- ☑ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Consult WSDOT Maintenance for guidance.

## Introduction

### *General Description*

Pervious (porous) surfaces can be applied to non-pollution-generating surfaces such as pedestrian/bike paths, raised traffic islands, and sidewalks. Pervious surfaces with a media filtration sublayer (such as sand or an amended soil) could be applied to pollution-generating surfaces (such as parking lots) for calculating runoff treatment. Sublayers constructed of amended soils could affect the performance of permeable pavement and should not be used in areas intended to carry vehicle traffic. Pervious surfaces allow stormwater to pass through and infiltrate the soil below, thereby reducing the rate and volume of runoff associated with conventional surfacing and fostering groundwater recharge.

### *Applications and Limitations*

*Applications*

Permeable pavement has not been proven to stand up to high traffic levels. The use of permeable pavement by WSDOT is limited to applications that can accommodate pedestrians and light- to medium-load parking areas, excluding heavy truck traffic. Areas where permeable pavement could be considered include the following:

- Sidewalks, bicycle trails, and community trail/pedestrian path systems
- Light vehicle access areas such as maintenance/enforcement areas on divided highways
- Public and municipal parking lots, including perimeter and overflow parking areas
- Driveways

Pervious surface systems function as stormwater infiltration areas and temporary stormwater retention areas. This combination of functions offers the following benefits:

- Captures and retains precipitation on-site
- Mimics natural soils filtration throughout the pavement depth, underlying sub-base reservoir, and native soils for improved groundwater quality
- Eliminates surface runoff, depending on existing soil conditions
- Greatly reduces or eliminates the need for an on-site stormwater management system
- Reduces drainage water runoff temperatures
- Increases recharge of groundwater
- Provides runoff treatment with a media filtration layer
- Thaws quicker when covered by ice or snow

*Limitations*

Pervious surfaces are vulnerable to clogging from sediment in runoff or from dirt and debris that accumulates and falls off vehicles. The following techniques will reduce this potential:

- **Surface runoff**. Pervious surfaces should not be located where turbid runoff from adjacent areas can introduce sediments onto the pervious surface. Designs should slope impervious runoff away from permeable pavement installations to the maximum extent possible.
- **Diversion**. French drains, or other diversion structures, may be designed into the system to avoid unintended off-site runoff. Pervious systems can be separated using edge drain systems, turnpikes, and curbing.
- **Cold climates**. Sanding or repeated snow removal can lead to clogging and a reduction in surface permeability. Pervious surfaces should not be used in traffic areas where sanding or extensive snow removal is carried out in the winter.
- **Slopes**. Off-site drainage slopes immediately adjacent to the pervious surface should be less than 5% to reduce the chance of soil loss that would cause clogging.

Examples of situations where the use of pervious surfaces is not recommended include the following:

- Main line roadway.
- Roadway shoulders.
- Roadways with high volume and heavy trucks.
- Areas such as maintenance yards that are subject or potentially subject to higher pollutant loadings, spills, and piles of bulk materials (such as sand or salt).
- Areas prone to the accumulation of organic debris from overhanging vegetation or areas prone to moss growth.
- Where the requirements defined in the Site Suitability Criteria cannot be met, (see Section 4-5.1) specifically:
- Areas where the risk of groundwater contamination from organic compounds is high (for example, fueling stations, commercial truck parking areas, and maintenance and storage yards).
- Within 100 feet of a drinking water well and within areas designated as sole-source aquifers.
- Areas with a high water table or impervious soil layer as defined in Section 4-5, Infiltration Design Criteria.

- Within 100 feet up-gradient or 10 feet down-gradient from building foundations. Closer up-gradient distances may be considered where the minimum seasonal depth to groundwater lies below the foundation or where it can be demonstrated that infiltrating water from the pervious surface will not affect the foundation.

- Construction Practices

Handling and placement practices for pervious surfaces are different from conventional pavement placement. Unlike conventional pavement construction, it is important that the underlying native or subgrade soils be nominally consolidated to prevent settling and to minimize the effect of intentional or inadvertent heavy compaction due to heavy equipment operation during construction. Consolidation can be accomplished using static dual-wheel small mechanical rollers or plate vibration machines. If heavy compaction does occur, then tilling may be necessary to a depth of 2 feet or more below the materials placement. This would occur prior to subsequent application of the separation and aggregate storage layer.

## Design Criteria

All projects considering the use of pervious surfaces require the coordination of the Headquarters (HQ) Design, Materials Lab, and Maintenance offices, and the HQ Highway Runoff Unit. The final design shall be approved by the HQ Materials Office and Highway Runoff Unit.

*General Criteria*

- As long as runoff is not directed to the pervious asphalt from adjacent surfaces, the estimated long-term infiltration rate may be as low as 0.1 inch/hour. Soils with lower infiltration rates should have underdrains to prevent prolonged saturated soil conditions at or near the ground surface within the pavement section (PSAT, 2005).

- For initial planning purposes, pervious surface systems will work well on Hydrologic Soil Groups A and B and can be considered for Group C soils. Standard three-layer placement sections for Group D soils may not be applicable.

- For projects constructed upon Group C and D soils, a minimum of three soil gradation analyses or three infiltration tests should be conducted to establish on-site soil permeability. Otherwise, a minimum of one such test should be conducted for Group A and B soils to verify adequate permeability.

- Ideally, the base layer should be designed with sufficient depth to meet flow control requirements (taking into account infiltration). If the infiltration rate and base layer's recharge bed storage does not meet flow control requirements, an underdrain system may be required. The underdrain may be discharged to a bioretention area, dispersion system, or stormwater detention facility.

- Turbid runoff to the pervious surface from off-site areas is not allowed. Designs may incorporate infiltration trenches or other options to ensure long-term infiltration through the pervious surface.

- Any necessary boreholes must be installed to a depth of 10 feet below the base of the reservoir layer, and the water table must be monitored at least monthly for a year.
- Pervious surfaces require more maintenance than conventional pavement installations. The primary concern in maintaining the continued effectiveness of a pervious surface system is to prevent the surface from clogging with fine sediments and debris. (See Section 5-5 for operation and maintenance guidelines.)

*Pavement Structure Elements*

Pervious surfaces consist of a number of components: the surface pavement, an underlying aggregate storage layer, a separation layer, and the native soil or subgrade soil (see Figure IN.06.1). An overflow or underdrain system may need to be considered as part of the pavement's overall design.

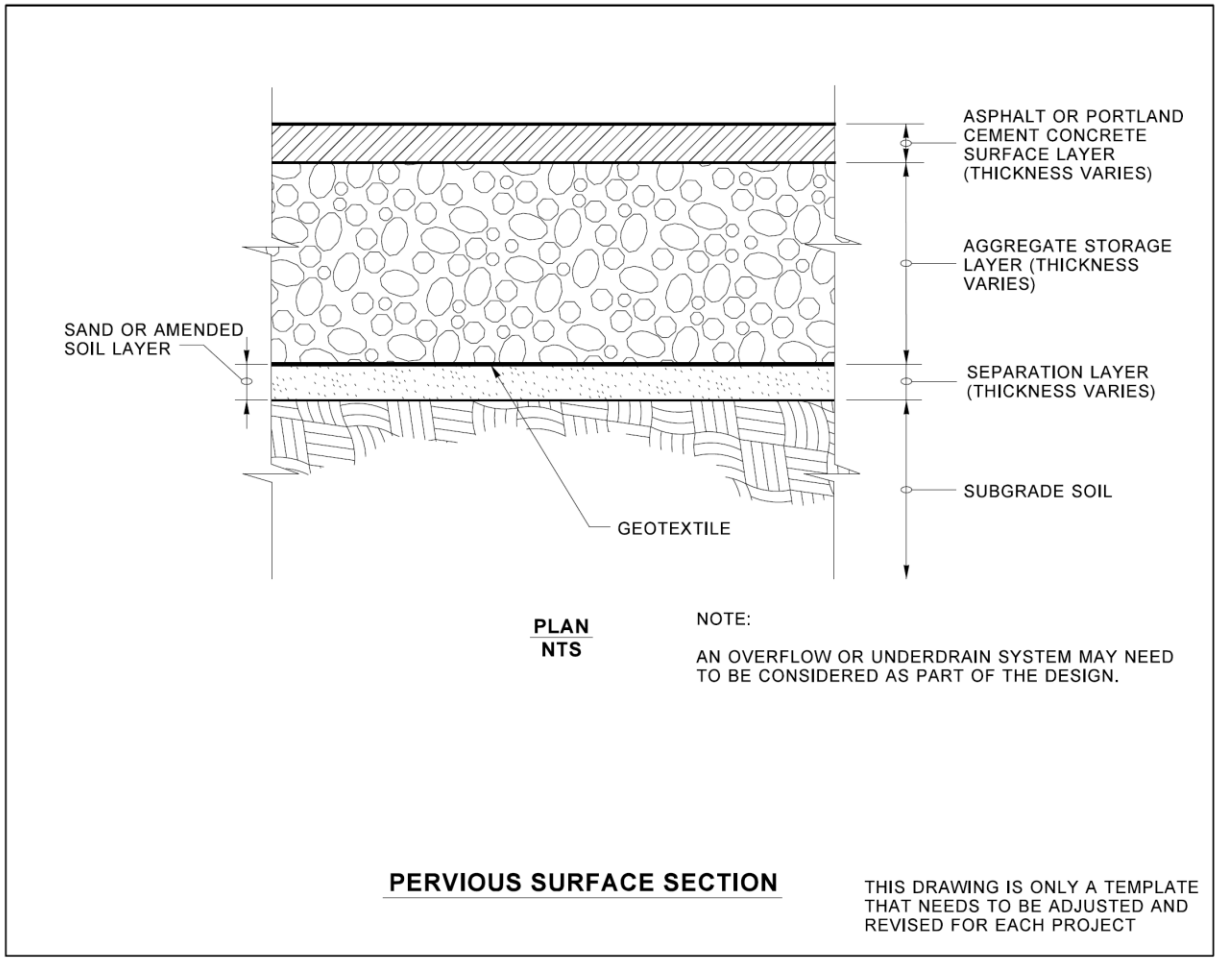



**Figure IN.06.1 Permeable pavement structure elements.**

*Surface Layer*

The surface layer is the first component of a pervious system's design that creates the appropriate conditions for water to infiltrate through the surface. Pervious paving systems allow infiltration of storm flows; however, the wearing course should not be allowed to become saturated from excessive water volume stored in the aggregate storage layer (PSAT, 2005). The two types of surfaces layers that will be described (or are considered appropriate for the locations described in this section) are: Portland Cement-Based Permeable Pavement Materials and Asphalt-Based Permeable Pavement Materials. Each of these materials is further described in the following sections.

*Portland Cement-Based Permeable Pavement Materials*

The surface layer consists of specially formulated mixtures of Portland cement, uniform open-graded coarse aggregate, and potable water. The depth of the surface layer may increase from a minimum of 4 inches, depending on the required bearing strength and pavement design requirements. The gradation required to obtain a pervious concrete pavement is of the open-graded or coarse type (AASHTO Grading No. 67 is typical). For additional information, refer to the permeable pavement specifications.

Due to the relatively low water content of the concrete mix, an agent may be added to retard concrete setup time. When properly handled and installed, permeable pavement has a higher percentage of void space than conventional pavement (approximately 12% to 20%), which allows rapid percolation of stormwater through the pavement. The initial permeability can commonly exceed 200 inches per hour (Chollack et al., 2001; Mallick et al., 2000).

*Asphalt-Based Permeable Pavement Materials*

The surface asphalt layer consists of an open-graded asphalt mixture. The depth of the surface layer may increase from a minimum of 4 inches, depending on the required infiltration, subgrade bearing strength, and pavement design requirements.

Pervious asphalt pavement consists of an open-graded coarse aggregate. The pervious asphalt creates a surface layer with interconnected voids that provide a high rate of permeability.

*Aggregate Storage Layer*

The underlying aggregate storage layer is the second component of a pervious surface's design. The aggregate storage layer is composed of a crushed aggregate and provides the following:

- A stable base for the pavement.
- A high degree of permeability to disperse water downward through the underlying layer to the separation layer.

- A temporary reservoir that slows the migration of water prior to infiltration into the underlying soil.
- Base material is often composed of larger aggregate (1.5 to 2.5 inches) with smaller stone (leveling or choker course) between the larger stone and the wearing course. Typical void space in base layers ranges from 20% to 40% (WSDOT, 2003; Cahill, Adams, and Marm, 2003).
- Depending on the target flow control standard and physical setting, retention or detention requirements can be partially or entirely met in the aggregate base (PSAT, 2005).
- Aggregate base depths of 18 to 36 inches are common depending on storage needs, and they provide the additional benefit of increasing the strength of the wearing course by isolating underlying soil movement and imperfections that may be transmitted to the wearing course (Cahill et al., 2003).

*Separation Layer*

The third component of permeable pavement is the separation layer. This layer consists of a nonwoven geotextile fabric and possibly a treatment media base material. A geotextile fabric layer is placed between the base material and the native soil to prevent migration of fine soil particles into the base material, followed by a runoff treatment media layer if required.

- For geotextile, see WSDOT Standard Specification 9-33.
- For separation base material, see the FHWA manual *Construction of Pavement Subsurface Drainage Systems* (2002) for aggregate gradation separation base guidance.
- A treatment media layer is not required where subgrade soil is determined to have a long-term infiltration rate less than 2.4 inches per hour and a CEC of the subgrade soil that is at least 5 milliequivalents/100 grams of dry soil or greater (Ecology, 2001).
- If a treatment media layer is used, it must be distributed below the geotextile layer and above the subgrade soil. The media can consist of a sand filter layer or amended soil. Engineered amended soil layers should be a minimum of 18 inches and incorporate compost, sphagnum peat moss, or other organic material to provide a cation exchange capacity of greater than or equal to 5 milliequivalents/100 grams of dry soil (Ecology, 2001). Gradations of the treatment media should follow base sizing.

*Subgrade Soil*

The underlying subgrade soil is the fourth component of permeable pavement. Runoff infiltrates into the soil and moves to the local interflow or groundwater layer. Compaction of the subgrade must be kept to an absolute minimum to ensure the soil maintains a high rate of permeability while maintaining the structural integrity of the pavement.

## Permeable Pavement Structural Design

*Permeable Pavement Thickness*

Thickness designs for pervious asphalt or concrete shall match those shown in the 2011 Pavement Policy available through the State Materials Laboratory:
http://www.wsdot.wa.gov/nr/rdonlyres/d7971b81-5443-45b9-8b9b-bfc0d721f5a1/0/wsdotpavementpolicyfinal71211.pdf

*Aggregate Storage Layer Thickness*

Once a pervious surface site is identified, contact the WSDOT Materials Lab for a required geotechnical investigation to be performed. On-site soils will be tested for porosity, permeability, organic content, and potential for cation exchange. The WSDOT Materials Lab, Geotechnical Services Division, will determine the quantity and depth of borings/test pits required and any groundwater monitoring needed to characterize the soil infiltration characteristics of the site. Where subgrade materials are marginal, the use of a geogrid placed directly on subgrade may be necessary. A sand layer is placed above the heavy geogrid, followed by geotextile for drainage. Coordination with the HQ Geotechnical Services Division should be made for these applications.

For determining a final design-level infiltration rate, refer to the design criteria provided in Section 4-5. Note: These criteria apply primarily to infiltration basins and may therefore exclude slower-percolating soils such as loams, which are potentially suitable for pervious surfaces.

Flow control modeling guidance for western Washington can be found in Table 4-3 of Chapter 4. For sizing the permeable pavement aggregate recharged bed, contact the HQ Highway Runoff Unit.

*Special Provisions*

For special provisions in the development of Plans, Specifications, and Estimates (PS&E), contact the State Materials Office.

## Design Flow Elements

### *Flows to Be Infiltrated*

*The design criteria below assume that it is feasible to meet the flow control requirements by sizing a storage volume within the subsurface layers. This needs to be explored further for viability. It is possible that the design criteria for an infiltration trench may be more comprehensive and applicable than the general guidelines provided below. There has been discussion in the past that using permeable pavement surfaces is a part of low-impact development (LID) practices and would only result in some form of credit being applied to flow control mitigation.*

For western Washington, use an acceptable continuous runoff simulation model to size an infiltration basin, as described in Section 4-5, Infiltration Design Guidelines. Modeling guidelines can be derived from Section 4-3.6.1, Continuous Simulation Method. For eastern Washington, use an appropriate single-event-based model consistent with Section 4-5 guidelines. For sizing purposes, use the following guidelines:

- The bottom area of an "infiltration basin" will typically be equivalent to the area below the surrounding grade underlying the pervious surface. Adjust the depth of this "infiltration basin" so that it is sufficient to store the required design volume.
- Multiply this depth by a factor of 5. This will determine the depth of the gravel base underlying the pervious surface. This assumes a void ratio of 0.20—a conservative assumption. When a base material that has a different porosity will be used, that value may be substituted to determine the depth of the base. The minimum base depth is 6 inches, which allows for adequate structural support of the pervious surface.
- For a large, contiguous area of pervious surface, such as a parking lot, the area may be designed with a level surface grade and a sloped subgrade to prevent water buildup on the surface, except under extreme conditions. Rare instances of shallow ponding in a parking lot are normally acceptable.
- For projects where ponding is unacceptable under any condition, the surface of the parking lot may be graded at a 1% slope leading to a shallow swale, which would function to ensure emergency drainage (similar to an emergency overflow from a conventional infiltration pond). However, the design depth of the base material must be maintained at all locations.

## 5-4.2.2 Dispersion BMPs

### *FC.01 – Natural Dispersion*

Natural Dispersion Area Along SR 516 in King County

**Description:** Existing soils, vegetation, and topography are used to provide flow control and runoff treatment. Runoff enters the dispersion area as sheet flow and disperses into the surrounding landscape. It requires little or no construction activity.

**Geometry Limitations**

| | |
|---|---|
| Resultant Slope | ≤ 9.4% |
| Contributing Flow Path | ≤ 150' |
| Embankment Slope | 2% - 33%[2] |

2. Up to 33% with a gravel spreader or 15% without.

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment
  - ☑ Oil Control
  - ☑ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 50-100

| Capital Cost | O & M Cost |
|---|---|
| ➲ Low | ➲ Low |

**Additional Constraints/Requirements**

| | |
|---|---|
| ☑ 4-5 Infiltration Design Criteria | ☐ Soil Amendments/Compost |
| ☑ Setback | ☑ Energy Dissipater/Level Spreader |
| ☐ Landscaping/Planting | ☐ 5-4.3.3 Facility Liners |
| ☐ Wetland Planting and Plant Establishment | ☑ 5-4.3.7 Signing |
| ☐ Inlet and Outlet Spacing | ☐ Fencing |
| ☐ Overflow | ☐ Presettling/Pretreatment |
| ☐ Multidisciplinary Team | ☐ Underdrain |
| ☐ WSDOT Pavement Engineer Approval | ☐ Soil Preparation |

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☐ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. See Table 5.5.12.

## Introduction

### *General Description*

*Natural dispersion* is the simplest method of flow control and runoff treatment. This BMP can be used for impervious or pervious surfaces that are graded to avoid concentrating flows. Natural dispersion uses the existing vegetation, soils, and topography to effectively provide flow control and runoff treatment. It generally requires little or no construction activity. Site selection is very important to the success of this BMP. The pollutant-removal processes include infiltration into the existing soils and through vegetation root zones; evaporation; and uptake and transpiration by the vegetation.

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

Using natural dispersion on projects will result in benefits when determining applicable minimum requirements and thresholds. New impervious surfaces that drain to dispersion areas should be accounted for when determining the project's total new impervious surface area, but the area should be counted as a noneffective impervious surface (and noneffective PGIS). When modeling the hydrology of the project site and threshold discharge area, the designer 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.

### *Applications and Limitations*

*Applications*

- Natural dispersion is ideal for highways and linear roadway projects.
- There are two types of natural dispersion: sheet flow dispersion and channelized dispersion.
- 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.
- Natural dispersion areas meet basic, enhanced runoff treatment, oil control, and phosphorus criteria set forth in Minimum Requirement 5 (Runoff Treatment) in Section 3.3.5.
- Natural dispersion areas meet flow control criteria set forth in Minimum Requirement 6 (Flow Control) in Section 3.3.6.

*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. (See the *Site Design Elements* section of this BMP.) WSDOT may ultimately have to purchase right of way or easements to satisfy the criteria for natural dispersion areas, but this should be the last option a designer should choose.
- Natural dispersion areas initially may cost as much as other constructed BMPs (ponds or vaults) because right 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.
- Refer to the Glossary for "noneffective PGIS" and "noneffective impervious surfaces" to see how natural dispersion areas are analyzed with respect to minimum requirements. This does not apply to engineered dispersion.
- Floodplains are not suitable areas for natural dispersion. In these situations, please contact the Region or HQ Hydraulics Office.

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. Dispersal BMPs create sheet flow conditions.
- Energy dissipaters in conjunction with dispersal BMPs 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. There may be situations where it might be more beneficial to disperse off-site flows. In these situations, please contact the Region or HQ Hydraulics Office.

## Site Design Elements

### *Siting Criteria*

The key to natural dispersions 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:

- WSDOT rights of way
- Protected beautification areas
- Agricultural areas
- State parks
- Commercial or government-owned forest lands

- Rural areas with zoned densities of less than one dwelling unit per 5 acres

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.

## Design Flow Elements

### *Flows to Be Dispersed*

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.

*Sheet Flow*

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

- The sheet flow path leading to the natural dispersion area should not be longer than 150 feet. The sheet flow path is measured in the direction of flow and generally represents the width of the pavement area.
- Pervious shoulders and side slopes are not counted in determining the sheet flow path.
- The longitudinal length of the dispersion area should be equivalent to the longitudinal length of roadway that is contributing sheet flow.
- The resultant slope from the contributing pavement should be less than or equal to 9.4%, calculated using Equation FC.01-1.

$$S_{CFS} = (G^2 + e^2)^{0.5} \quad \textbf{(FC.01.1)}$$

where:

$S_{CFS}$ = resultant slope of the lateral and longitudinal slopes
e = lateral slope (superelevation) (%)
G = longitudinal slope (grade) (%)

- Where gravel level spreaders are not located between the highway and the dispersion area, as shown in Figure FC.01.1a, roadway side slopes leading to natural dispersion areas should be 25% (4H:1V) or flatter. Roadway side slopes that are 25% to 15% (7H:1V) should not be considered part of the dispersion area. Slopes steeper than 25% are allowed if the existing side slopes are well vegetated and show no signs of erosion problems.
- Where gravel level spreaders are located between the highway and the dispersion area, as shown in Figure FC.01.1b, roadway side slopes 33% or flatter can be considered part of the natural dispersion area if the existing side slopes are well vegetated and show no signs of erosion problems.[11]

[11] "Eastern Washington Steep Slope Research for Management of Highway Stormwater," WARD 77.1, Research Report, May 2011.

- 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.

### *Sizing Criteria*

*Sheet flow*

- There are two sheet flow options that can be applied to size natural dispersion areas only. The first option, described below, is based on a simplified equation (termed the LID Design Equation[12]) that was derived from a water balance model and is applicable only to eastern Washington. This equation takes into account the roadway width, saturated hydraulic conductivity, and rainfall intensity to derive the width needed for the natural dispersion. The second option is based on soil characteristics and is described after Option 1.

**Option 1 – Design Process (eastern Washington only):**

$$LID = \frac{ACP}{\frac{K_s}{r_i} - 1} \qquad \textbf{(FC.01.2)}$$

where:

$LID$ = width of the natural dispersion in feet
$ACP$ = width of the roadway in feet
$K_s$ = saturated hydraulic conductivity in inches per hour (see Section 4-5.2)
$r_i$ = rainfall intensity in inches per hour

*The* $K_s / r_i$ ratio must be greater than 2 for natural dispersion to have a viable benefit. If the ratio is less than 1 or equal to 1, the equation is not valid and will result in negative values.

### *Calculating Rainfall Intensity in Eastern Washington:*

The rainfall intensity ($r_i$) is the peak 5-minute intensity of the 6-month, 3-hour short-duration storm. To calculate $r_i$, multiply the rainfall depth (2-year, 2-hour) by the *Peak Intensity Factor (PIF)* based on its Mean Annual Precipitation for the area. Use the table below to convert the Mean Annual Precipitation value to *PIF*.

The 2-year, 2-hour rainfall depth information is contained in Appendix 4A – Web Links, under the Eastern Washington Isopluvial and Mean Annual Precipitation Map. WSDOT's ArcMap GIS system also contains this information.

$$r_i = \textit{2-year, 2-hour rainfall depth} * \textit{PIF}$$

[12] "Application of a Simplified Analysis Method for Natural Dispersion of Highway Stormwater Runoff," WA-RD 618.1, Research Report, August 2005.

| DOE Climate Region # | Mean Annual Precipitation | Isopluvial to Peak Intensity Factor: |
|---|---|---|
| 2 | 6-8 | 1.85 |
| | 8-10 | 1.88 |
| | 10-12 | 1.94 |
| 2-3 | 12-16 | 2.00 |
| 3 | 16-22 | 2.03 |
| 1-4 | 22-28 | 2.09 |
| | 28-40 | 2.12 |
| | 40-60 | 2.19 |
| | 60-120 | 2.25 |

Example:

Spokane 2-year, 2-hour rainfall depth = 0.48 inches
Spokane Mean Annual Precipitation depth = 18 inches
Spokane *PIF* for 18 inches = 2.03 in/hr

Calculate $r_i$ = 0.48 in * 2.03 in/hr
= 0.97 in/hr

**Option 2 – Based on Soil Characteristics**

- The following criteria are specific to sheet flow dispersion on all Type A and some Type B soils on slopes 15% or less (depending on saturated hydraulic conductivity rates):
- For saturated hydraulic conductivity rates (as determined in Section 4-5.2) 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 should 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 saturated hydraulic conductivity rates of 4 inches per hour or less on slopes 15% or less:

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

- For slopes greater than 15%, the dispersion area should be multiplied by the slope factor in the table below.

| Embankment Slopes (%)[1] | Slope Factor |
|---|---|
| ≤15 | 1.00 |
| 20 | 1.09 |
| 25 | 1.17 |
| 30 | 1.23 |
| 33 | 1.27 |

[1]For eastern Washington, use 1.0 for all slopes.

Figure FC.01.1a illustrates the configuration of a typical sheet flow natural or engineered dispersion area relative to the roadway.

*Channelized Flow*

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

- Concentrated runoff from the roadway and adjacent upstream areas (such as in a ditch or cut slope) must be incrementally discharged from the conveyance system (such as a ditch, gutter, or storm sewer) via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows must not exceed 0.5 cubic feet per second (cfs) at any single discharge point from the conveyance system for the 100-year runoff event (determined by an approved continuous flow model as described in Chapter 4). 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 feet by 2 feet in section; 50 feet in length; filled with ¾- to 1½-inch washed rock; and provided with a level notched grade board (see Sections 5-4.3.4 and 5-4.3.5). 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.

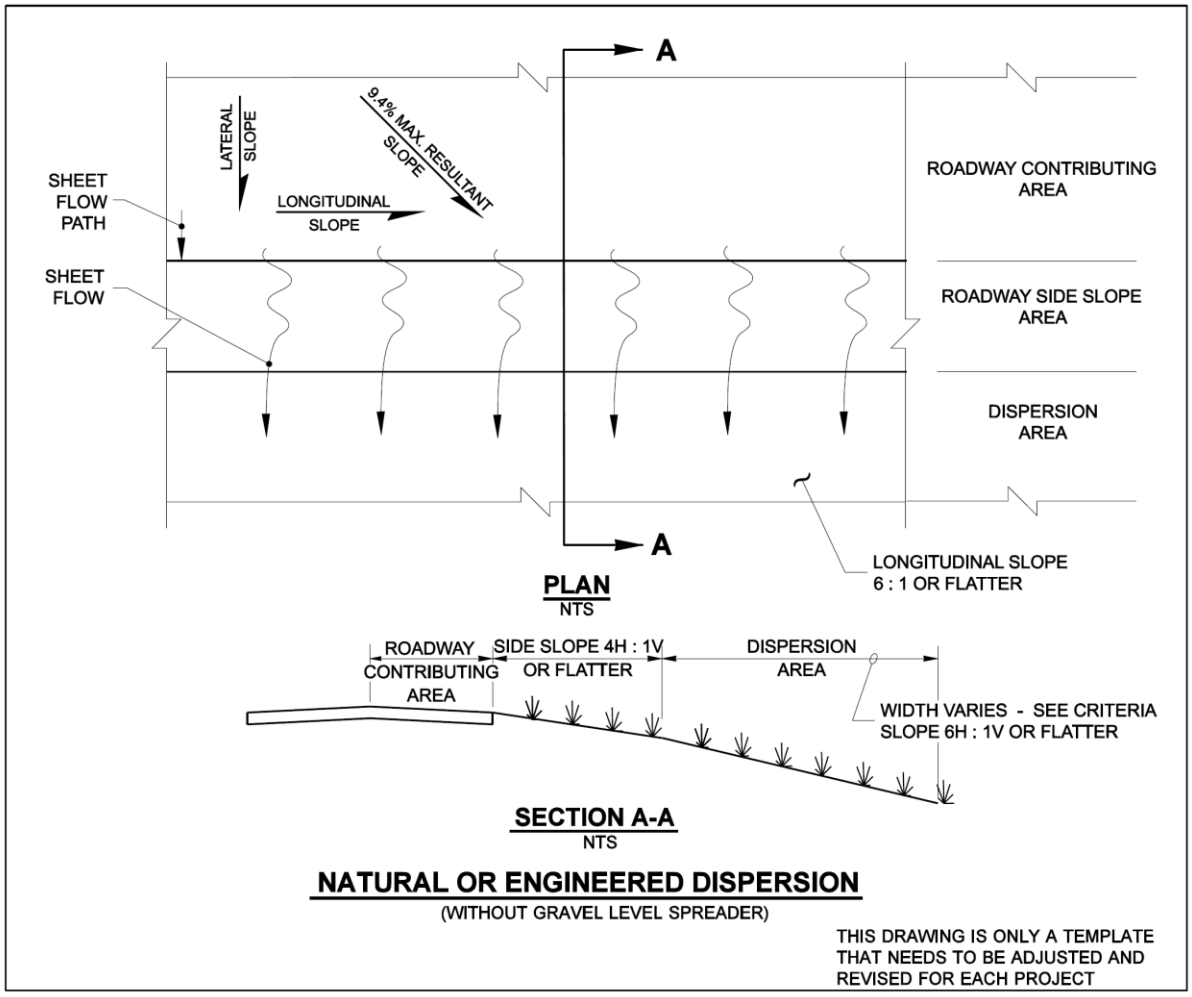



**Figure FC.01.1a Natural or engineered dispersion without a gravel level spreader.**

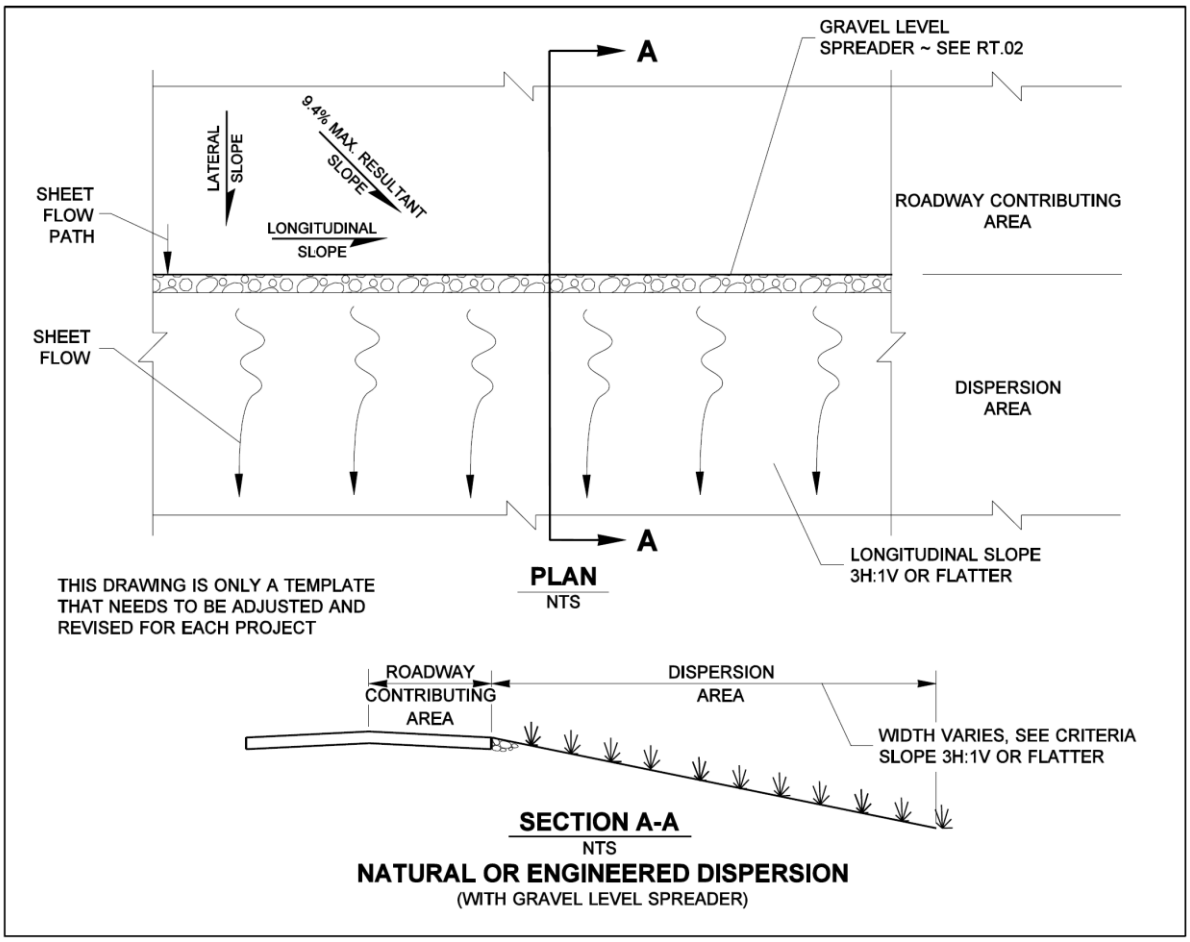



**Figure FC.01.1b Natural or engineered dispersion with a gravel level spreader.**

- 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 steep slopes (slopes steeper than 40% within a vertical elevation change of at least 10 feet), wetlands, and streams.

- Where the local jurisdiction 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 that discharged on slopes 15% or less to all Type A and some Type B soils, depending on saturated hydraulic conductivity rates.

- For saturated hydraulic conductivity rates (as determined in Section 4-5.2) of 4 inches per hour or greater, the dispersion area should be at least 50% of the tributary drainage area.

The following criteria are specific to channelized flow dispersion that discharged on slopes 15% or less to all Type C and D soils and some Type B soils, depending on saturated hydraulic conductivity rates.

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

For slopes greater than 15%, the dispersion area should be multiplied by the slope factor in the table below.

| Embankment Slopes (%)[1] | Slope Factor |
|---|---|
| ≤15 | 1.00 |
| 20 | 1.09 |
| 25 | 1.17 |
| 30 | 1.23 |
| 33 | 1.27 |

[1]For eastern Washington, use 1.0 for all slopes.

Figure FC.02.1 illustrates the configuration of a typical channelized flow natural or engineered dispersion area relative to the roadway.

### *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 (such as gravel-filled trenches or level spreaders) and techniques, see Sections 5-4.3.4 and 5-4.3.5. (See the *Hydraulics Manual* for energy dissipater designs and considerations.)

## Structural Design Considerations

### *Geometry*

Natural dispersion areas should have the following attributes:

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

- Have an average lateral slope of 6H:1V or flatter for both the roadway side slope and natural area to be part of the natural dispersion area, except where a level spreader is located immediately upstream of the dispersion area. Then the average slope shall not exceed 3H:1V.
- Have infiltrative soil properties that are verified by the WSDOT Materials Lab, the Regional Materials Engineer, or a geotechnical engineer.

Natural dispersion areas that have impervious areas (for example, abandoned roads with compacted subgrades) within them should have those areas tilled and restored using the soil amendments described in Section 5-4.3.2.

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

Natural dispersion areas should have a separation of at least 3 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 flow paths through the dispersion area.

When selecting natural dispersion areas, the designer should 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. These areas typically restrict stormwater infiltration; however, the local jurisdiction may waive this requirement. Designers should contact Region Hydraulics Office personnel for assistance in these situations.

The WSDOT GIS Workbench (an ArcView geographic information system tool maintained by the HQ Geographic Services Division and the HQ Office of Information Technology to provide staff with access to comprehensive, current, and detailed environmental and natural resource management data) may be a source of initial information about wells within the project limits.

*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.*

### *Setback Requirements*

- Natural dispersion areas can extend beyond WSDOT right of way provided that documentation on right of way plans ensures (via easements or agreements) the dispersion area is not developed in the future.

- Natural dispersion areas should be set back at least 100 feet from drinking water wells, septic tanks or drain fields, 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 must comply with the Washington State Department of Health (DOH) requirements (Washington Wellhead Protection Program, DOH, 12/93).
- The designer should check with the local jurisdiction for additional setback requirements.
- If the project significantly increases flows to off-site properties, a drainage easement may be required or additional right of way may be purchased.

### *Signage*

- The limits of the natural dispersion area should be marked as a stormwater management facility on WSDOT right of way sheets and also should 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. (See Section 5-4.3.7 for signing requirements.)

### *Construction Considerations*

- For installation of dispersal BMPs and conveyance systems near dispersion areas, the area that needs to be cleared or grubbed should be minimized. Maintaining plant root systems is important for dispersion areas.
- The area around dispersion areas should not be compacted.
- To the maximum extent practicable, low-ground-pressure vehicles and equipment should be used during construction.

### *Maintenance Considerations*

- Maintenance pullout areas should be considered to promote successful maintenance practices at dispersion areas. Pullout areas should be large enough to accommodate a typical maintenance vehicle. Please contact the local maintenance office to determine the typical size of maintenance vehicle used at the project site.
- General maintenance criteria should follow Table 5.5.7 (energy dissipaters).

## *FC.02 – Engineered Dispersion*

Engineered Dispersion Area Along I-5

**Description:** Existing soils, vegetation, and topography are used to provide flow control and runoff treatment. Runoff enters the dispersion area as sheet flow and disperses into the surrounding landscape. It requires little or no construction activity.

**Geometry Limitations**

| | |
|---|---|
| Resultant Slope | ≤ 9.4% |
| Contributing Flow Path | ≤ 150' |
| Embankment Slope | 2% - 33%[2] |

2. Up to 33% with a gravel spreader or 15% without.

**BMP Function**

- ☑ Flow Control
- ☑ Runoff Treatment
  - ☑ Oil Control
  - ☑ Phosphorus
  - ☑ TSS - Basic
  - ☑ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 50-100

| Capital Cost | O & M Cost |
|---|---|
| ➲ Low | ➲ Low |

**Additional Constraints/Requirements**

| | |
|---|---|
| ☑ 4-5 Infiltration Design Criteria | ☑ Soil Amendments/Compost |
| ☑ Setback | ☑ Energy Dissipater/Level Spreader |
| ☑ Landscaping/Planting | ☐ 5-4.3.3 Facility Liners |
| ☐ Wetland Planting and Plant Establishment | ☑ 5-4.3.7 Signing |
| ☐ Inlet and Outlet Spacing | ☐ Fencing |
| ☐ Overflow | ☐ Presettling/Pretreatment |
| ☐ Multidisciplinary Team | ☐ Underdrain |
| ☐ WSDOT Pavement Engineer Approval | ☐ Soil Preparation |

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☑ | Fecal Coliform |
| ☐ | ☑ | Phosphorus |
| ☐ | ☑ | Nitrogen |
| ☐ | ☑ | Temperature |
| ☐ | ☑ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☑ | Dissolved Oxygen |
| ☐ | ☑ | pH |
| ☐ | ☑ | Oil/Grease |
| ☐ | ☑ | PAHs |
| ☐ | ☑ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☐ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. See Maintenance Considerations in Section RT.02 for Vegetative Filter Strips. Also, see Table 5.5.12.

## Introduction

### *General Description*

*Engineered dispersion* is similar to natural dispersion. This BMP can be used for impervious or pervious 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. This differs from natural dispersion in that flows may not have previously (preproject) been directed to the selected engineered dispersion area. 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 any surface runoff will reach a flowing body of water.

### *Applications and Limitations*

Applications and limitations are the same as described in Natural Dispersion and also include the following:

- Engineered dispersion areas may cost as much as other BMPs (ponds or vaults) because compost-amended soils may need to be added.

## Design Flow Elements

### *Flows to Be Dispersed*

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 yet been developed for designing engineered dispersion areas, a set of conservative guidelines similar to those given for natural dispersion have been agreed upon by WSDOT and Ecology. Designers should check with Region or HQ Hydraulics Office staff for updates to the engineered dispersion criteria.

## Structural Design Considerations

### *Geometry*

- The average longitudinal slope of the dispersion area should not exceed 6H:1V.
- The average lateral slope of the dispersion area should not exceed 6H:1V, except where a level spreader is located immediately upstream of the dispersion area. Then the average slope shall not exceed 3H:1V.
- There should be no discernible flow paths through the dispersion area.
- There should be no surface water discharge from the dispersion area to a conveyance system or Category I and II wetlands (as defined by Ecology's Wetland Rating Systems for western and eastern Washington).

### *Materials*

- Compost-amended soils should be generously applied to the dispersion areas. The final organic content of the soil in the dispersion areas should be 10%. Design information for determining the amount and type of compost needed and the necessary planted vegetation to meet those requirements is given in Section 5-4.3.2.

## Site Design Elements

### *Siting Criteria*

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

- WSDOT rights of way
- Protected beautification areas
- Agricultural areas
- State parks
- Commercial or government-owned forestlands
- Rural areas with zoned densities of less than one dwelling unit per 5 acres

Engineered dispersion areas should have infiltrative soil properties that are verified by the WSDOT Materials Lab or a geotechnical engineer using the testing methods in Chapter 4.

Engineered dispersion areas that have impervious areas (such as abandoned roads with compacted subgrades) within them should have those areas tilled and reverted using the soil amendments described in Section 5-4.3.2.

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% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by the local jurisdiction.

Engineered dispersion areas should have a separation of at least 3 feet between the existing ground elevation and the average annual maximum groundwater elevation.

When selecting engineered dispersion areas, the designer should 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. These areas typically restrict stormwater infiltration; however, the local jurisdiction may waive this requirement. The WSDOT GIS Workbench may be a source of initial information about wells within the project limits.

### *Sizing Criteria*

Figure FC.02.1 illustrates a typical engineered dispersion area relative to the adjacent roadway.

*Sheet Flow*

Sheet flow dispersion criteria for Type A, B, C, and D soils are the same as described for Natural Dispersion, with the following exceptions:

- Where gravel level spreaders are not located between the highway and the dispersion area, as shown in Figure FC.01.1a, roadway side slopes leading to engineered dispersion areas should be 25% (4H:1V) or flatter. Roadway side slopes that are 25% to 15% (7H:1V) should not be considered part of the dispersion area. Roadway slopes steeper than 25% 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% 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). Roadway side slopes up to 33% or flatter are considered part of the dispersion area if a gravel level spreader is located between the highway and the dispersion area, as shown in Figure FC.01.1b.[13] The use of natural and engineered dispersion concepts within one threshold discharge area is acceptable.

[13] "Eastern Washington Steep Slope Research for Management of Highway Stormwater," WARD 77.1, Research Report, May 2011.

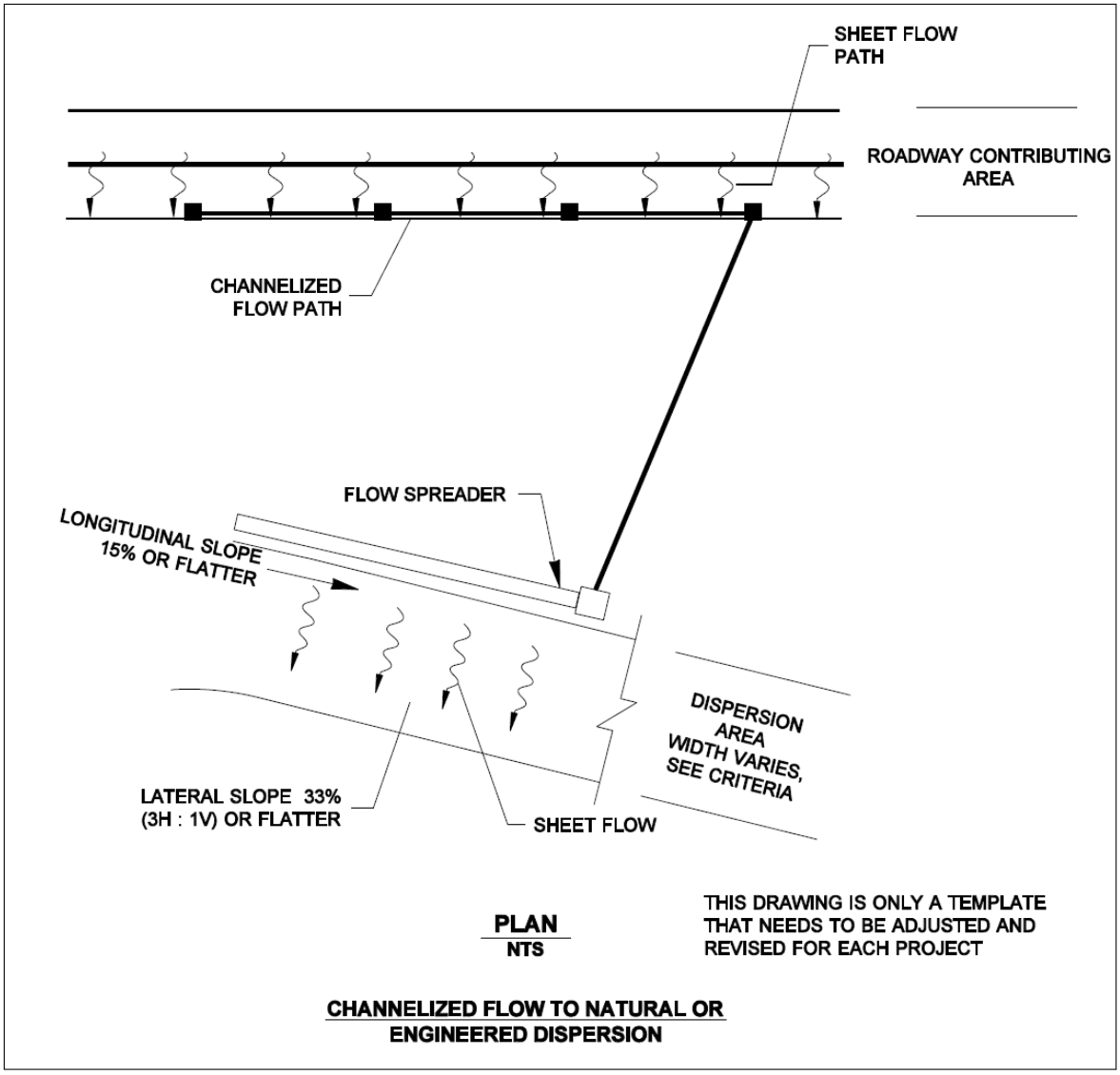



**Figure FC.02.1 Channelized flow to natural or engineered dispersion area.**

*Channelized Flow*

Channelized flow dispersion criteria for Type A, B, C, and D soils are the same as described for natural dispersion, with the following exceptions:

The following criterion is specific to channelized flow engineered dispersion on all Type A and some Type B soils on slopes 15% or less, depending on saturated hydraulic conductivity rates:

- For saturated hydraulic conductivity rates (as determined in Section 4-5.2) 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 should be provided.

The following criteria are specific to channelized flow dispersion on Type C and D soils and some Type B soils on slopes 15% or less, depending on saturated hydraulic conductivity rates:

- For every 1 foot of contributing pavement width, a dispersion area width of 6.5 feet is needed
- The dispersion area should have a minimum width of 100 feet, measured in the direction of the flow path
- Figure FC.02.1 illustrates the configuration of typical channelized flow for natural or engineered dispersion areas relative to the roadway.

For slopes greater than 15%, the dispersion area should be multiplied by the slope factor in the table below.

| Embankment Slopes (%)[1] | Slope Factor |
|---|---|
| ≤15 | 1.00 |
| 20 | 1.09 |
| 25 | 1.17 |
| 30 | 1.23 |
| 33 | 1.27 |

[1]For eastern Washington, use 1.0 for all slopes.

***Pipe or Ditch Conveyance System***

Pipe or ditch conveyance systems are the same as described for Natural Dispersion.

***Setback Requirements***

Setback requirements are the same as described for Natural Dispersion.

***Signage***

Refer to Section 5-4.3.7 for signing requirements.

***Construction Considerations***

Construction considerations are the same as described for Natural Dispersion.

***Maintenance Considerations***

Maintenance considerations are the same as described for Natural Dispersion and include the following:

- Maintenance pullout areas should be considered to promote successful maintenance practices of dispersion areas. Pullout areas should be large enough to accommodate a typical maintenance vehicle. Please contact the local maintenance office to determine the typical size of maintenance vehicle used at the project site.
- General maintenance criteria should follow Table 5.5.7 (energy dissipaters) and Table 5.5.9 (vegetated filter strips).

## 5-4.2.3 Detention BMPs

### *FC.03 – Detention Pond*

SR 405 at Coal Creek – South Bellevue/Factoria Detention Pond

**Description:** Open basins that provide live storage to enable the reduction of stormwater runoff flow rates and matching predeveloped flow durations discharge.

**Geometry Limitations**

| | |
|---|---|
| Freeboard | 1' |
| Pond Bottom | Level |
| Interior Side Slope | 3H:1V |
| Exterior Side Slope | 2H:1V |

**BMP Function**

- ☑ Flow Control
- ☐ Runoff Treatment
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☐ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 20-50

| Capital Cost | O & M Cost |
|---|---|
| ➲ Moderate | ➲ Low |

**Additional Constraints/Requirements**

| | |
|---|---|
| ☑ 4-5 Infiltration Design Criteria | ☐ Soil Amendments/Compost |
| ☑ Setback | ☐ Energy Dissipater/Level Spreader |
| ☑ Landscaping/Planting | ☑ 5-4.3.3 Facility Liners |
| ☐ Wetland Planting and Plant Establishment | ☑ 5-4.3.7 Signing |
| ☐ Inlet and Outlet Spacing | ☑ Fencing |
| ☑ Overflow | ☐ Presettling/Pretreatment |
| ☐ Multidisciplinary Team | ☐ Underdrain |
| ☐ WSDOT Pavement Engineer Approval | ☐ Soil Preparation |

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☑ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☑ | ☐ | Temperature |
| ☐ | ☐ | Dissolved Metals |
| ☐ | ☐ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☑ Vactor Truck Access
- ☐ Mowing
- ☑ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Also, see Table 5.5.1.

## Introduction

### *General Description*

*Detention ponds* are open basins that provide live storage volume to enable reduction of stormwater runoff flow rates and matching of predeveloped flow durations discharged from a project site (see Figures FC.03.1, FC.03.2, and FC.03.3). Detention ponds are commonly used for flow control in locations where space is available for an aboveground stormwater facility but where infiltration of runoff is infeasible. Detention ponds are designed to drain completely after a storm event so that the live storage volume is available for the next event.

### *Applications and Limitations*

Infiltration of runoff is the preferred method of flow control following appropriate runoff treatment. However, in areas where infiltration is not feasible, runoff detention must be implemented.

Detention ponds are designed to drain completely between storm events. They can be combined with wet pool runoff treatment BMPs to make more effective use of available land area (see BMP CO.01, Combined Wet/Detention Pond, and BMP CO.02, Combined Stormwater Treatment Wetland/Detention Pond).

## Design Flow Elements

### *Flows to Be Detained*

The volume and outflow design for detention ponds with a minimum 1-foot freeboard above the design water surface elevation must be determined in accordance with the flow control criteria presented in Section 3-3.6 under Minimum Requirement 6 (Flow Control). The design water surface elevation is the highest water surface elevation that is projected in order to satisfy the flow control requirements listed in Table 3-6 for western Washington and Table 3-7 for eastern Washington. Hydrologic analysis and design methods are presented in Sections 4-3.6.1 for western Washington and 4-4.5 for eastern Washington. Designers should read these sections for guidelines on how to incorporate the detention pond water surface into the flow control modeling.

Note: If the inlet pipe is submerged below the design water surface elevation, the designer shall then compute the hydraulic grade line (HGL) of the inlet pipe to verify that backwater conditions are acceptable. (See the *Hydraulics Manual* for computing an HGL.)

*Detention Ponds in Infiltrative Soils*

Detention ponds may occasionally be sited on soils that are sufficiently permeable for a properly functioning infiltration system. These detention ponds have both a surface discharge and a subsurface discharge. If infiltration is accounted for in the detention pond sizing calculations, the pond design process and corresponding site conditions must meet all the requirements for infiltration ponds (see BMP IN.02), including a soils report, soil infiltration testing, groundwater protection, presettling, and construction techniques.

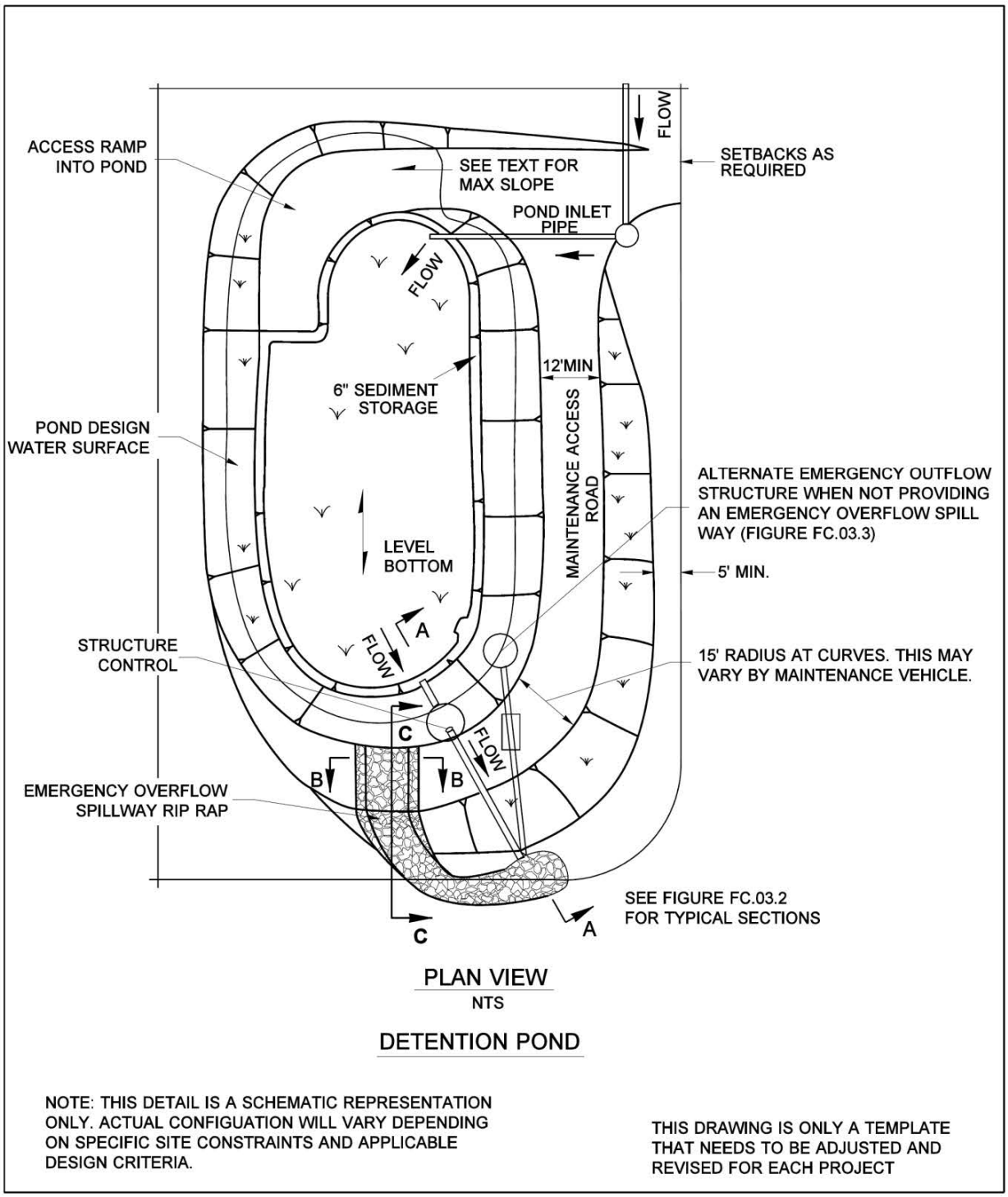



**Figure FC.03.1 Detention pond.**

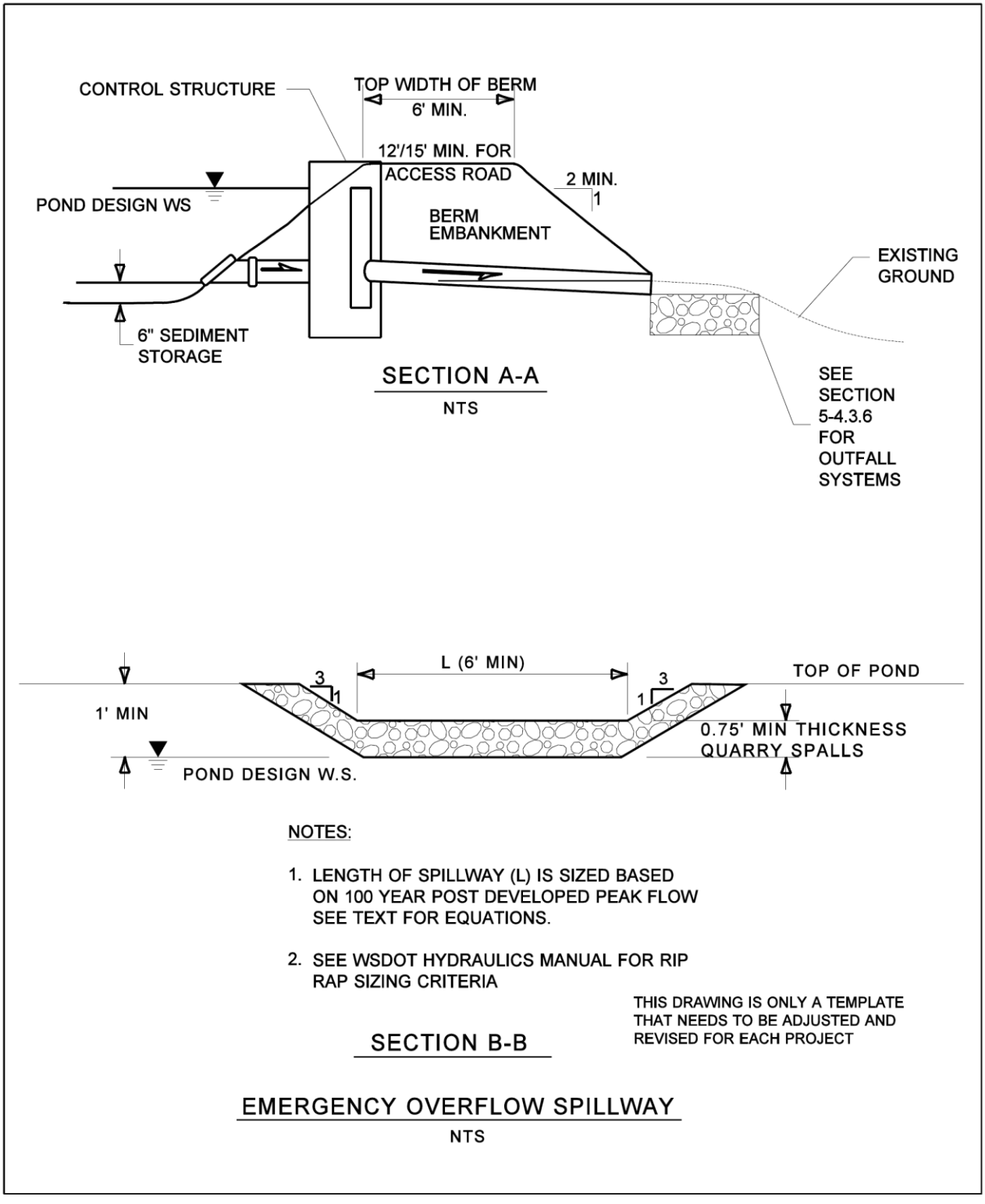



**Figure FC.03.2 Detention pond: Cross sections.**

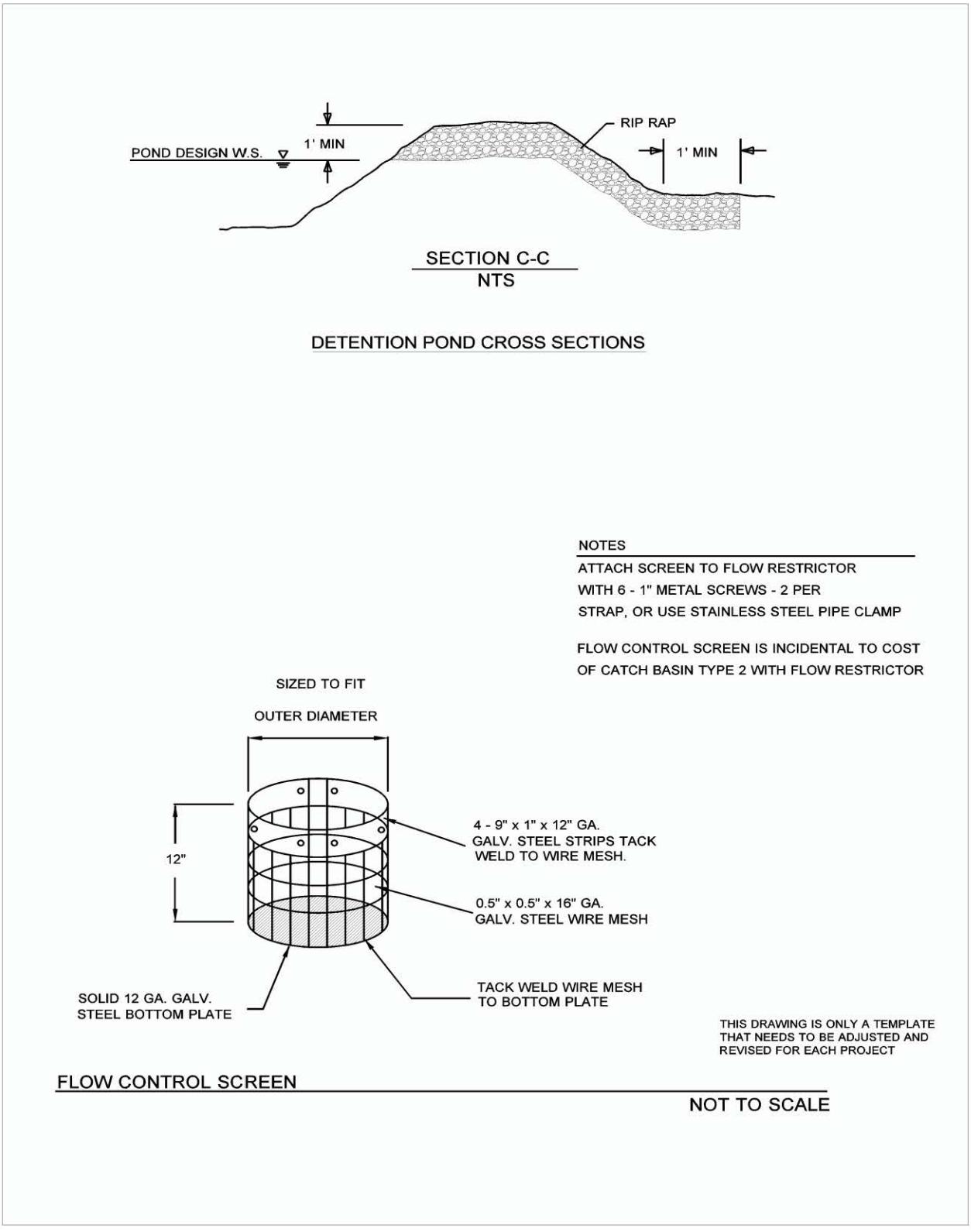



**Figure FC.03.3 Detention pond: Cross sections.**

### *Overflow or Bypass*

A primary overflow (usually a riser pipe within the outlet control structure) must be provided for the detention pond system to bypass the 100-year postdeveloped peak flow over or around the flow restrictor system. Overflow can occur when the facility is full of water due to plugging of the outlet control structure or high inflows; the primary overflow is intended to protect against breaching of the pond embankment (or overflows of the upstream conveyance system). The design must provide controlled discharge of pond overflows directly into the downstream conveyance system or another acceptable discharge point.

A secondary inlet to the pond discharge control structure can be provided as additional protection against overflows should the designer determine that the primary inlet pipe to the control structure would likely become plugged. In these situations, the designer should first consult with the area maintenance office to decide whether a secondary inlet to the control structure would be appropriate. One option for the secondary inlet is a grated opening (called a jailhouse window) in the control structure that functions as a weir when used as a secondary inlet. Contact the Region Hydraulics Office staff for the specific structural design modification requirements on this design option.

Another common option for a secondary inlet is to allow flow to spill into the top of the discharge control structure, or another structure linked to the discharge control structure, that is fitted with a debris cage (called a birdcage; see Figure FC.03.4). Other options can be used for secondary inlets, subject to assurance that they would not be plugged by the same mechanism that plugged the primary inlet pipe. The maximum circumferential length of a jailhouse window weir opening must not exceed one-half the control structure circumference.

### *Outlet Control Structure*

Control structures are catch basins or manholes with a restrictor device for controlling outflow from a facility to meet the desired performance. Riser-type restrictor devices (tees or FROP-Ts) also provide some incidental oil/water separation to temporarily detain oil or other floatable pollutants in runoff due to accidental spill or illegal dumping.

The restrictor device usually consists of two or more orifices or an orifice/weir section sized to meet performance requirements.

Standard control structure details are shown in the *Standard Plans*.

#### *Multiple Orifice Restrictor*

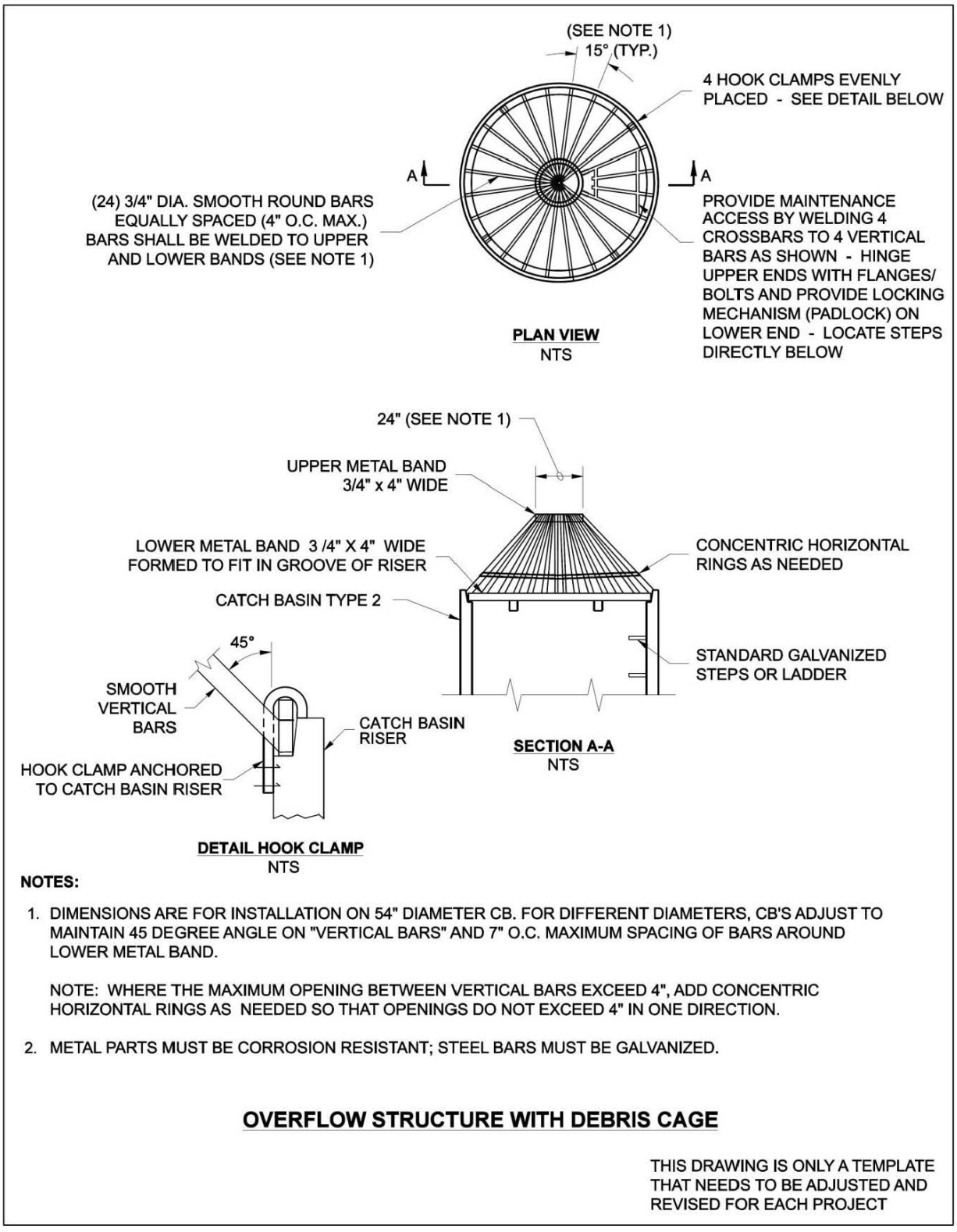
In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser (although additional orifices may optimize the detention storage volume). Several orifices may be located at the same elevation if necessary to meet performance requirements.

- The minimum circular orifice diameter is 0.5 inches. For orifices that have a diameter of less than 1 inch, the designer should consider using a flow screen that fits over the orifice to help prevent plugging. (See Figure FC.03.3 for more details on orifice screens.)

- The minimum vertical rectangular orifice length is 0.25 inches.
- Orifices may be constructed on a tee section as shown in the *Standard Plans*.
- In some cases, performance requirements may require the top orifice or elbow to be located too high on the riser to be physically constructed (for example, a 13-inch-diameter orifice cannot be positioned 6 inches from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements.
- 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. If these conditions are present, see Section 8.4 of the *MGSFlood Users Manual* for further design guidelines.

*Riser and Weir Restrictor*

- Properly designed weirs may be used as flow restrictors. 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.
- For different orifice, weir, and riser configurations and design equations and assumptions, see the MGSFlood or Western Washington Highways Hydrology Analysis Model (WHAM) training manuals:
  www.wsdot.wa.gov/design/hydraulics




**NOTES:**

1. DIMENSIONS ARE FOR INSTALLATION ON 54" DIAMETER CB. FOR DIFFERENT DIAMETERS, CB'S ADJUST TO MAINTAIN 45 DEGREE ANGLE ON "VERTICAL BARS" AND 7" O.C. MAXIMUM SPACING OF BARS AROUND LOWER METAL BAND.

   NOTE: WHERE THE MAXIMUM OPENING BETWEEN VERTICAL BARS EXCEED 4", ADD CONCENTRIC HORIZONTAL RINGS AS NEEDED SO THAT OPENINGS DO NOT EXCEED 4" IN ONE DIRECTION.

2. METAL PARTS MUST BE CORROSION RESISTANT; STEEL BARS MUST BE GALVANIZED.

**OVERFLOW STRUCTURE WITH DEBRIS CAGE**

THIS DRAWING IS ONLY A TEMPLATE THAT NEEDS TO BE ADJUSTED AND REVISED FOR EACH PROJECT

**Figure FC.03.4 Overflow structure with debris cage.**

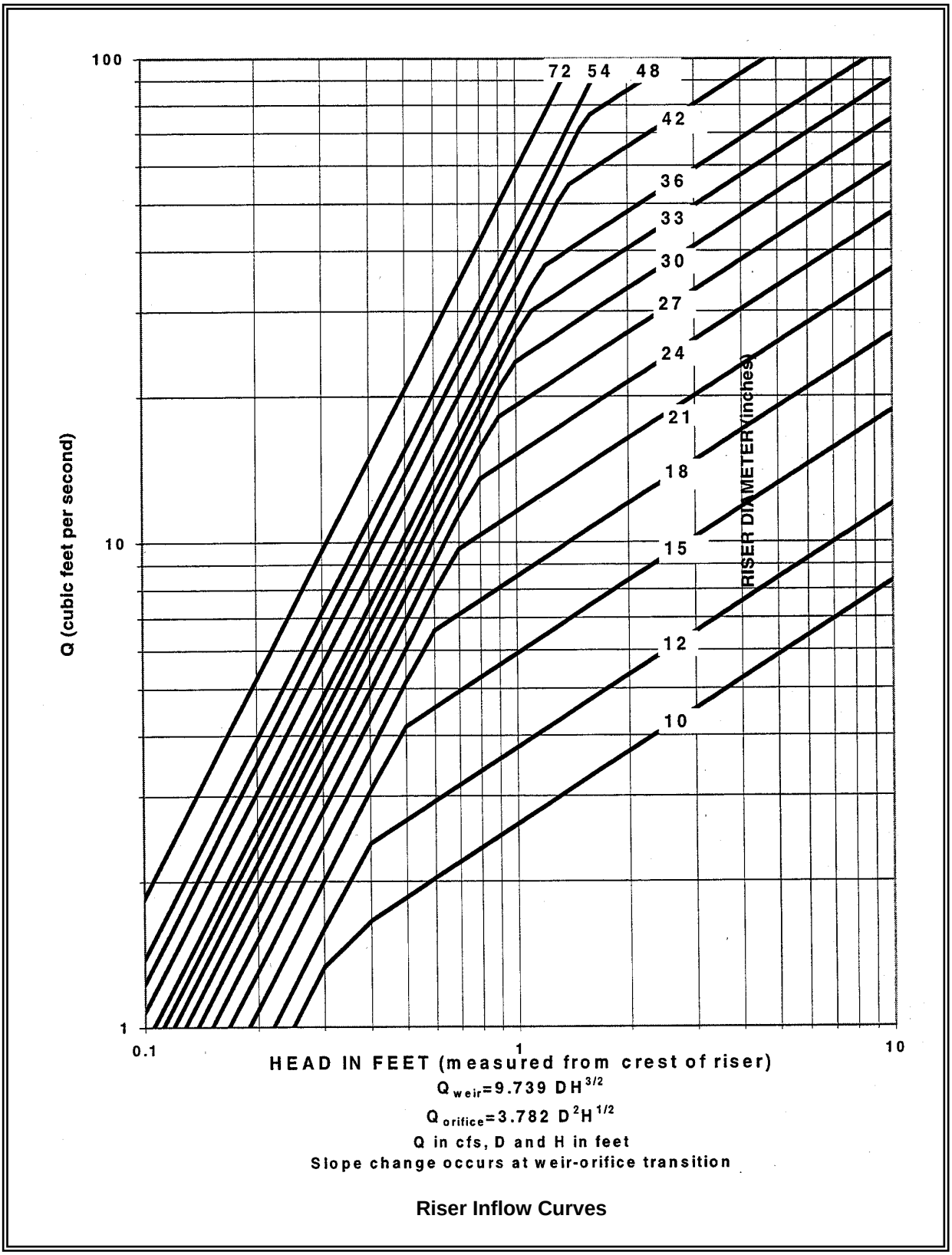



**Figure FC.03.5 Overflow structure sizing.**

### *Emergency Overflow Spillway*

In addition to the overflow provisions described above, detention ponds must have an emergency overflow spillway. For impoundments of 10 acre-feet or greater, the emergency overflow spillway must meet the state's dam safety requirements (see discussion on dam safety later in this section). For impoundments with less than 10 acre-feet of storage, ponds must have an emergency overflow spillway that is sized to pass the 100-year postdeveloped undetained peak flow in the event of total control structure failure (for example, blockage of the control structure outlet pipe) or extreme inflows. Emergency overflow spillways are intended to control the location where flows overtop the pond perimeter and direct overflows into the downstream conveyance system or other acceptable discharge point. The bottom of the emergency overflow spillway must be set at the design water surface elevation.

Emergency overflow spillways must be provided for ponds with constructed berms more than 2 feet high or for ponds located on grades more than 5%. As an option, emergency overflow may be provided by a Type II manhole fitted with a birdcage, as shown in Figure FC.03.4. The emergency overflow structure must be designed to pass the 100-year postdeveloped peak flow directly to the downstream conveyance system or to another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, consideration should be given to providing an emergency overflow structure *in addition to* the spillway.

The emergency overflow spillway must be armored with riprap that is sized in conformance with guidelines in the *Hydraulics Manual*. The spillway must be armored across its full width and also must be armored down the embankment, per Section C-C in Figure FC.03.3).

Emergency overflow spillway designs as shown in Figure FC.03.2 must be analyzed as broad-crested trapezoidal weirs using the following equation:

$$Q_{100} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}\,(\mathrm{Tan}\,\theta)\,H^{5/2}\right] \qquad \textbf{(FC.03-11)}$$

where:

$Q_{100}$ = peak flow for the 100-year runoff event (cfs)
C = discharge coefficient (0.6)
g = gravity (32.2 ft/sec$^2$)
L = length of weir (ft)
H = height of water over weir (ft)
$\theta$ = angle of side slopes

Assuming C = 0.6 and Tan $\theta$ = 3 (for 3H:1V slopes), the equation becomes:

$$Q_{100} = 3.21[LH^{3/2} + 2.4\,H^{5/2}] \qquad \textbf{(FC.03-12)}$$

To find the width *L* for the weir section, the equation is rearranged to use the computed $Q_{l00}$ and trial values of H (0.2 feet minimum):

$$L = [Q_{l00}/(3.21H^{3/2})] - 2.4\ H \text{ or } 6 \text{ feet minimum} \quad \textbf{(FC.03-13)}$$

Emergency overflow spillway designs using a Type II manhole fitted with a birdcage, as shown in Figure FC.03.4, must be analyzed using Figure FC.03.5 to pass the 100-year postdeveloped undetained peak flow.

## Structural Design Considerations

### *Geometry*

Pond inflows must enter through a conveyance system separate from the outlet control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sediment trapping.

Pond bottoms must be level and a minimum of 0.5 feet below the outlet invert elevation to provide sediment storage.

### *Berms, Baffles, and Slopes*

- Interior side slopes up to the emergency overflow water surface should not be steeper than 3H**:**1V unless a fence is provided (see *Fencing* below).
- Exterior side slopes must not be steeper than 2H**:**1V unless analyzed for stability by a geotechnical engineer.
- Pond walls may be vertical retaining walls subject to the following:
  - They are constructed of minimum 3000-psi structural reinforced concrete.
  - All construction joints must be provided with water stops.
  - Cast-in-place wall sections must be designed as retaining walls. A licensed civil engineer with structural expertise must stamp structural designs for cast-in-place walls.
  - Walls must be placed on stable, well-consolidated native material with suitable bedding, per the *Standard Specifications*. Walls must not be placed in fill slopes unless the slopes have been analyzed in a geotechnical report for stability and constructibility.
  - A fence is provided along the top of the wall.
  - Although the entire pond perimeter may be retaining walls, it is recommended that at least 25% of the pond perimeter be a vegetated soil slope not steeper than 7H**:**1V. Steeper slopes are permitted; consult with the local maintenance office.
  - The designer discusses the design of the pond with the local maintenance office to determine whether there are maintenance access issues.
  - The design is stamped by a licensed civil engineer with structural expertise.

- Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone-type walls may be used if designed under the direction of a geotechnical engineer or a civil engineer with structural expertise. If the entire pond perimeter is to be retaining walls, ladders should be provided on the full height of the walls for safe access by maintenance staff.

### *Embankments*

- Pond berm embankments must be constructed in accordance with Section 2-03.3(14)C, Method C, of the *Standard Specifications*.
- For berm embankments 6 feet high or less, the minimum top width should be 6 feet or as recommended by a geotechnical engineer.
- Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer), and free of loose surface soil materials, roots, and other organic debris.
- Pond berm embankments greater than 4 feet high must be constructed by excavating a key trench equal to 50% of the berm embankment cross-sectional height and width unless specified otherwise by a geotechnical engineer.
- Antiseepage 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. Additional guidance on filter-drain diaphragms is given in Ecology's Dam Safety Guidelines, Part IV, Dam Construction and Design (Section 3.3B): http://www.ecy.wa.gov/biblio/9255d.html

*Dam Safety for Detention BMPs*

Stormwater detention facilities that can impound 10 acre-feet (435,600 cubic feet, or 3.26 million gallons) or more of runoff with the water level at the embankment crest are subject to state 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 embankment or other impoundment structure should breach and allow an uncontrolled release of the pond contents. Peak flows from impoundment failures are typically much larger than the 100-year flows, which these ponds are generally designed to accommodate.

Ecology's Dam Safety Office uses consequence-dependent design levels for critical project elements. There are eight design levels with storm recurrence intervals ranging from 1 in 500 years for Design Step 1, to 1 in 1,000,000 years for Design Step 8. The specific design step for a particular project depends on the downstream population and other resources that would be at risk from a failure of the impoundment. Precipitation events more extreme than the 100-year event may be rare at any one location, but have historically occurred somewhere within Washington State every few years (on average).

With regard to the engineering design of stormwater detention facilities, the primary effect of the state's dam safety requirements is in sizing the emergency spillway to accommodate the runoff from the dam safety design storm without overtopping the impoundment structure (typically a berm or other embankment). The hydrologic computation procedures are the same as those for the original pond design, except that the computations must use more

extreme precipitation values and the appropriate dam safety design storm hyetographs. This information is described in detail within guidance documents developed by and available from the Dam Safety Office (contact information is provided below). In addition to the other design requirements for stormwater detention BMPs described elsewhere in this manual, dam safety requirements should be an integral part of planning and design for stormwater detention ponds. It is most cost effective to consider these requirements at the beginning of the project.

In addition to the hydrologic and hydraulic issues related to precipitation and runoff, other dam safety requirements relate to geotechnical issues; construction inspection and documentation; dam breach analysis; inundation mapping; emergency action planning; and periodic inspections by project owners and by engineers from the Dam Safety Office. All of these requirements, plus procedural requirements for plan review, approval, and payment of construction permit fees are described in detail in guidance documents developed by and available from the Dam Safety Office.

In addition to the written guidance documents, engineers from the Dam Safety Office are available to provide technical assistance to project owners and design engineers in understanding and addressing the dam safety requirements for their specific project. In the interest of providing a smooth integration of dam safety requirements into the stormwater detention project and streamlining the Dam Safety Office engineering review and issuance of the construction permit, it is recommended and requested that the Dam Safety Office be contacted early in the project planning process. The Dam Safety Office is located in the Ecology Headquarters building in Lacey. Electronic versions of the guidance documents are available on Ecology's website: www.ecy.wa.gov/programs/wr/dams/dss.html

## Groundwater Issues

### *Identification and Avoidance*

Flow control BMPs must be constructed above the seasonal high groundwater table. Storage capacity and proper flow attenuation are compromised if groundwater levels are allowed to fluctuate above the limits of live storage. The project should locate flow control pond, vault, and tank locations within the TDA such that there is a separation between the local groundwater table elevation and the bottom of the proposed BMP. In some cases, this may require that a much shallower pond be constructed in order to function properly.

The groundwater table elevation in and around the flow control facility needs to be determined early in the project. This can be done by installing piezometers at the BMP location and taking water table readings over at least one wet season. The wet season is generally defined as October 1 through April 30. Where it has been determined that site conditions within the project limits are not conducive to constructing flow control facilities due to high groundwater levels, it may be necessary to evaluate potential project impacts and solutions using the EEF Checklist in Appendix 2A or by following the *demonstrative approach* discussed in Section 1-1.3. Designers should look for opportunities to provide flow control to an equivalent area in the project that discharges to the same sensitive area or receiving water body.

### *Seeps and Springs*

Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are storm-driven and should discontinue after a few weeks of dry weather. However, if the site exhibits other more continuous seeps and springs extending through longer dry periods, they are likely from a deeper groundwater source. When continuous flows are intercepted and directed through flow control facilities, adjustments to the facility design may have to be made to account for the additional base flow (unless already considered in the design).

## Site Design Elements

### *Setback Requirements*

Detention ponds must be a minimum of 5 feet from any property line or vegetative buffer. This distance may need to be increased based on the permit requirements of the local jurisdiction.

Detention ponds must be 100 feet from any septic tank or drain field (except wet vaults, which must be a minimum of 20 feet).

The designer should request from the WSDOT Materials Lab a geotechnical report for the project that evaluates any potential structural site instability due to extended subgrade saturation or head loading of the permeable layer, including the potential impacts to downgradient properties—especially on hills with known side-hill seeps. The report should address the adequacy of the proposed detention pond locations and recommend the necessary setbacks from any steep slopes and building foundations.

### *Landscaping (Planting Considerations)*

The project should revegetate the side slopes of the flow control pond to the maximum extent practicable. The minimum vegetation effort would be to hydroseed the pond's interior above the 100-year water surface elevation and the exterior side slopes before completion of the project.

### *Fencing*

Pond walls may be retaining walls as long as a fence is provided along the top of the wall and at least 25% of the pond perimeter will have a slope of 3H:1V or flatter. (See the *Design Manual* for additional fencing requirements.)

### *Signage*

Refer to Section 5-4.3.7 for signing requirements.

### *General Maintenance Requirements*

For general maintenance requirements, see Section 5-3.6.1.

# 5-4.3 Stormwater Facility Components

## 5-4.3.1 Pretreatment

### *RT.24 – Presettling/Sedimentation Basin*

Presettling/Sedimentation Basin along I-5 in Snohomish County

**Description:** Provides pretreatment of runoff to remove suspended solids that can impact primary runoff treatment BMPs.

**Geometry Limitations**

| | |
|---|---|
| Length to Width Ratio | 3:1 Max (5:1 Preferred) |
| Interior Embankment Slope | 3H:1V |
| Exterior Embankment Slope | 2H:1V |
| Min Depth | 4' |
| Max Depth | 6' |
| Bottom Slope | 2% |

**BMP Function**

- ☐ Flow Control
- ☑ Runoff Treatment*
  - ☐ Oil Control
  - ☐ Phosphorus
  - ☑ TSS - Basic
  - ☐ Dissolved Metals - Enhanced

**Effective Life (Years)**

➲ 5-10

| Capital Cost | O & M Cost |
|---|---|
| ➲ Low to Moderate | ➲ Moderate |

**Additional Constraints/Requirements**

- ☐ 4-5 Infiltration Design Criteria
- ☑ Setback
- ☐ Landscaping/Planting
- ☐ Wetland Planting and Plant Establishment
- ☐ Inlet and Outlet Spacing
- ☐ Overflow
- ☐ Multidisciplinary Team
- ☐ WSDOT Pavement Engineer Approval
- ☐ Soil Amendments/Compost
- ☐ Energy Dissipater/Level Spreader
- ☑ 5-4.3.3 Facility Liners
- ☑ 5-4.3.7 Signing
- ☑ Fencing
- ☐ Presettling/Pretreatment
- ☐ Underdrain
- ☐ Soil Preparation

**TMDL/303(d) – Considerations[1]**

| Avoid | Preferred | |
|---|---|---|
| ☐ | ☐ | Fecal Coliform |
| ☐ | ☐ | Phosphorus |
| ☐ | ☐ | Nitrogen |
| ☐ | ☐ | Temperature |
| ☐ | ☐ | Dissolved Metals |
| ☐ | ☑ | Total Suspended Solids/Turbidity |
| ☐ | ☐ | Dissolved Oxygen |
| ☐ | ☐ | pH |
| ☐ | ☐ | Oil/Grease |
| ☐ | ☐ | PAHs |
| ☐ | ☐ | Pesticides |

1. See Table 3-1 and Section 2-6.4 for additional guidance.

**Maintenance Requirements**

- ☑ Access Roads or Pullouts
- ☐ Vactor Truck Access
- ☐ Mowing
- ☐ Valve Access
- ☐ Specialized Equipment
- ☐ Specialized Training

**Further Requirements:** See Sections 5-3.6.1 and 5.5. Sediment removal every 3-5 years.

**Provides pretreatment only.*

## Introduction

### *General Description*

A *presettling basin* provides pretreatment of runoff to remove suspended solids that can impact other primary runoff treatment BMPs (see Figures RT.24.1 and RT.24.2).

### *Applications and Limitations*

The most attractive aspect of a presettling basin is its isolation from the rest of the facility. Presettling basins remove excess sediment loads from runoff when sediment falls out of suspension and settles. However, they do not detain water long enough for removal of most pollutants (such as some metals). Presettling basins are used as pretreatment for downstream infiltration facilities. Runoff treated by a presettling basin may not discharge directly to a receiving water body. Presettling/Sedimentation basins do not qualify as basic or enhanced runoff treatment.

## Design Flow Elements

### *Flows to Be Treated*

A presettling basin should be designed with a wet pool. The runoff treatment volume must be at least 30% of the total volume of runoff from the 6-month, 24-hour storm event.

### *Overflow or Bypass*

Presettling basin design must take into consideration the possibility of overflows. A designed overflow section should be constructed along the presettling basin embankment to allow flows to exit at a nonerosive velocity during the 6-month, 24-hour storm event. The overflow may be set at the permanent pool level. The use of an aquatic bench with emergent vegetation around the perimeter helps with water quality.

### *Inlet Structure*

The runoff treatment volume should be discharged uniformly and at low velocity into the presettling basin to maintain near-quiescent conditions, which are necessary for effective treatment. It is desirable for the heavier suspended material to drop out near the front of the basin. Energy-dissipation devices may be necessary to reduce inlet velocities that exceed 3 feet per second.

### *Outlet Control Structure*

The outlet structure conveys the runoff treatment volume from the presettling basin to the primary treatment BMP (for example, a wetland or sand filtration basin). The passive outlet control structure can be created as an earthen berm, gabion, concrete, or riprap wall along the separation embankment preceding the primary treatment BMP.

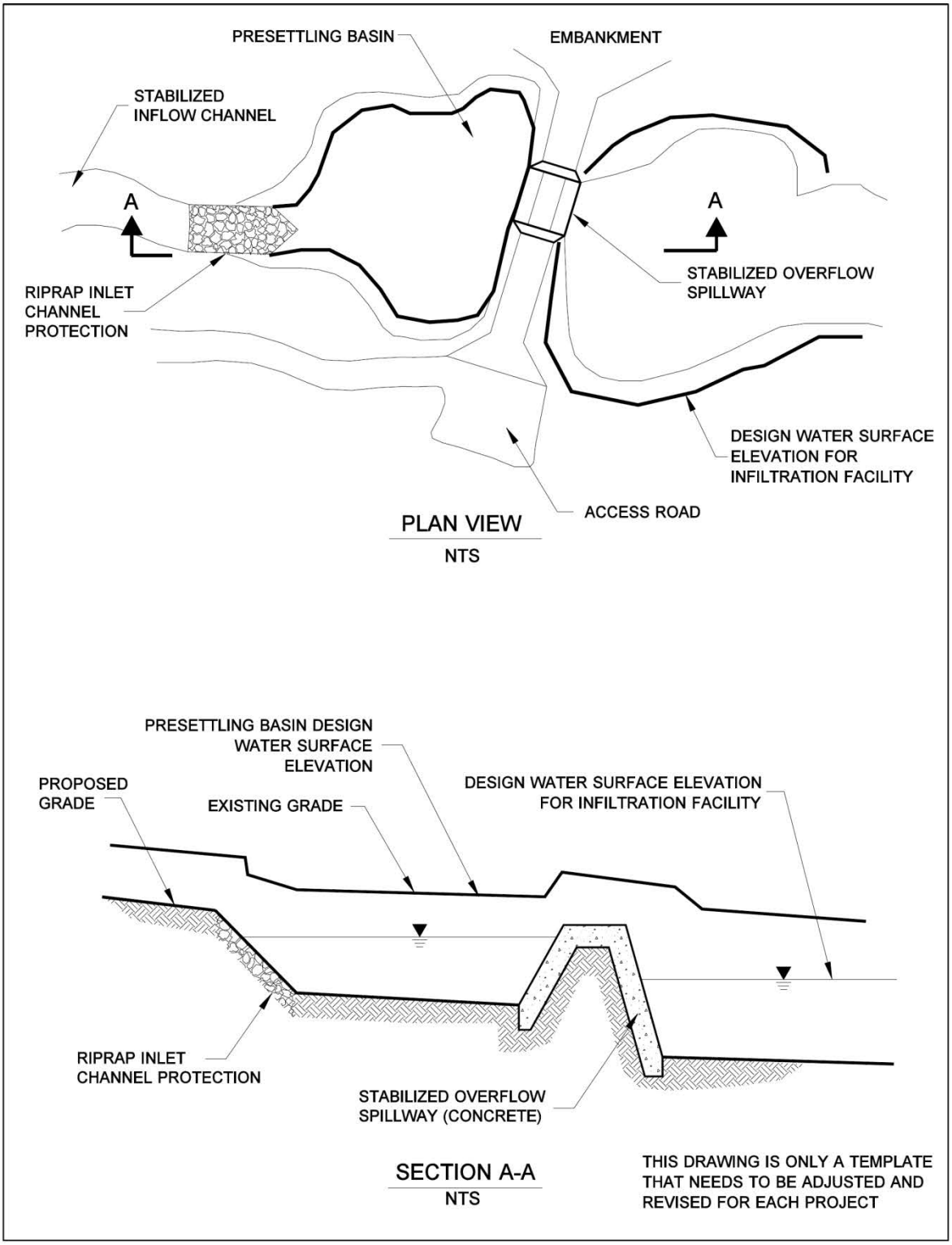



**Figure RT.24.1 Typical presettling/sedimentation basin.**

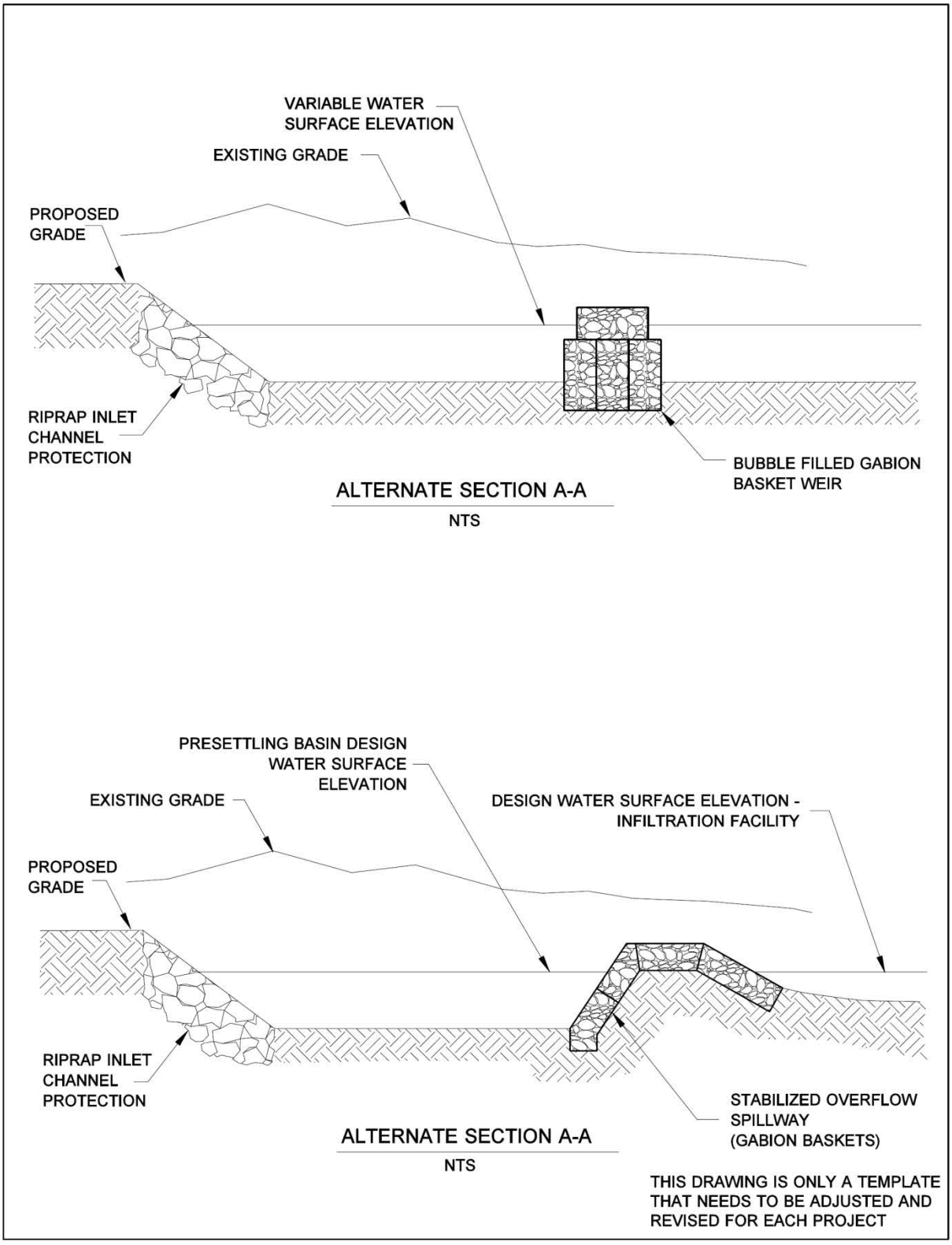



**Figure RT.24.2 Presettling/sedimentation basin: Alternate sections.**

## Structure Design Considerations

### *Geometry*

A long, narrow basin is preferred because it is less prone to short-circuiting and tends to maximize available treatment area. The length-to-width ratio should be at least 3**:**1 and preferably 5**:**1. The inlet and outlet should be at opposite ends of the basin, where feasible.

### *Materials*

Widely acceptable construction materials and specifications, such as those developed by the USDA National Resources Conservation Service (NRCS) or the U.S. Army Corps of Engineers for embankment ponds and reservoirs, may aid in building the impoundment.

### *Berms, Embankments, Baffles, and Slopes*

Berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report) free of loose surface soil materials, roots, and other organic debris.

The inlet and outlet should be at opposite ends of the basin where feasible. If this is not possible, then baffles can be installed to increase the flow path and water residence time.

Exposed earth on the side slopes and bottom should be sodded or seeded with the appropriate seed mixture as soon as is practicable. If necessary, geotextile or matting may be used to stabilize slopes until seeding or sodding become established.

If composed of a structural retaining wall, interior side slopes may be nearly vertical as long as maintenance access is provided. Otherwise, they should be no steeper than 3H**:**1V. Exterior embankment slopes should be 2H**:**1V or less. The bottom of the basin should have a 2% slope to allow complete drainage. The minimum depth must be 4 feet; the maximum depth must be 6 feet.

Embankments that impound water must comply with Washington dam safety regulations (WAC 173-175). If the impoundment has a storage capacity (including both water and sediment storage volumes) greater than 10 acre-feet (435,000 cubic feet, or 3.26 million gallons) above natural ground level, then a dam safety design and review are required.

### *Liners*

If the basin intercepts the seasonal high groundwater table, a liner is recommended. In these situations, a low-permeability liner or treatment liner must cover the bottom and side areas. (See liner criteria in Section 5-4.3.3 for further information.)

## Site Design Elements

### *Setback Requirements*

- Presettling basins must be a minimum of 5 feet from any property line or vegetative buffer. This distance may need to be increased based on the permit requirements of the local jurisdiction.

- Presettling basins must be 100 feet from any septic tank or drain field, except wet vaults, which must be a minimum of 20 feet.
- The designer should request from the WSDOT Materials Lab a geotechnical report for the project that evaluates any potential structural site instability due to extended subgrade saturation or head loading of the permeable layer, including the potential impacts to downgradient properties (especially on hills with known side-hill seeps). The report should address the adequacy of the proposed presettling basin locations and recommend the necessary setbacks from any steep slopes and building foundations.

#### *Safety, Signage, and Fencing*

Basins that are readily accessible to populated areas should incorporate all possible safety precautions. Dangerous outlet facilities should be protected by enclosure. Warning signs should be used wherever appropriate. Signs should be placed so that at least one is clearly visible and legible from all adjacent streets, sidewalks, or paths.

#### *Maintenance*

Failure of large impoundment structures can cause significant property damage and even loss of life. Impoundment structures should be regularly inspected for signs of failure, such as seepage or cracks in the walls or berm.

Presettling basins are less likely than wet ponds to build up excessive levels of heavy metals from sediments washed off impervious areas. Routine maintenance should remove and properly dispose of any significant sediment deposits. Sediment should be removed every three to five years or when 6 to 12 inches have accumulated, whichever comes first. More frequent removal of sediment from the presettling basin may be less costly over the same time period than a one-time cleaning of the entire basin. (See Section 5-5 for further criteria.)

## 5-4.3.2 Soil Amendments

### Introduction

#### *General Description*

Soil amendments, including compost and other organic materials, help restore the health of the soil and increase environmental functions such as rainwater infiltration and natural detention, evapotranspiration, and plant health. Soil amendments can help prevent or minimize adverse stormwater impacts during construction and are used along with vegetation as a permanent runoff treatment BMP. Compost is a versatile material that can be used as a component in many other permanent and temporary stormwater BMPs.

Compost-amended soils can be modeled as pasture on native soil. The final organic content of these soils should be 10% for all areas, excluding turf areas, which are expected to receive a high amount of foot traffic. Turf (lawn) areas with high foot traffic must have a 5% final organic content.

### *Applications and Limitations*

Soil amendments can be used in most unpaved areas within the project. If soil amendments are applied as a blanket, they perform erosion control functions immediately by providing a cover to bare soils. When incorporated into the soil, they increase infiltration and adsorption of metals and aid in the uptake of nutrients. They also enhance vegetation growth and plant establishment.

Compost provides an excellent growing medium for roadside vegetation. Traditional highway construction methods typically result in the excavation and removal of the area's topsoil. Roadway embankments are then constructed from material that has few nutrients, is low in organic material, and is compacted to 95% maximum density. Adding compost to roadway slopes and ditches provides soil cover, improves soil fertility and texture, and greatly improves the vegetative growth and soil stability (thereby reducing erosion).

Organic soil amendments soak up water like a sponge and store it until it can be slowly infiltrated into the ground or taken up by plants. (For instance, 4 inches of compost tilled into 8 inches of Alderwood series soil increased the water storage capacity by 100% [Harrison et al., 1997].) In some BMP applications, the volume of compost can be sized to absorb and hold the runoff treatment storm.

Compost is an excellent filtration medium, which provides treatment for highway runoff. Compost has a high cation exchange capacity (CEC) that chemically traps dissolved heavy metals and binds them to the compost material. Oils, grease, and floatables are also removed from stormwater as it is filtered through the compost.

Compost is very absorbent when dry, but when saturated it has a high infiltration rate. Therefore, greater storm events can pass through compost medium without hindering the infiltration rates of underlying soils or drain materials. Compost has also been shown to improve the infiltration rates of underlying soils, even till soils.

Placement of a compost blanket on bare soil helps stabilize the soil and prevent surface erosion by intercepting rainfall. This type of application changes the texture and workability of the soil, lengthens the acceptable seeding windows, and encourages plant growth.

Compost soil amendments can be used in the construction phase of projects as compost berms and compost socks in lieu of conventional geotextile silt fences for sediment control (see BMP 30, Filter Berm, in Appendix 6A). While being an effective sediment trap during the construction phase, compost berms are advantageous in that they can be bladed out at the construction site, which avoids bid items for the haul and disposal of silt fences. If the permanent stormwater design involves use of compost-amended vegetated filter strips, a batch of compost can be used as sediment control in a berm, then the berm can be bladed out along a highway roadside, where it can be used as part of vegetated filter strip construction. Compost socks can be left in place and will deteriorate with time. For information on compost sock use, limitations, and placement, contact the Region Hydraulics Office, the HQ Roadside and Site Development Section, or the HQ Environmental Services Office.

### *Maintenance*

Compost, as with sand filters or 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 frame has not yet been established.

## Structural Design Considerations

### *Materials*

Compost material must be aged and cured according to Section 9-14.4(8) of the *Standard Specifications*.

There are two types of compost specified in the *Standard Specifications*: fine and coarse. Fine compost is a finer and usually more mature form of compost. It is for general soil amendment use and should not be used for compost filter berms or socks. Coarse compost has been screened to remove most of the fines. To prevent failure due to clogging, this type of compost is specified for compost berms and socks. Both types of compost can be used as a soil amendment or blanket depending on the soil type and desired final outcome. Consult the Region or HQ Landscape Architect or the State Horticulturist for site-specific recommendations.

## Compost

Organic soil amendment, suitable for landscaping and stormwater management, should be a stable, **mature compost** derived from organic waste materials, including yard debris, manures, biosolids, wood wastes, or other organic materials that meet the intent of the organic soil amendment specification. **Compost stability** indicates the level of microbial activity in the compost and is measured by the amount of $CO_2$ produced over a given period of time by a sample in a closed container. Unstable compost can render nutrients temporarily unavailable and create objectionable odors.

Compost quality can be determined by examining the material and by qualitative tests. A simple way to judge compost quality is to smell and examine the finished product, which should have the following characteristics (WORC, 2003):

- Earthy smell that is not sour, sweet, nor ammonia-like
- Brown to black in color
- Mixed particle sizes
- Stable temperature and does not get hot when rewetted
- Crumbly texture

Qualitative tests and producer documentation should have the following specifications:

- Material must meet the definition for "composted materials" in WSDOT's *Standard Specifications*, Section 9-14, and WAC 173-350, Section 220, which is available online: www.ecy.wa.gov/programs/swfa/facilities/350.html
- Compost used in enhanced runoff treatment applications must not contain biosolids or any street or highway sweepings
- For further information, see the *Roadside Manual*, Chapter 700.

## Organic Matter Content of Soil Mixes

The minimum organic matter content may be achieved by amending soils using the preapproved *Presumptive Method* (as outlined below) or by amending soils using the *Custom Method*, where the designer would have to calculate a custom amendment rate for the existing site soil conditions. The Presumptive Method simplifies planning and implementation; however, the organic matter content of the disturbed on-site soils may be relatively good and not require as extensive an application of amendment material. In many cases, calculating a site-specific rate using the Custom Method may result in significant savings in amendment material and application costs.

Presumptive Method for Determining Soil Organic Content

Soil amendments can be used two ways: placed on top of the soil or incorporated into it. The intent of incorporation is to increase the organic content of the soil, replicating a forested soil condition. Figure 5.4.3.1 shows typical details for soil amendments used in woody planting areas and grass or CAVFS areas.

To encourage native woody plant species, the following *presumptive* technique can be employed:

- Incorporate 3 inches of coarse compost into the top 9 inches of soil
- Place 3 inches of bark or wood chip mulch on the surface
- Plant through the layers

To encourage grass or CAVFS, the following *presumptive* technique can be employed:

- Incorporate 3 inches of coarse compost into the top 9 inches of soil
- Establish vegetation on top of incorporated soil

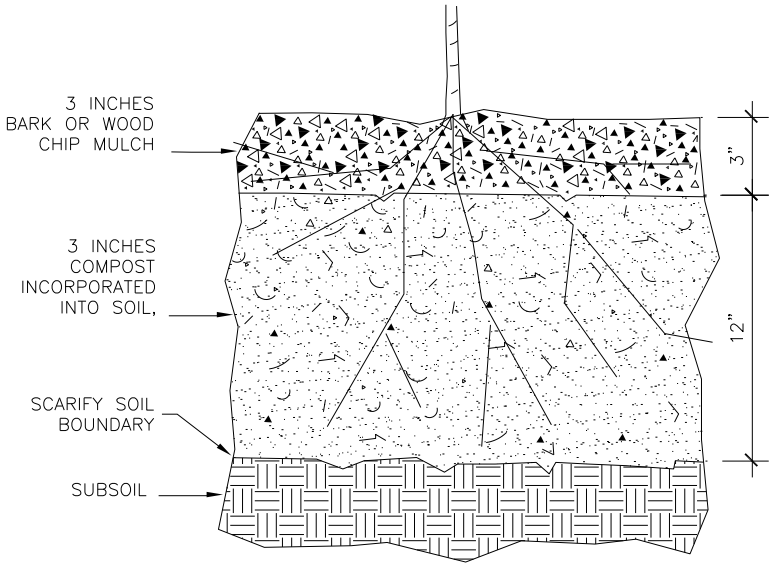



**Figure A – Amendments to encourage native woody plants.**

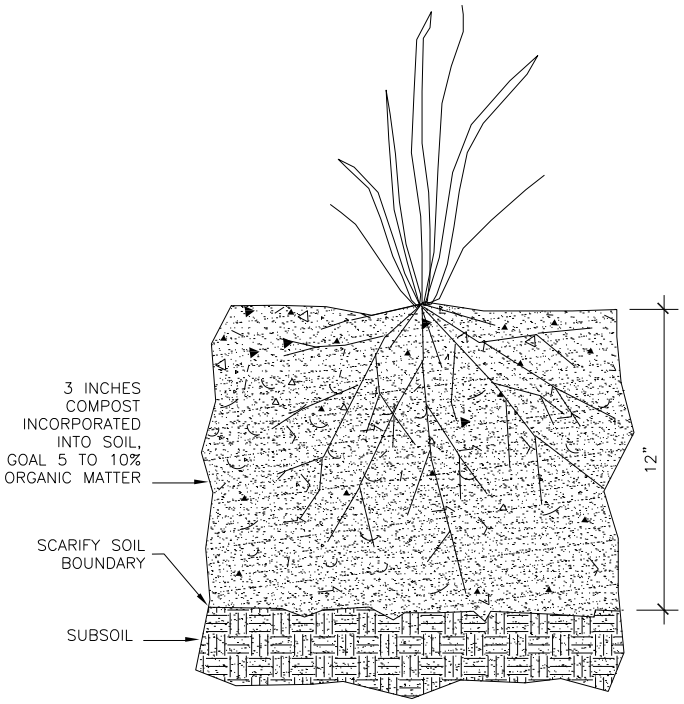



**Figure B – Amendments for grass or CAVFS areas.**

**Figure 5.4.3.1 Soil amendments for vegetation.**

The organic content of the soil should be 10% for areas planted with woody species and 5% for lawn areas after adding the amendments. (Note that WSDOT does not construct many lawn areas. Some projects in urban and semiurban areas may include lawn areas. Lawns are areas that will be mowed regularly and may contain irrigation. Roadside areas that are hydroseeded for erosion control are not considered lawn areas.) 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 presumptive technique described above and still be able to achieve the 10% organic content target. The State Horticulturist, located in the HQ Design Office, is available to determine the amount of organic material in the project soils and the amount of soil amendments needed to bring the organic matter to the percentages listed above.

The design of the final soil composition is critical to the success of the facility. Use the following guidelines to design the soil mix:

- The texture for the soil component of the LID BMP soil mix should be loamy sand (USDA Soil Textural Classification).
- The final soil mix (including compost and soil) should have a minimum long-term hydraulic conductivity of 1.0 inch/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 80% compaction per ASTM Designation D 1557 (Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort) (Tackett, 2004). Infiltration rate and hydraulic conductivity are assumed to be approximately the same in a uniform mix soil.
- The final soil mixture should have a minimum organic content of 10% 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). Currently, gravelly sand LID BMP soil mixtures are being developed and installed to provide adequate infiltration rates at 85% to 95% compaction. While designers anticipate good performance from this specification, the mix may be slightly less than optimal for plant growth and has not been tested long term for plant health performance.
- Achieving the above recommendations will depend on the specific soil and compost characteristics. In general, the recommendation can be achieved with 60% to 65% loamy sand mixed with 25% to 30% compost or 30% sandy loam, 30% coarse sand, and 30% compost.
- The final soil mixture should be tested by the WSDOT Materials Lab prior to installation for fertility, micronutrient analysis, and organic material content. Soil amendments per State Horticulturist recommendations (if any) should be uniformly incorporated for optimum plant establishment and early growth (Tackett, 2004).
- Clay content for the final soil mix should be less than 5%.
- Compost must not contain biosolids or any street or highway sweepings.

- 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).
- Soil depth should follow the design criteria in the *Roadside Manual* and provide acceptable minimum pollutant attenuation and good growing conditions for selected plants.
- 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.
- The above guidelines should provide a soil texture, an organic content, and an infiltration rate suitable to meet the SSC-7, Soil Physical and Chemical Suitability for Treatment (in Chapter 4), recommendations for designing infiltration systems. A soils report evaluating these parameters should be provided to verify the treatment capability of the soil mix.

Custom Method for Determining Soil Organic Content

Calculating a custom rate requires collecting soil samples from the area to be amended and samples from the compost material. The soil and compost are then tested for percent organic matter. Compost and topsoil producers can often supply the required information for the amendment material. A quick way to determine the approximate organic matter content of a soil mix would be to use the following rules of thumb:

- Compost is typically 40% to 50% organic matter (use 45% as an average)
- Compost weighs approximately 50% as much as loam
- A mix that is 40% compost measured by volume is roughly 20% organic matter by volume
- Compost is only 50% as dense as the soil, so the mix is approximately 10% organic matter by weight (the organic matter content in soil is determined by weighing the organic material before combustion and then weighing the ash post combustion)

Compost that is applied as a land cover must have a minimum blanket depth of 2 to 3 inches, depending on slope and soil types. Slopes steeper than 4H:1V should receive 3 inches of compost as a cover. Likewise, more erodible soils must be at the higher end of the compost application range.

Compost is not recommended for areas of concentrated flow. However, it can be used in swales or on the sides of ditches above the expected flow line.

For more information on soil amendments and applications, see Chapter 700 of the *Roadside Manual*.

### 5-4.3.3 Facility Liners

Liners are intended to reduce the likelihood of stormwater pollutants reaching groundwater beneath runoff treatment facilities. In addition to groundwater protection considerations, liners are sometimes used to hold water, such as for a permanent pool in a wet pond.

***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, but not as slow as low-permeability liners. Treatment liners may use 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. These types of liners are generally used for sites with a potential for high pollutant loading in the stormwater runoff or when it is necessary to maintain a constant pool of water for extended periods of time. For WSDOT, low-permeability liners consist of the geosynthetic clay liner (GCL), HDPE geomembrane liner, and PVC geomembrane liner.

#### General Design Criteria

Table 5.4.1 shows recommendations for the type of liner generally best suited for use with various runoff treatment facilities. The intent of this table is to ensure stormwater receives the required minimum amount of runoff treatment before being allowed to infiltrate in areas of relatively permeable soils.

Liners must be evenly placed over the bottom and/or sides of the treatment area of the facility, as indicated in Table 5.4.1. Areas above the treatment volume that are required to pass flows greater than the runoff 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.

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. A low-permeability liner must not be used in this situation unless 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 of compost tilled into 6 inches of native till soil) must be placed over the liner in the area to be planted; 12 inches of cover is preferred.

If a treatment liner is 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 groundwater level.

**Table 5.4.1. Lining types recommended for runoff treatment facilities.**

| Runoff Treatment Facility | Area to Be Lined | Type of Liner Recommended |
|---|---|---|
| RT.24 – Presettling Basin | Bottom and sides | Low-permeability liner or treatment liner; if the basin intercepts the seasonal high groundwater table, a treatment liner is recommended |
| RT.12 – Wet Pond, and CO.01 – Combined Wet/Detention Pond | First cell: bottom and sides to runoff treatment design water surface<br>Second cell: bottom and sides to runoff treatment design water surface | Low-permeability liner or treatment liner; if the facility intercepts the seasonal high groundwater table, a treatment liner is recommended<br>Treatment liner |
| RT.13 – Constructed Stormwater Treatment Wetland, and CO.02 – Combined Stormwater Treatment Wetland/Detention Pond | Bottom and sides: both cells | Low-permeability liner or treatment liner; if the facility intercepts the seasonal high groundwater table, a treatment liner is recommended |
| Treatment BMPs in underground structures | Not applicable | No liner needed |

## Design Criteria for Treatment Liners

The design criteria for treatment liners are as follows:

- A 2-foot-thick layer of soil with a minimum organic content of 5% and a minimum cation exchange capacity (CEC) of 5 milliequivalents per 100 grams can be used as a treatment layer beneath a runoff treatment or detention facility.
- To demonstrate that in-place soils meet the above criteria, one sample per 1000 square feet of facility area must be tested. Each sample must be a composite of subsamples taken throughout the depth of the treatment layer (usually 2 to 6 feet below the proposed facility invert).
- Typically, sidewall 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 sidewalls may be significant. In those cases, the treatment BMP sidewalls may be lined with at least 18 inches of treatment soil, as described above, to prevent untreated seepage. The soil thickness in the sidewalls is less than in the bottom because unsaturated flow occurs with alternating wet-dry periods.
- Organic content is measured on a dry weight basis using ASTM D2974.
- CEC is tested using U.S. EPA laboratory method 9081.
- A soils testing laboratory must certify that imported soil meets the organic content and CEC criteria above and must provide this certification to the local jurisdiction.
- Animal manure used in treatment soil layers must be sterilized because of the potential for bacterial contamination of the groundwater.

### Design Criteria for Low-Permeability Liner Options

This section presents the general design criteria for the following three low-permeability liner options: geosynthetic clay liners (GCL), HDPE geomembrane liners, and PVC geomembrane liners. Each liner has its own advantages and disadvantages. GCL consist of two layers of geosynthetics stitched together enclosing a layer of processed sodium bentonite clay. The clay expands to help create a good watertight seal. An HDPE liner has excellent chemical resistance, but is inflexible and suffers from environmental stress cracking and thermal stresses. PVC geomembrane liners are very flexible and as a result can conform to uneven surfaces without becoming punctured. Consult the Region Materials Office for low-permeability liner options for each site-specific installation.

#### *Geosynthetic Clay Liners and Geomembrane Liners*

- Geomembrane liners must be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils is used in areas of maintenance access or where heavy machinery must be operated over the membrane.
- Geomembranes must be bedded according to manufacturers' recommendations.
- Liners must be installed so that they can be covered with 12 inches of top dressing forming the bottom and sides of the runoff treatment facility, except for liner sand filters. Top dressing consists 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 can easily spot any area where a liner may have become exposed.
- Geomembrane liners must 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 is stable for all conditions of operation, including maintenance operations.

## 5-4.3.4 Flow Splitters

Although volume-based (wet pool) runoff treatment BMPs must be designed as on-line facilities, many flow rate-based runoff treatment BMPs can be designed as either on-line or off-line. On-line systems allow flows above the runoff treatment design flow to pass through the facility at a lower pollutant-removal efficiency. However, it is sometimes desirable to restrict flows to an off-line runoff treatment facility and bypass the remaining higher flows around the BMP. This can be accomplished by splitting flows in excess of the runoff treatment design flow upstream of the facility and diverting higher flows to a bypass pipe or channel. The bypass typically enters a detention pond or the downstream receiving drainage system, depending on flow control requirements. In most cases, it is the designer's choice whether runoff treatment facilities are designed as on-line or off-line; an exception is oil/water separators, which must be designed off-line.

A crucial factor in designing flow splitters is to ensure low flows are delivered to the treatment facility up to the runoff treatment design flow rate. Above this rate, additional flows are diverted to the bypass system, with minimal increase in head at the flow splitter structure, to avoid surcharging the runoff treatment facility under high flow conditions.

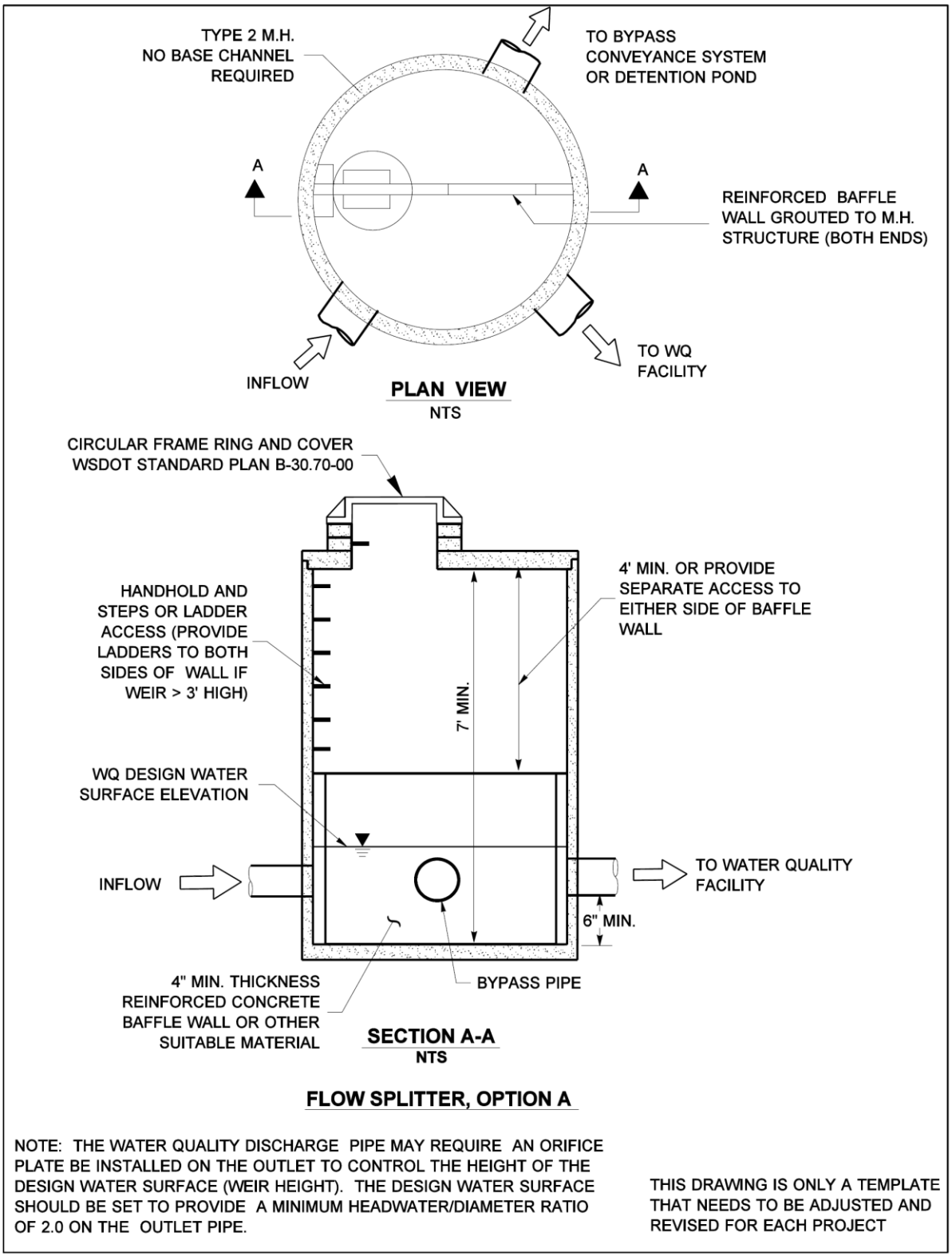
Flow splitters are typically manholes or vaults with concrete baffles. In place of baffles, the splitter mechanism may be a half tee section with a solid top and an orifice in the bottom of the tee section. A full tee option may also be used, as described below in *General Design Criteria*. Two possible design options for flow splitters are shown in Figures 5.4.3.2 and 5.4.3.3. Other equivalent designs that achieve the result of splitting low flows and diverting higher flows around the facility are also acceptable.

## General Design Criteria

- A flow splitter must be designed to deliver the runoff treatment design flow rate to the runoff treatment facility. For the basic sand filter, which is sized based on volume, use the runoff treatment design flow rate to design the splitter.
- The top of the weir must be located at the water surface for the design flow. Remaining flows enter the bypass line. Flows modeled using a continuous simulation model should use 15-minute time steps, if available. Otherwise, use 1-hour time steps.
- The maximum head must be minimized for flow in excess of the runoff treatment design flow. Specifically, flow to the runoff treatment facility in the 100-year event must not increase the runoff treatment design flow by more than 10%.
- Either the Figure 5.4.3.2 or the Figure 5.4.3.3 design (or an equivalent design) may be used.
- As an alternative to using the solid top plate shown in Figure 5.4.3.3, a full tee section may be used with the top of the tee at the 100-year water surface. This alternative routes emergency overflows (if the overflow pipe is plugged) through the runoff treatment facility rather than backing up in the splitter manhole.
- Special applications may require the use of a modified flow splitter. The baffle wall may be fitted with a notch and adjustable weir plate to proportion runoff volumes other than high flows.
- For ponding facilities, backwater effects must be addressed in designing the height of the standpipe in the manhole.
- Ladder or step-and-handhold access must be provided. If the weir wall is higher than 36 inches, two ladders—one on either side of the wall—must be used.

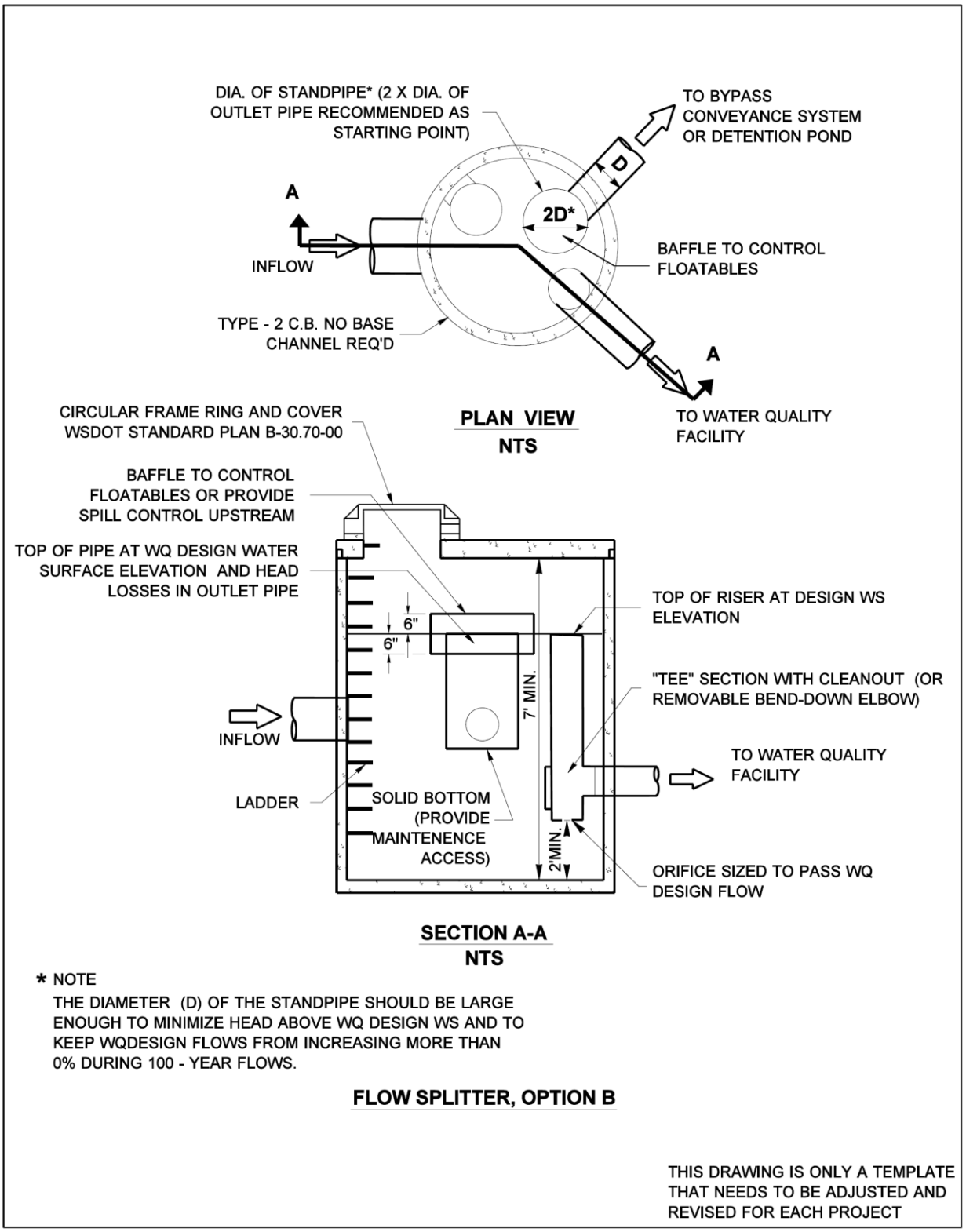
### *Materials*

- The splitter baffle may be installed in a Type 2 manhole or vault.




Source: King County.

**Figure 5.4.3.2 Flow splitter: Option A.**




Source: King County.

**Figure 5.4.3.3 Flow splitter: Option B.**

- The baffle wall must be made of reinforced concrete, or another suitable material resistant to corrosion, and have a minimum 4-inch thickness. The minimum clearance between the top of the baffle wall and the bottom of the manhole cover must be 4 feet; otherwise, dual access points should be provided.
- All metal parts must be corrosion resistant. Examples of preferred materials include aluminum, stainless steel, and plastic. Avoid the use of zinc and galvanized materials—because of their aquatic toxicity potential—when substitutes are available. Painting metal parts for corrosion resistance is not allowed because paint does not provide long-term protection.

### 5-4.3.5 Flow Spreading Options

*Flow spreaders* function to uniformly spread flows across the inflow portion of runoff treatment facilities (such as a sand filter, biofiltration swale, or vegetated filter strip). Five flow spreader options are presented 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. Any one of these options can be used when spreading is required by the facility design criteria. Options A through C can also be used for unconcentrated flows; in some cases they must be used, such as to correct for moderate grade changes along a vegetated filter strip.

Options D and E are only for flows that are already unconcentrated and enter a vegetated filter strip or continuous inflow biofiltration swale. Other flow spreader options are permitted with approval from the HQ Hydraulics Office.

#### General Design Criteria

Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practicable to dissipate energy as much as possible.

For higher inflows (greater than 5 cubic feet per second for the 100-year storm), a Type 1 catch basin should 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 should be lower than the level spreader plate or, if a notched spreader is used, lower than the bottom of the V-notches.

For guidelines on outfall protection, see Section 5-4.3.6.

### *Option A – Anchored Plate*

An anchored plate flow spreader (see Figure 5.4.3.4) must be preceded by a sump having a minimum depth of 8 inches and a minimum width of 24 inches. If not otherwise stabilized, the sump area must be lined to reduce erosion and to dissipate energy.

The top surface of the flow spreader plate must be level, projecting a minimum of 2 inches above the ground surface of the runoff treatment 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 must extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The horizontal extent should protect the bank for all flows up to the 100-year flow or the maximum flow that enters the runoff treatment facility.

Flow spreader plates must be securely fixed in place.

Flow spreader plates may be made of wood, metal, fiberglass-reinforced plastic, or other durable material. If wood, pressure-treated 4-inch by 10-inch lumber/landscape timbers are acceptable.

Anchor posts must be 4-inch-square concrete, tubular stainless steel, or other material resistant to decay.

### *Option B – Concrete Sump Box*

The wall of the downstream side of a rectangular concrete sump box (see Figure 5.4.3.5) must 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 must have wing walls at both ends. Sidewalls and returns must 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 must be reinforced with wire mesh for cast-in-place sumps.

Sump boxes must be placed over bases consisting of 4 inches of crushed rock, ⅝-inch minus, to help ensure the sump remains level.

### *Option C – Notched Curb Spreader*

Notched curb spreader sections (see Figure 5.4.3.6) must be made of extruded concrete laid side by side and level. Typically, five teeth per 4-foot section provides good spacing. The space between adjacent teeth forms a V-notch.

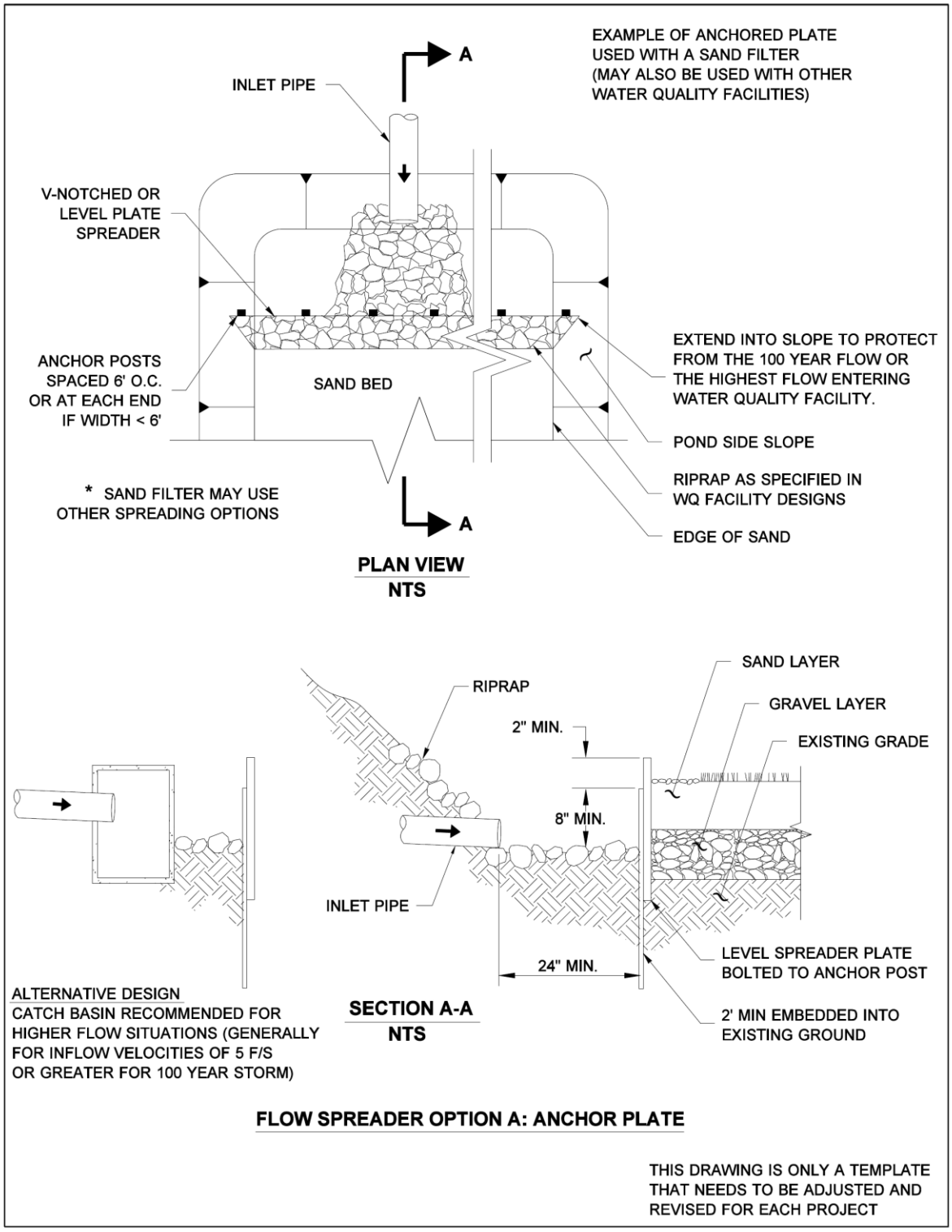



**Figure 5.4.3.4 Flow spreader Option A: Anchor plate.**

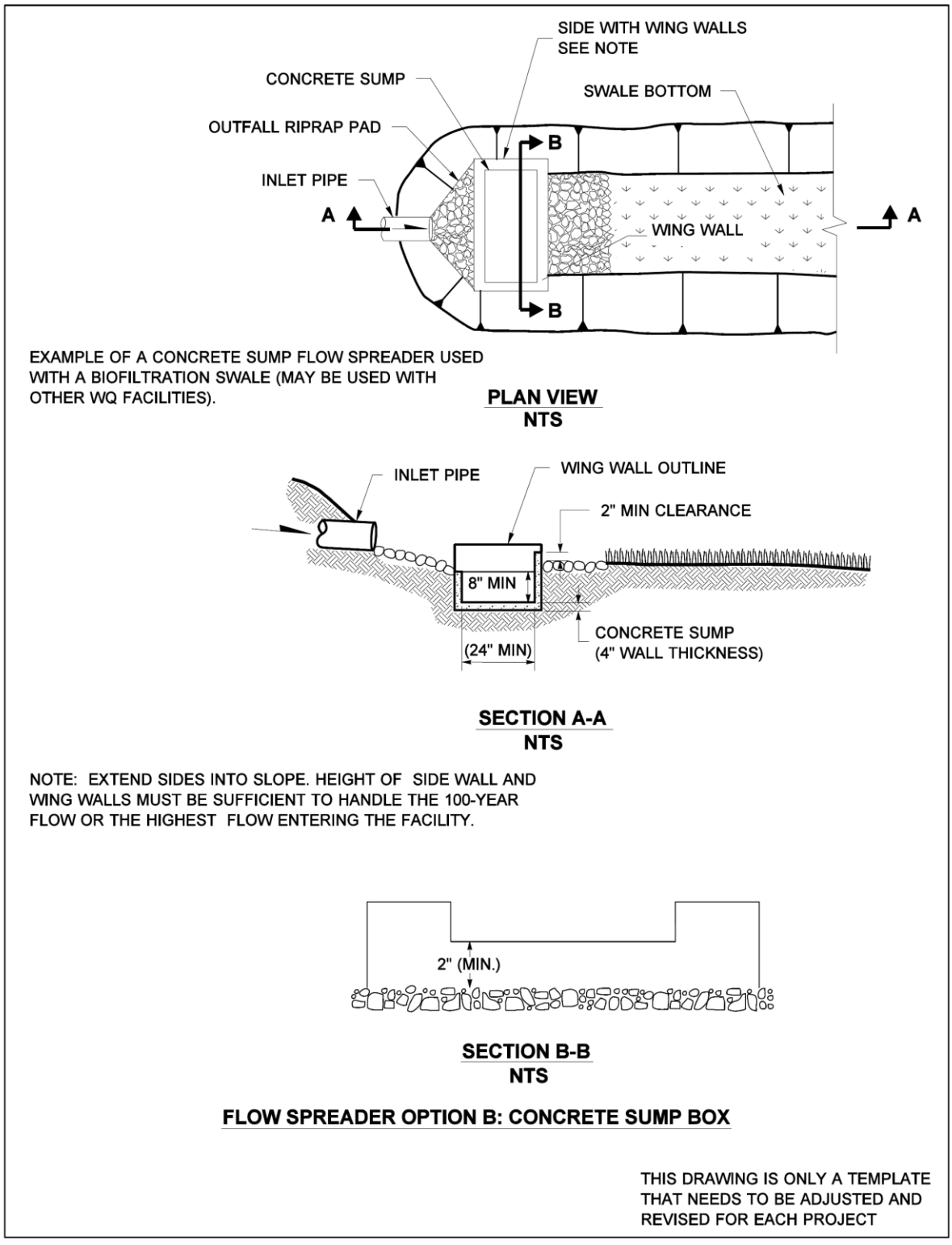



**Figure 5.4.3.5 Flow spreader Option B: Concrete sump box.**

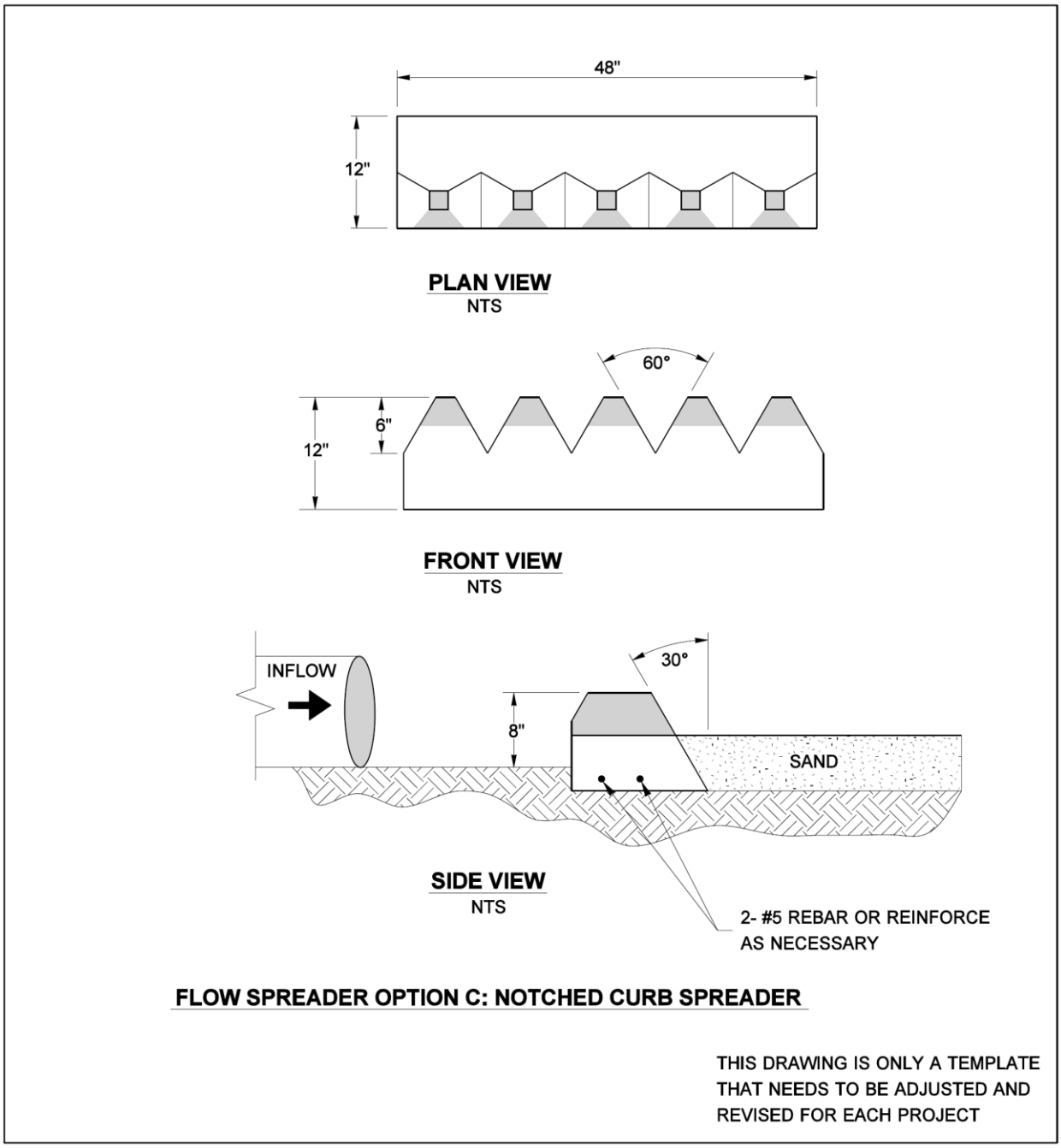



**Figure 5.4.3.6 Flow spreader Option C: Notched curb spreader.**

### *Option D – Through-Curb Ports*

Unconcentrated flows from paved areas entering vegetated filter strips or continuous inflow biofiltration swales can use curb ports (see Figure 5.4.3.7) 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, with an opening through the base to admit water to the runoff treatment facility.

Openings in the curb must be at regular intervals—at least every 6 feet (minimum). The width of each curb port opening must be a minimum of 11 inches. Approximately 15% or more of the curb section length should be in open ports, and no port should discharge more than about 10% of the flow.

***Option E – Interrupted Curb***

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on the facility) of the treatment area. At a minimum, gaps must be every 6 feet to allow distribution of flows into the treatment facility before the flows become too concentrated. The opening must be a minimum of 11 inches. As a general rule, no opening should discharge more than 10% of the overall flow entering the facility.

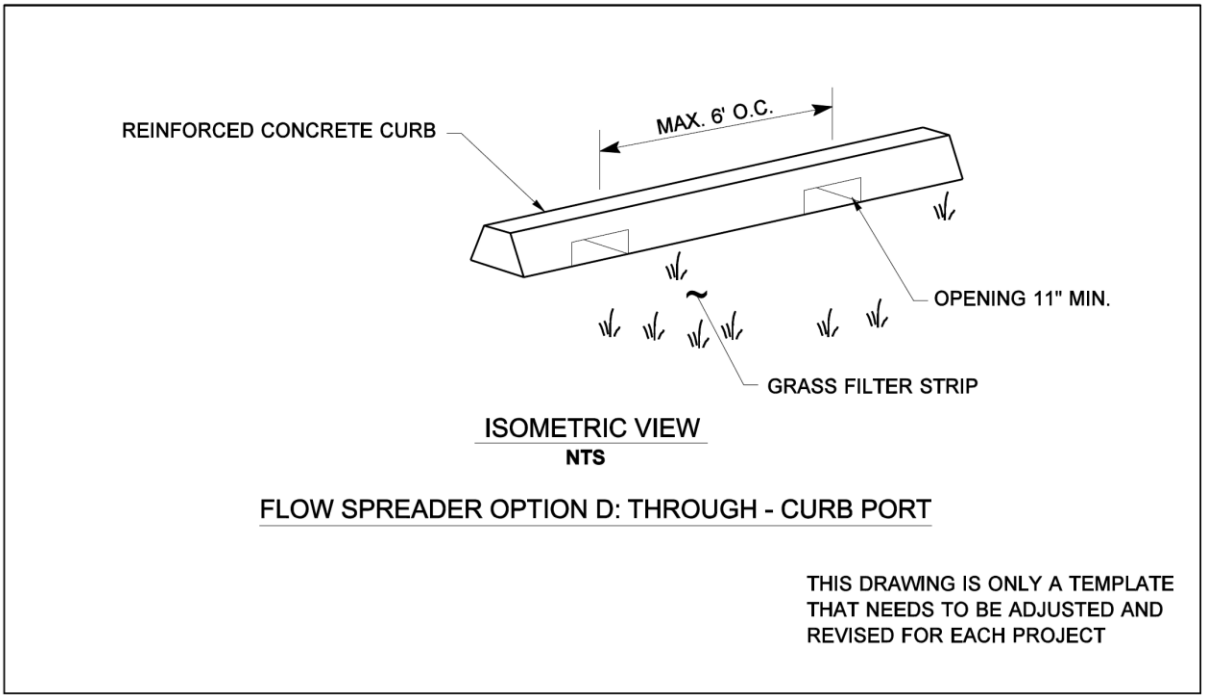



**Figure 5.4.3.7 Flow spreader Option D: Through-curb port.**

## 5-4.3.6 Outfall Systems

Properly designed outfalls are critical to reducing the chance of adverse impacts as the result of concentrated discharges from pipe systems and culverts, both on-site and downstream. Outfall systems include rock splash pads; flow dispersal trenches; gabion or other energy dissipaters; and tight-line systems. A tight-line system is typically a continuous length of pipe used to convey flows down a steep or sensitive slope with appropriate energy dissipation at the discharge end.

### General Design Criteria

Following are the general design criteria for both outfall features and tight-line systems.

### *Outfall Features*

At a minimum, all outfalls must be provided with a rock splash pad, except as specified below and in Table 5.4.2 (see Figure 5.4.3.8).

The flow dispersal trenches shown in Figures 5.4.3.9 and 5.4.3.10 should be used only when both the following criteria are met:

- An outfall is necessary to disperse concentrated flows across uplands where no conveyance system exists and the natural (existing) discharge is unconcentrated
- The 100-year peak discharge rate is less than or equal to 0.5 cubic feet per second

For freshwater outfalls with a design velocity greater than 10 feet per second, a gabion dissipater or engineered energy dissipater may be required (see Figure 5.4.3.11). There are many possible designs.

Note: The gabion outfall detail shown in Figure 5.4.3.11 is illustrative only. A design engineered to specific site conditions must be developed.

Tight-line systems may be needed to prevent aggravation or creation of a downstream erosion problem.

In marine waters, rock splash pads and gabion structures are not recommended. Rock splash pads can be destroyed by wave action, and gabion baskets will corrode in saltwater and potentially be dislocated by wave action. Diffuser tee structures, such as the one depicted in Figure 5.4.3.12, are also not generally recommended in or above the intertidal zone. They may be acceptable in low-bank or rock shoreline locations. Stilling basins or bubble-up structures are acceptable. Generally, tight-lines should be trenched to extreme low water or else the energy of the discharge must be dissipated above the ordinary high water line. Outfalls below extreme low water may still need an energy-dissipation device (such as a tee structure) to prevent nearby erosion.

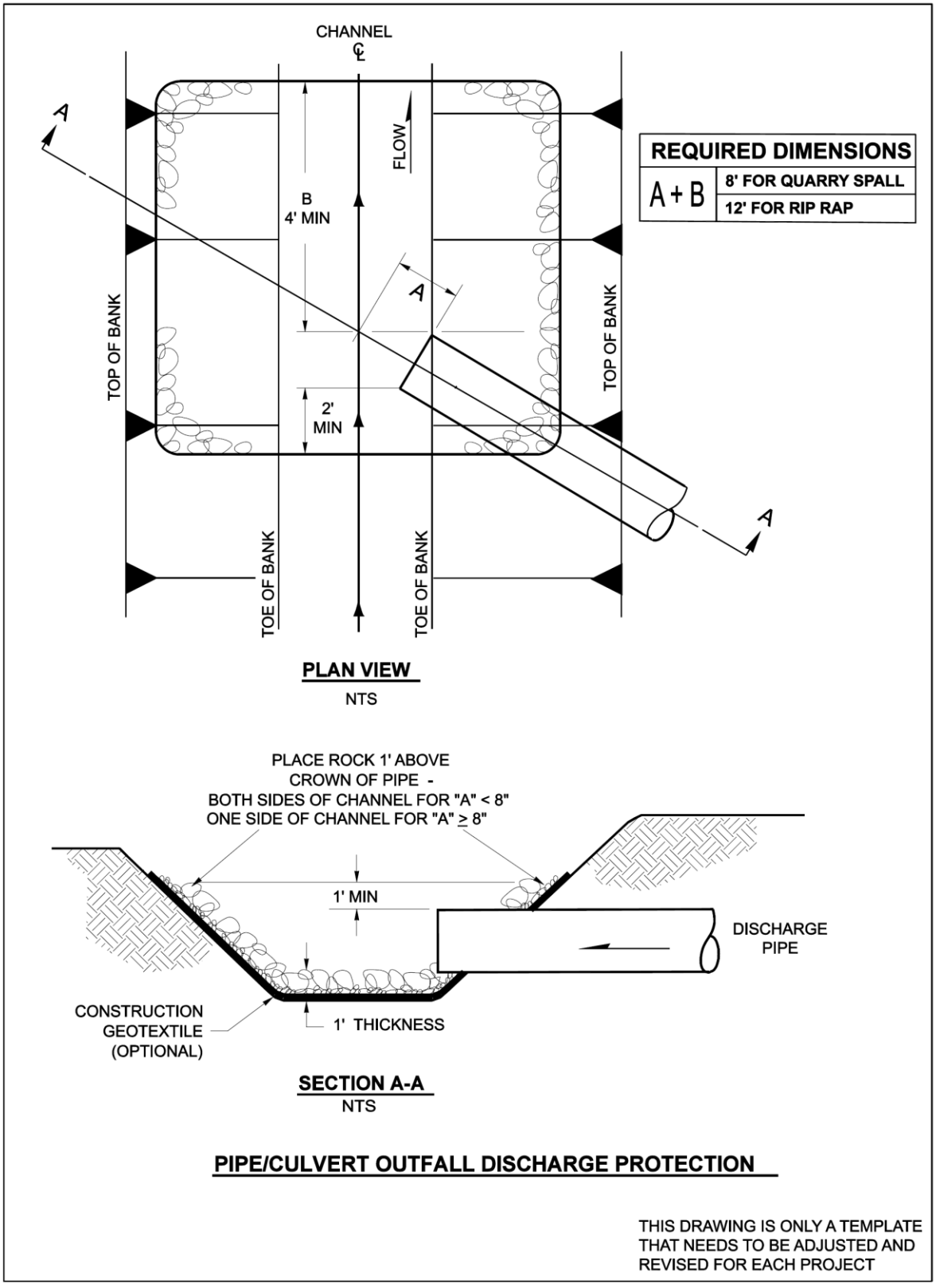



**Figure 5.4.3.8 Pipe/culvert outfall discharge.**

## Table 5.4.2. Rock protection at outfalls.

| Discharge Velocity at Design Flow (ft/sec) | Required Protection: Minimum Dimensions | | | | |
|---|---|---|---|---|---|
| | **Type** | **Thickness** | **Width** | **Length** | **Height** |
| 0 – 5 | Rock lining[1] | 1 foot | Diameter + 6 feet | 8 feet *or* 4 x diameter, whichever is greater | Crown + 1 foot |
| 5+ – 10 | Riprap[2] | 2 feet | Diameter + 6 feet *or* 3 x diameter, whichever is greater | 12 feet *or* 4 x diameter, whichever is greater | Crown + 1 foot |
| 10 – 20 | Gabion outfall | As required | As required | As required | Crown + 1 foot |
| 20+ | Engineered energy dissipater required | | | | |

[1] **Rock lining** must be quarry spalls with gradation as follows:

Passing 8-inch-square sieve: 100%
Passing 3-inch-square sieve: 40% to 60% maximum
Passing ¾-inch-square sieve: 0 to 10% maximum

[2] **Riprap** must be reasonably well-graded with gradation as follows:

Maximum stone size: 24 inches (nominal diameter)
Median stone size: 16 inches
Minimum stone size: 4 inches

Note: Riprap sizing on outlet channel is assumed to be governed by side slopes of approximately 3H**:**1V.

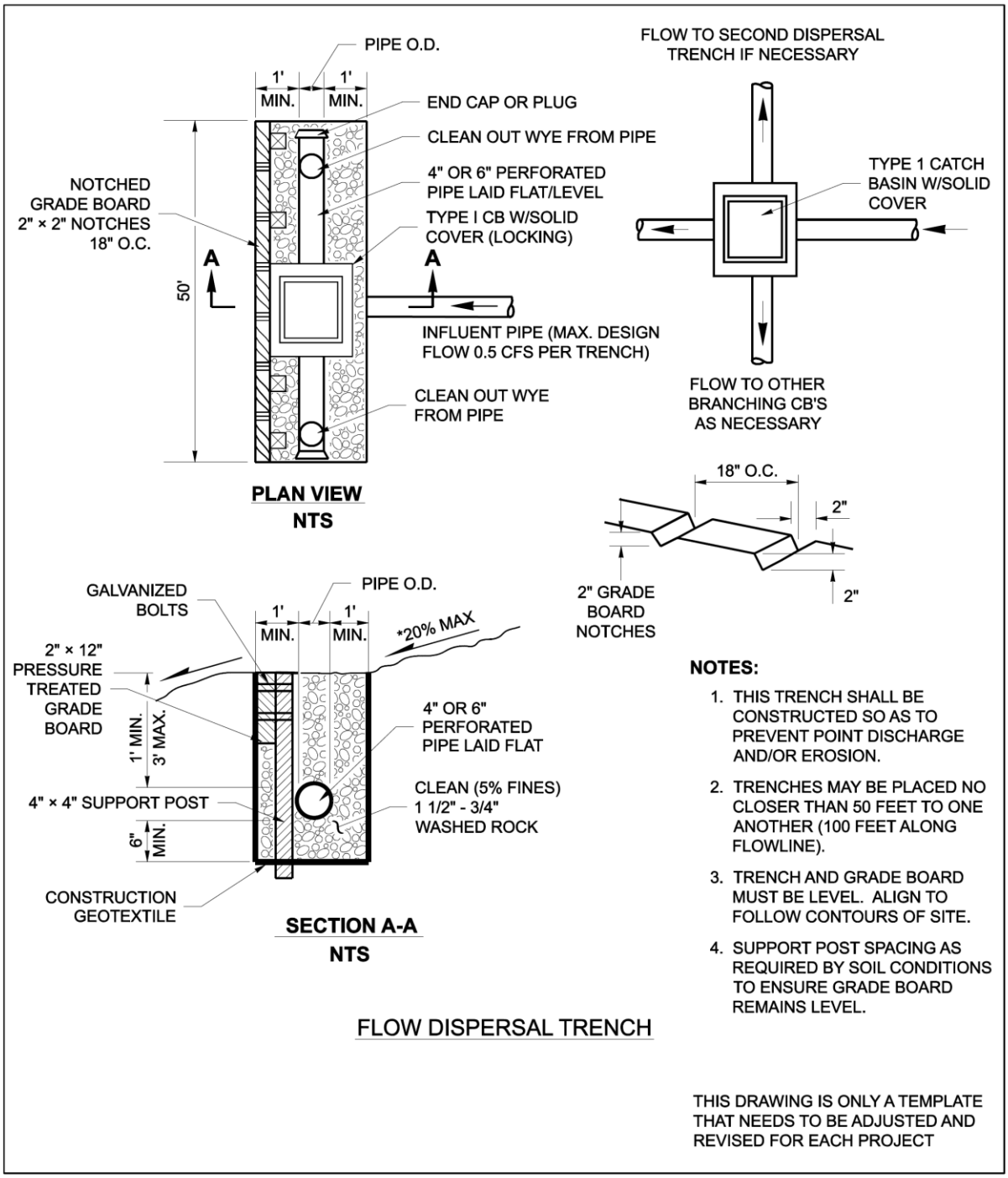



**Figure 5.4.3.9 Flow dispersal trench.**

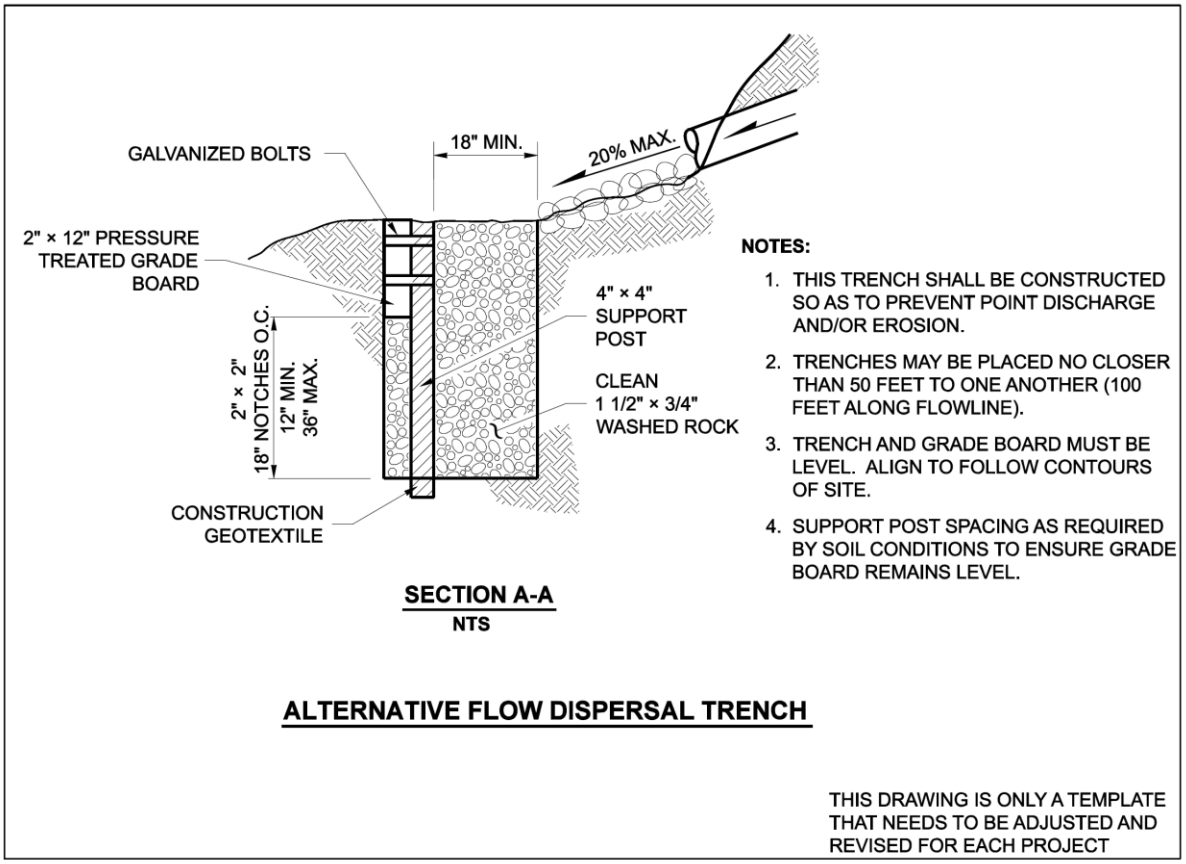



**Figure 5.4.3.10 Alternative flow dispersal trench.**

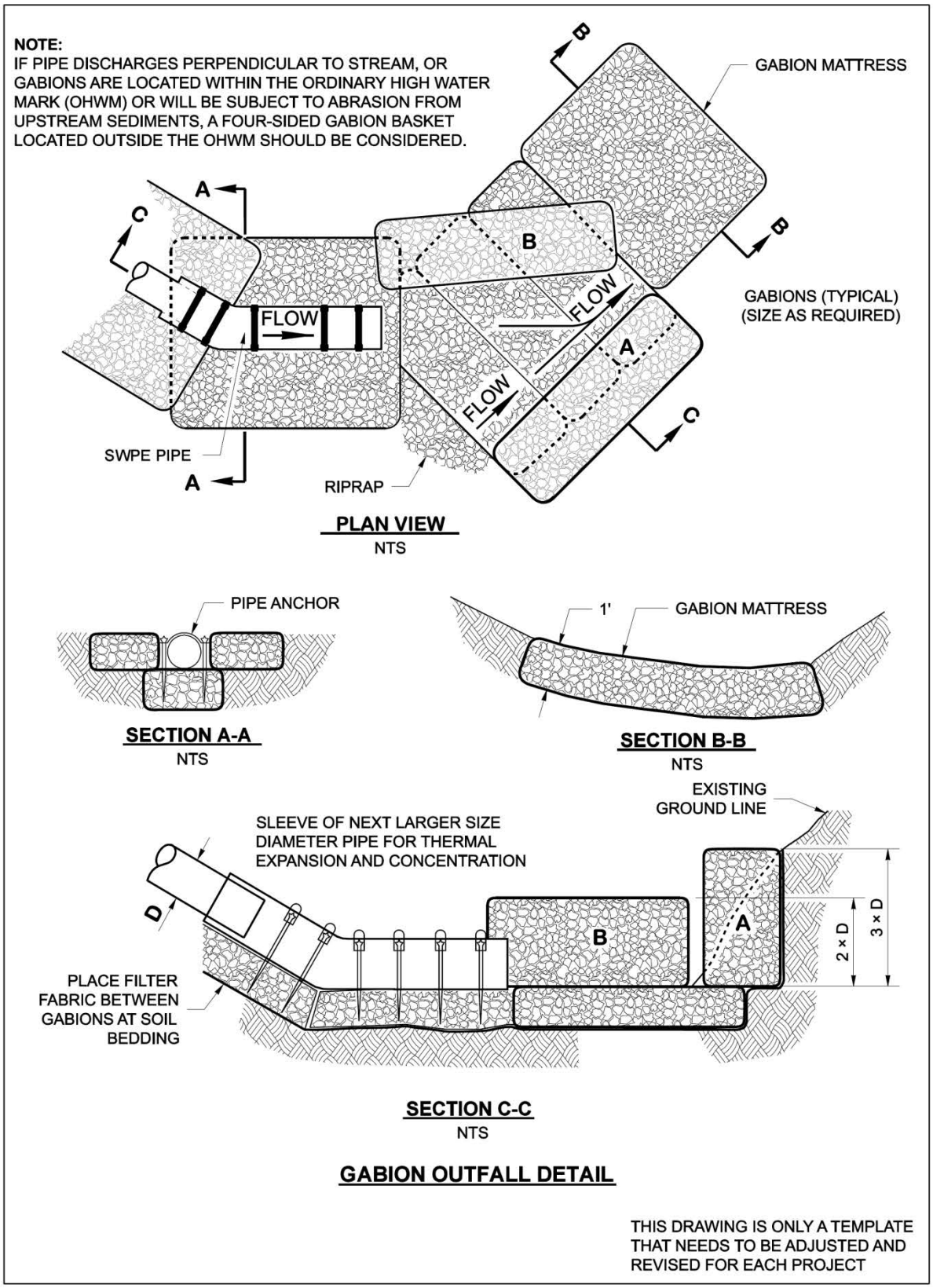



**Figure 5.4.3.11 Gabion outfall detail.**

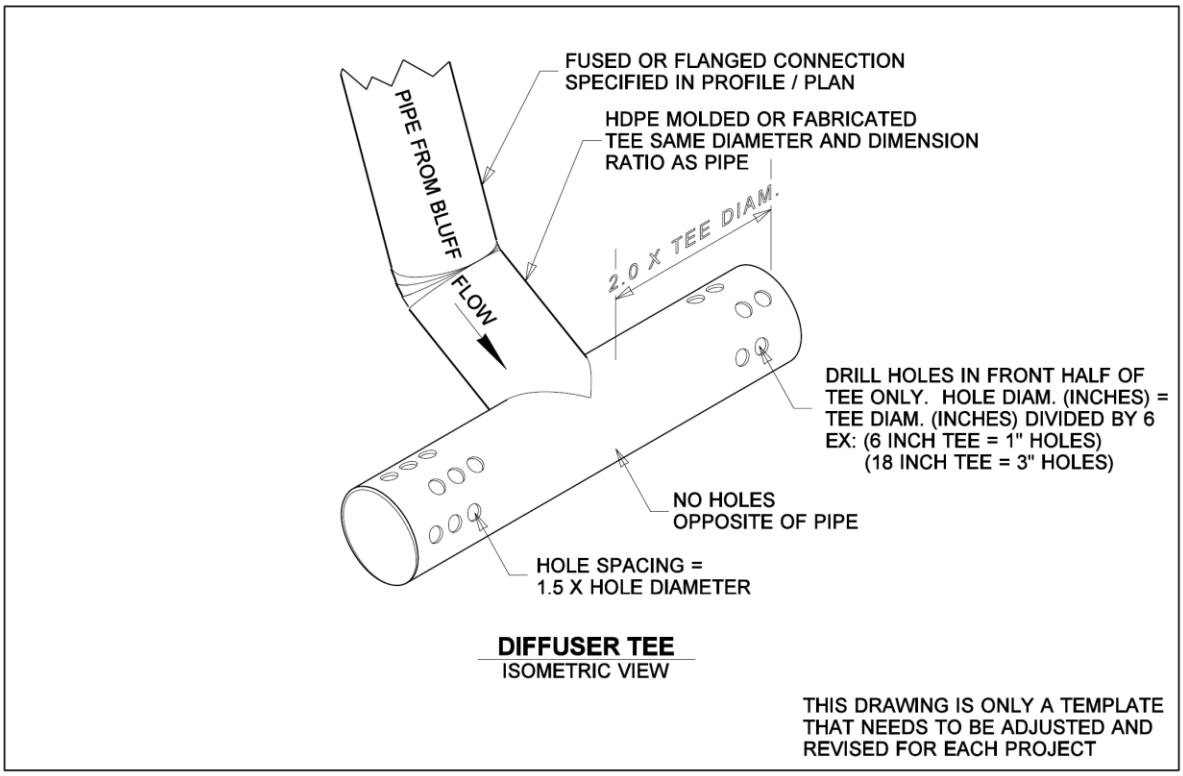



**Figure 5.4.3.12 Diffuser tee: Example of energy-dissipating end feature.**

Engineered energy dissipaters, including stilling basins, drop pools, hydraulic jump basins, baffled aprons, and bucket aprons, are required for outfalls with design velocity greater than 20 feet per second. These energy dissipaters should be designed using published or commonly known techniques found in such references as *Hydraulic Design of Energy Dissipaters for Culverts and Channels*, published by the Federal Highway Administration (1983); *Open Channel Flow*, by V.T. Chow (1959); *Hydraulic Design of Stilling Basins and Energy Dissipaters*, EM 25, Bureau of Reclamation (1978); and other publications such as those prepared by the Natural Resources Conservation Service (formerly the Soil Conservation Service).

Alternative mechanisms may be used, such as bubble-up structures that eventually drain and structures fitted with reinforced concrete posts. If alternative mechanisms are considered, they should be designed using sound hydraulic principles and consideration of the ease of construction and maintenance.

### *Tight-Line Systems*

Mechanisms that reduce runoff velocity prior to discharge from an outfall are encouraged. Two of these mechanisms are drop manholes and rapid expansion of pipe diameter. Other discharge end features may be used to dissipate the discharge energy. An example of an end feature is a diffuser tee with holes in the front half, as shown in Figure 5.4.3.12.

Note: Stormwater outfalls submerged in a marine environment can be subject to plugging due to biological growth and shifting debris and sediments. Therefore, unless intensive maintenance is regularly performed, they may not meet their designed function.

New pipe outfalls can provide an opportunity for low-cost fish habitat improvements. For example, an alcove of low-velocity water can be created by constructing the pipe outfall and associated energy dissipater back from the stream edge and digging a channel, overwidened to the upstream side, from the outfall to the stream, as shown in Figure 5.4.3.13. Overwintering juvenile and migrating adult salmonids may use the alcove as shelter during high flows. Potential habitat improvements should be discussed with the Washington Department of Fish and Wildlife before inclusion in design.

Bank stabilization, bioengineering, and habitat features may be required for disturbed areas.

Outfall structures should be located where they minimize impacts to fish, shellfish, and their habitats.

One caution to note is that the in-stream gabion mattress energy dissipater may not be acceptable within the ordinary high water level of fish-bearing waters or where gabions are subject to abrasion from upstream channel sediments. A four-sided gabion basket located above the ordinary high water level should be considered for these applications.

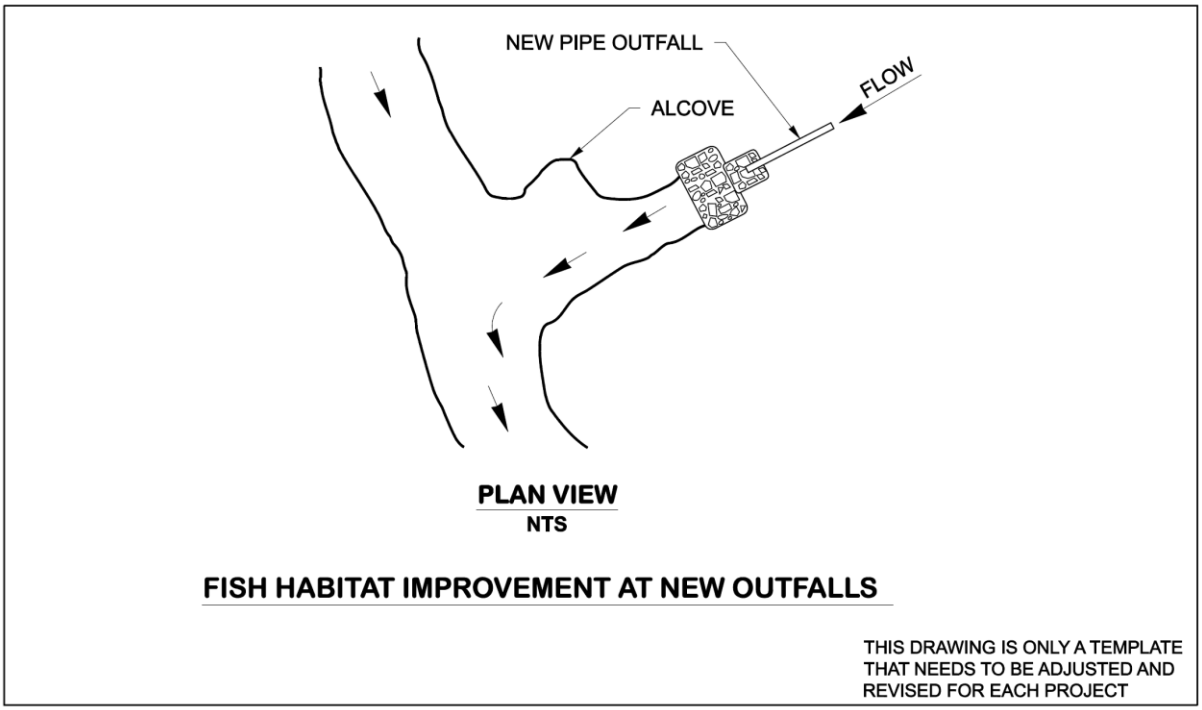



**Figure 5.4.3.13 Fish habitat improvement at new outfalls.**

Note: A Hydraulic Project Approval (RCW 77.55) may be required for any work within the ordinary high water level. Other provisions of this RCW or the Hydraulics Code (WAC 220-110) may also apply.

Outfall tight-lines may be installed in trenches with standard bedding on slopes up to 20%. To minimize disturbance to slopes greater than 20%, it is recommended that tight-lines be placed at grade with proper pipe anchorage and support.

Except as indicated above, tight-lines or conveyances that traverse the marine intertidal zone and connect to outfalls must be buried deep enough to avoid exposure of the line during storm events or future changes in beach elevation. If non-native material is used to bed the tight-line, such material must be covered with at least 3 feet of native bed material or equivalent.

High-density polyethylene (HDPE) pipe tight-lines must be designed to address the material limitations, particularly thermal expansion and contraction and pressure design, as specified by the manufacturer. The coefficient of thermal expansion and contraction for solid wall polyethylene (SWPE) pipe is on the order of 0.001-inch per foot per degree Fahrenheit. Sliding sleeve connections must be used to address this thermal expansion and contraction. These sleeve connections consist of a section of the appropriate length of the next larger size diameter of pipe into which the outfall pipe is fitted. The sleeve connections must be located as close to the discharge end of the outfall system as is practicable.

Due to the ability of HDPE pipe tight-lines to transmit flows of very high energy, special consideration for energy dissipation must be made. Details of a typical gabion mattress energy dissipater are included in Figure 5.4.3.11. Flows of very high energy require a specifically engineered energy dissipater structure.

### 5-4.3.7 Stormwater BMP Signing Requirements

All stormwater BMPs need to be properly signed in the field. BMPs fall into three general categories: linear BMPs, pond-type BMPs, and underground stormwater BMPs. A signing scheme is presented below for each category.

#### *Signing for Linear BMPs*

Linear BMPs include dispersion, engineered dispersion, vegetated filter strips (basic, CAVFS, and narrow), media filter drains, bioswales (basic, CABS, wet, and continuous inflow), and infiltration trenches.

Use brown, flexible, non-reflective guidepost markers. The beginning, intermediate, and end guideposts shall be placed at the BMP back edge farthest from the roadway to help facilitate mowing and other maintenance operations. Plastic cross culvert pavement markers shall be placed at the beginning and end of the BMP. The beginning and end guideposts shall have the general green WSDOT stormwater BMP sticker that names the type of stormwater BMP installed, matching the name found in the HRM. Intermediate guideposts shall not have the stickers. Intermediate guide posts shall be spaced at 100 feet. (See Figures 5.4.3.14 and 5.4.3.15 for details.)

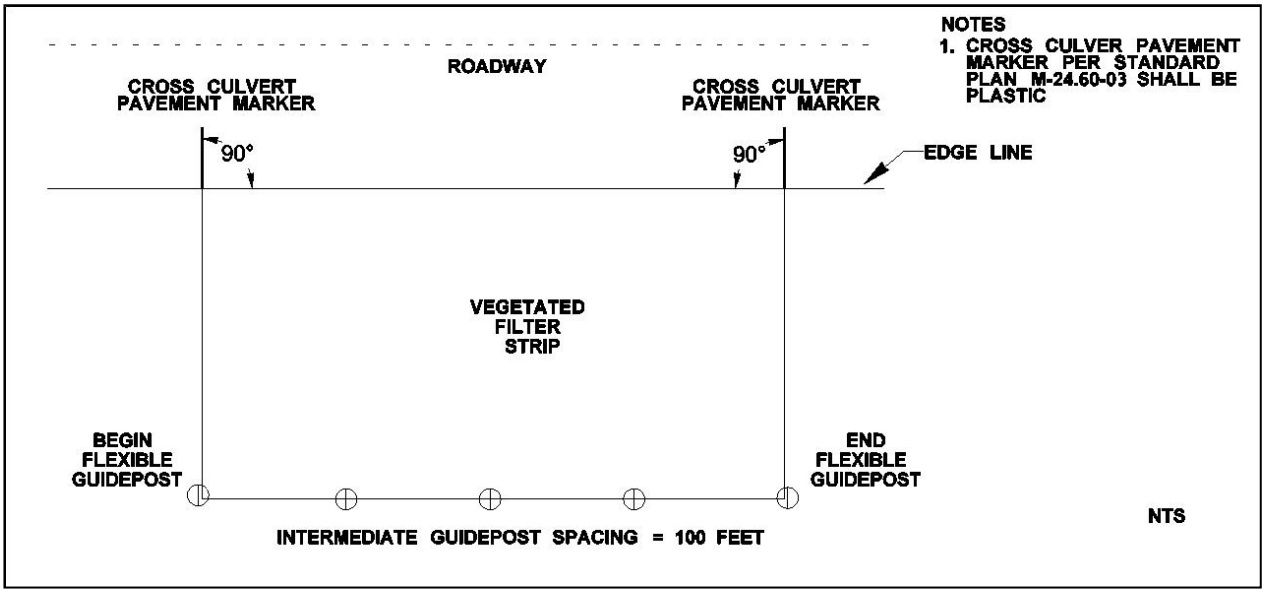



**Figure 5.4.3.14 Signing for sheet flow BMPs.**

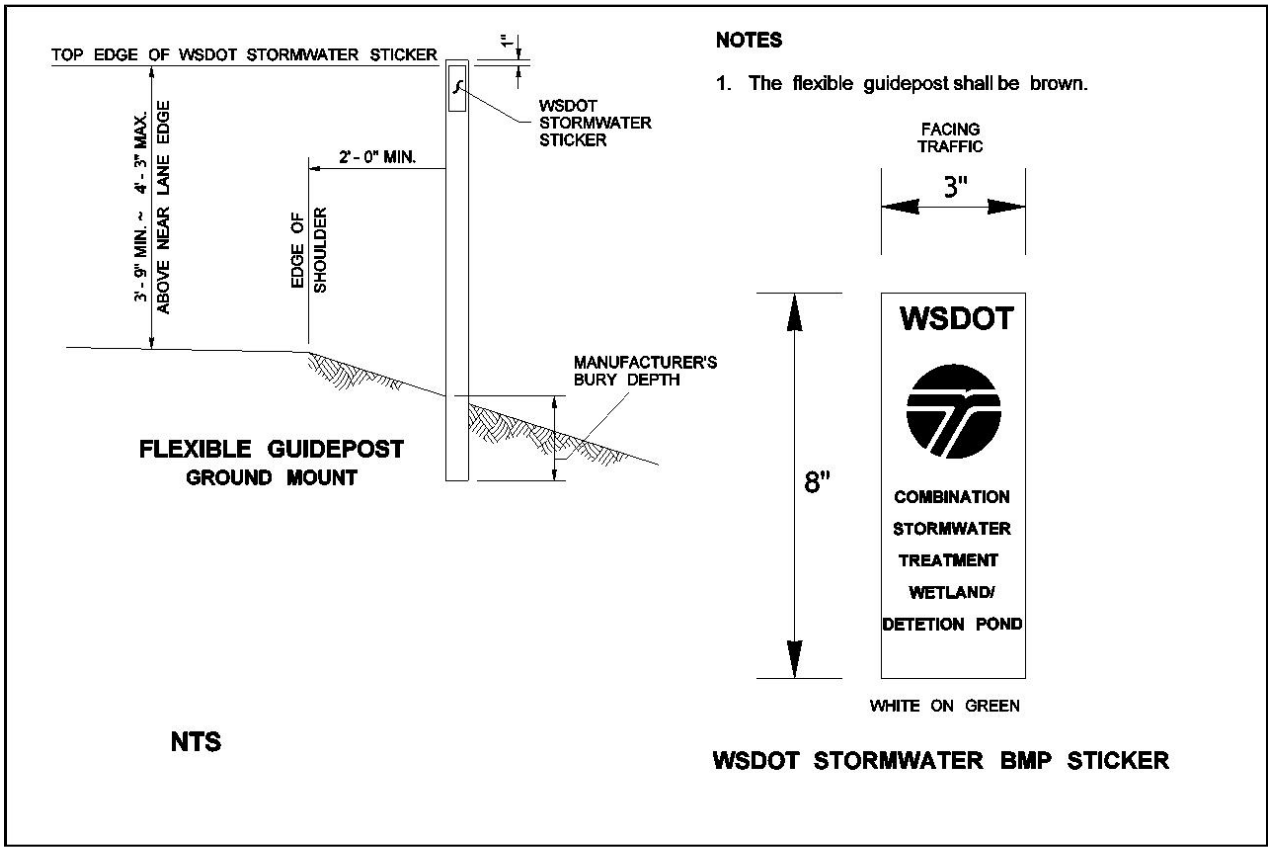



**Figure 5.4.3.15 Stormwater signing details.**

### *Signing for Pond-Type BMPs*

Pond-type BMPs include detention ponds, infiltration ponds, bioinfiltration ponds, dry wells, presettling basins, wet ponds, bioretention areas, constructed stormwater treatment wetlands, combination wet/detention ponds, and combination stormwater wetland/detention ponds. Use at least one brown flexible non-reflective guidepost marker and place it near the pond access road. A plastic cross culvert pavement marker shall be placed at the pond access road. The guideposts shall have the general green WSDOT stormwater BMP sticker that names the type of stormwater BMP installed, matching the name found in the HRM (see Figure 5.4.3.16).

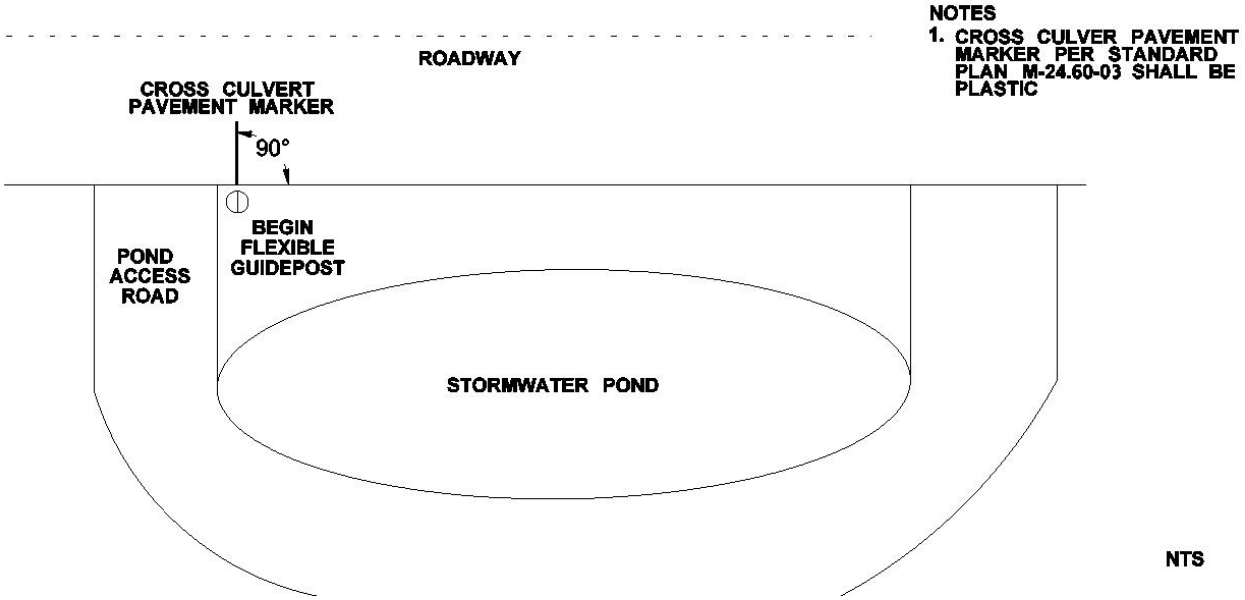



**Figure 5.4.3.16 Signing for pond-type BMPs.**

### *Signing for Underground BMPs*

Underground-type BMPs include infiltration vaults and Category 1 BMPs such as detention vaults and oil control vaults (see Section 5-3.5.1). A stencil showing the same information as the general WSDOT stormwater sticker would be painted adjacent to the last structure on pavement that flows to the underground stormwater BMP (see Figure 5.4.3.17).

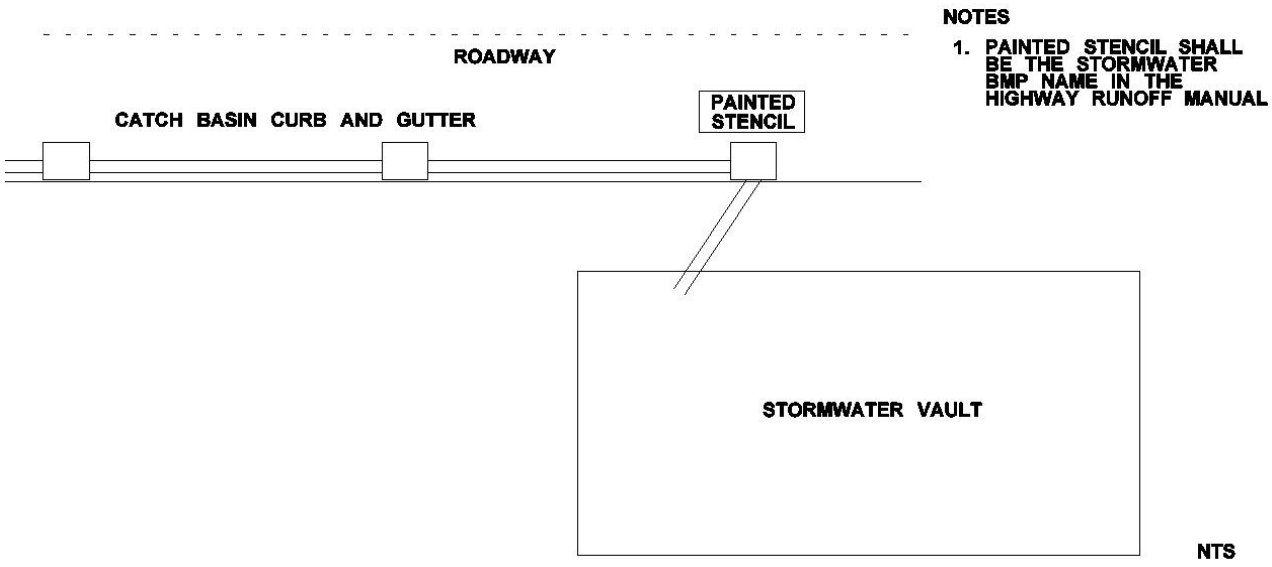



**Figure 5.4.3.17 Signing for underground-type BMPs.**

# 5-5 Operation and Maintenance

Inadequate maintenance is a common cause of failure for stormwater control facilities. All stormwater facilities require routine inspection and maintenance and thus must be designed so that these functions can be easily conducted.

## 5-5.1 Typical BMP Maintenance Standards

The facility-specific maintenance standards contained in this section (see Tables 5.5.1 through 5.5.13) are intended to be used for determining when maintenance actions are required for conditions identified through inspection. They are not intended to be measures of a facility's required condition at all times between inspections. In other words, exceeding these conditions at any time between inspections or maintenance does not automatically constitute a need for immediate maintenance. Based upon inspection observations, 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.

## 5-5.2 Natural and Landscaped Areas Designated as Stormwater Management Facilities

Maintenance of natural and landscaped areas designated as stormwater management facilities requires special attention. Generally, maintenance in these areas should be performed with light equipment. Heavy machinery and vehicles with large treads or tires can compact the ground surface, decreasing the effectiveness of the BMPs.

## Table 5.5.1. Maintenance standards for detention ponds.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| **General** | Trash and debris | Accumulations exceed 5 cubic feet (about equal to the amount of trash needed to fill one standard-size garbage can) per 1,000 square feet. In general, there should be no visual evidence of dumping.<br>If less than threshold, all trash and debris will be removed as part of the next scheduled maintenance. | Trash and debris are cleared from site. |
| | Poisonous vegetation and noxious weeds | Poisonous or nuisance vegetation may constitute a hazard to maintenance personnel or the public.<br>Noxious weeds as defined by state or local regulations are evident.<br>(Apply requirements of adopted integrated pest management [IPM] policies for the use of herbicides). | No danger is posed by poisonous vegetation where maintenance personnel or the public might normally be.<br>(Coordinate with local health department.)<br>Complete eradication of noxious weeds may not be possible. Compliance with state or local eradication policies is required. |
| | Contaminants and pollution | Oil, gasoline, contaminants, or other pollutants are evident.<br>(Coordinate removal/cleanup with local water quality response agency.) | No contaminants or pollutants are present. |
| | Rodent holes | For facilities acting as a dam or berm: rodent holes are evident or there is evidence of water piping through dam or berm via rodent holes. | Rodents are destroyed and dam or berm repaired.<br>(Coordinate with local health department; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.) |
| | Beaver dams | Dam results in change or function of the facility. | Facility is returned to design function.<br>(Coordinate trapping of beavers and removal of dams with appropriate permitting agencies.) |
| | Insects | Insects such as wasps and hornets interfere with maintenance activities. | Insects are destroyed or removed from site.<br>Insecticides are applied in compliance with adopted IPM policies. |
| | Tree growth and hazard trees | Tree growth does not allow maintenance access or interferes with maintenance activity (slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove.<br>Dead, diseased, or dying trees are observed. (Use a certified arborist to determine health of tree or removal requirements.) | Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (such as alders for firewood).<br>Hazard trees are removed. |
| **Side slopes of pond** | Erosion | Eroded damage is over 2 inches deep and cause of damage is still present, or there is potential for continued erosion.<br>Erosion is observed on a compacted berm embankment. | Slopes are stabilized using appropriate erosion control measures (such as rock reinforcement, planting of grass, and compaction).<br>If erosion is occurring on compacted berms, a licensed civil engineer should be consulted to resolve source of erosion. |

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| **Storage area** | Sediment | Accumulated sediment exceeds 10% of the designed pond depth, unless otherwise specified, or affects inletting or outletting condition of the facility. | Sediment is cleaned out to designed pond shape and depth. Pond is reseeded if necessary to control erosion. |
| | Liner (if applicable) | Liner is visible and has more than three ¼-inch holes in it. | Liner is repaired or replaced. Liner is fully covered. |
| **Pond berms (dikes)** | Settlements | Any part of berm has settled 4 inches lower than the design elevation.<br>If settlement is apparent, measure berm to determine amount of settlement.<br>Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement. | Dike is built back to the design elevation. |
| | Piping | Water flow is discernible through pond berm. Ongoing erosion is observed, with potential for erosion to continue.<br>(Recommend a geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.) | Piping is eliminated. Erosion potential is resolved. |
| **Emergency overflow/ spillway and berms over 4 feet high** | Tree growth | Tree growth on emergency spillways reduces spillway conveyance capacity and may cause erosion elsewhere on the pond perimeter due to uncontrolled overtopping.<br>Tree growth on berms over 4 feet high may lead to piping through the berm, which could lead to failure of the berm and related erosion or flood damage. | Trees should be removed. 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 licensed civil engineer should be consulted for proper berm/spillway restoration. |
| | Piping | Water flow is discernible through pond berm. Ongoing erosion is observed, with potential for erosion to continue.<br>(Recommend a geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.) | Piping is eliminated. Erosion potential is resolved. |
| **Emergency overflow/ spillway** | Spillway lining insufficient | Only one layer of rock exists above native soil in area 5 square feet or larger, or native soil is exposed at the top of outflow path of spillway.<br>(Riprap on inside slopes need not be replaced.) | Rocks and pad depth are restored to design standards. |

## Table 5.5.2. Maintenance standards for bioinfiltration ponds/infiltration trenches/basins.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| **General** | Trash and debris | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| | Poisonous/noxious vegetation | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| | Contaminants and pollution | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| | Rodent holes | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| **Storage area** | Sediment | Water ponds in infiltration pond after rainfall ceases and appropriate time has been allowed for infiltration. (A percolation test pit or test of facility indicates facility is working at only 90% of its designed capabilities. If 2 inches or more of sediment present, remove sediment). | Sediment is removed or facility is cleaned so that infiltration system works according to design. |
| **Rock filters** | Sediment and debris | By visual inspection, little or no water flows through filter during heavy rainstorms. | Gravel in rock filter is replaced. |
| **Side slopes of pond** | Erosion | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| **Emergency overflow/spillway and berms over 4 feet high** | Tree growth | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| | Piping | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| **Emergency overflow/spillway** | Rock missing | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| | Erosion | See Table 5.5.13 (wet ponds). | See Table 5.5.13 (wet ponds). |
| **Presettling ponds and vaults** | Facility or sump filled with sediment or debris | Sediment/debris exceeds 6 inches or designed sediment trap depth. | Sediment is removed. |

## Table 5.5.3. Maintenance standards for closed treatment systems (tanks/vaults).

| Maintenance Component | 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 are open and functioning. |
| | Debris and sediment | Accumulated sediment depth exceeds 10% of the diameter of the storage area for ½ length of storage vault or any point depth exceeds 15% of diameter.<br>(Example: 72-inch storage tank requires cleaning when sediment reaches depth of 7 inches for more than ½ the length of the tank.) | All sediment and debris are removed from storage area. |
| | Joints between tank/pipe section | Openings or voids allow material to be transported into facility.<br>(Will require engineering analysis to determine structural stability.) | All joints between tank/pipe sections are sealed. |
| | Tank/pipe bent out of shape | Any part of tank/pipe is bent out of shape for more than 10% of its design shape.<br>(Review required by engineer to determine structural stability.) | Tank/pipe is repaired or replaced to design specifications. |
| | Vault structure: includes cracks in walls or bottom, damage to frame or top slab | Cracks are wider than ½ inch and there is evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound. | Vault is replaced or repaired to design specifications and is structurally sound. |
| | | Cracks are wider than ½ inch at the joint of any inlet/outlet pipe, or there is evidence of soil particles entering the vault through the walls. | No cracks are more than ¼-inch wide at the joint of the inlet/outlet pipe. |
| **Manhole** | Cover not in place | Cover is missing or only partially in place. Any open manhole requires maintenance. | Manhole is closed. |
| | Locking mechanism not working | Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than ½ inch of thread (may not apply to self-locking lids). | Mechanism opens with proper tools. |
| | Cover difficult to remove | One maintenance person cannot remove lid after applying normal lifting pressure.<br>*Intent: To prevent cover from sealing off access to maintenance*. | Cover can be removed and reinstalled by one maintenance person. |
| | Ladder unsafe | Ladder is unsafe due to missing rungs, misalignment, insecure attachment to structure wall, rust, or cracks. | Ladder meets design standards. Allows maintenance person safe access. |
| **Catch basins** | See Table 5.5.5 (catch basins). | See Table 5.5.5 (catch basins). | See Table 5.5.5 (catch basins). |

## Table 5.5.4. Maintenance standards for control structure/flow restrictor.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| **General** | Trash and debris (includes sediment) | Accumulation exceeds 25% of sump depth or is within 1 foot below orifice plate. | Control structure orifice is not blocked. All trash and debris are removed. |
| | Structural damage | Structure is not securely attached to manhole wall. | Structure is securely attached to wall and outlet pipe. |
| | | Structure is not in upright position; allow up to 10% from plumb. | Structure is in correct position. |
| | | Connections to outlet pipe are not watertight and show signs of rust. | Connections to outlet pipe are watertight; structure is repaired or replaced and works as designed. |
| | | Holes other than designed holes are observed 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. |
| | | Gate cannot be moved up and down by one maintenance person. | Gate moves up and down easily and is watertight. |
| | | Chain/rod leading to gate is missing or damaged. | Chain is in place and works as designed. |
| | | Gate is rusted over 50% 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. |
| | Obstructions | Trash, debris, sediment, or vegetation blocks the plate. | Plate is free of all obstructions and works as designed. |
| **Overflow pipe** | Obstructions | Trash or debris blocks (or has the potential to block) the overflow pipe. | Pipe is free of all obstructions and works as designed. |
| **Manhole** | See Table 5.5.3 (closed treatment systems). | See Table 5.5.3 (closed treatment systems). | See Table 5.5.3 (closed treatment systems). |
| **Catch basin** | See Table 5.5.5 (catch basins). | See Table 5.5.5 (catch basins). | See Table 5.5.5 (catch basins). |

## Table 5.5.5. Maintenance standards for catch basins.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| **General** | Trash and debris | Trash or debris is immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%. | No trash or debris is immediately in front of catch basin or on grate opening. |
| | | Trash or debris (in the basin) exceeds 60% 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 is clearance less than 6 inches from the debris surface to the invert of the lowest pipe. | No trash or debris is in the catch basin. |
| | | Trash or debris in any inlet or outlet pipe blocks more than ⅓ of its height. | Inlet and outlet pipes are free of trash or debris. |
| | | Dead animals or vegetation could generate odors that might cause complaints or dangerous gases (such as methane). | No vegetation or dead animals are present within the catch basin. |
| | Sediment | Sediment (in the basin) exceeds 60% of the sump depth as measured from the bottom of the basin to invert of the lowest pipe into or out of the basin, but in no case is clearance less than 6 inches from the sediment surface to the invert of the lowest pipe. | No sediment is in the catch basin. |
| | Structure damage to frame and/or top slab | Top slab has holes larger than 2 square inches or cracks wider than ¼ inch.<br>*Intent: To make sure no material is running into basin.* | Top slab is free of holes and cracks. |
| | | Frame is not sitting flush on top slab (separation of more than ¾ inch of the frame from the top slab). Frame is not securely attached. | Frame is sitting flush on the riser rings or top slab and is firmly attached. |
| | Fractures or cracks in basin walls/bottom | Maintenance person judges that structure is unsound. | Basin is replaced or repaired to design standards. |
| | | Grout fillet has separated or cracked wider than ½ inch and longer than 1 foot at the joint of any inlet/outlet pipe, or there is evidence that soil particles have entered catch basin through cracks. | Pipe is regrouted and secure at the basin wall. |
| | Settlement/ misalignment | Failure of basin has created a safety, function, or design problem. | Basin is replaced or repaired to design standards. |
| | Vegetation | Vegetation is growing across and blocking more than 10% of the basin opening. | No vegetation blocks the opening to the basin. |
| | | Vegetation growing in inlet/outlet pipe joints is more than 6 inches tall and less than 6 inches apart. | No vegetation or root growth is present. |
| | Contamination and pollution | Oil, gasoline, contaminants, or other pollutants are evident.<br>(Coordinate removal/cleanup with local water quality response agency.) | No pollution is present. |
| **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. |
| | Locking mechanism not working | Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than ½ inch of thread. | Mechanism opens with proper tools. |
| **Catch basin cover (continued)** | Cover difficult to remove | One maintenance person cannot remove lid after applying normal lifting pressure.<br>*Intent: To prevent cover from sealing off access to maintenance.* | Cover can be removed by one maintenance person. |

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| **Ladder** | Ladder unsafe | Ladder is unsafe due to missing rungs, insecure attachment to basin wall, misalignment, rust, cracks, or sharp edges. | Ladder meets design standards and allows maintenance staff safe access. |
| **Metal grates (if applicable)** | Grate opening unsafe | Grate opening is wider than 7/8 inch. | Grate opening meets design standards. |
| | Trash and debris | Trash and debris block more than 20% of grate surface inletting capacity. | Grate is free of trash and debris. |
| | Damaged or missing | Grate is missing or components of the grate are broken. | Grate is in place and meets design standards. |

## Table 5.5.6. Maintenance standards for debris barriers (such as trash racks).

| Maintenance Components | Defect or Problem | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| **General** | Trash and debris | Trash or debris plugs more than 20% of the openings in the barrier. | Barrier is cleared to design flow capacity. |
| **Metal** | Damaged/missing bars | Bars are bent out of shape more than 3 inches. | Bars are in place with no bends more than ¾ inch. |
| | | Bars are missing or entire barrier is missing. | Bars are in place according to design. |
| | | Bars are loose and rust is causing 50% deterioration to any part of barrier. | Barrier is replaced or repaired to design standards. |
| | Inlet/outlet pipe | Debris barrier is missing or not attached to pipe. | Barrier is firmly attached to pipe. |

## Table 5.5.7. Maintenance standards for energy dissipaters.

| Maintenance Components | 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 5 square feet or larger, or native soil is exposed. | Rock pad is replaced to design standards. |
| | Erosion | Soil erosion is evident in or adjacent to rock pad. | Rock pad is replaced to design standards. |
| **Dispersion trench** | Pipe plugged with sediment | Accumulated sediment exceeds 20% of the design depth. | Pipe is cleaned/flushed so that it matches design. |
| | Not discharging water properly | There is visual evidence of water discharging at concentrated points along trench—normal condition is a "sheet flow" of water along trench. *Intent: To prevent erosion damage*. | Trench is redesigned or rebuilt to standards. |
| | Perforations plugged | Over ½ of perforations in pipe are plugged with debris and sediment. | Perforated pipe is cleaned or replaced. |
| | Water flows out top of "distributor" catch basin | Maintenance person observes or receives credible report of water flowing out during any storm less than the design storm, or water is causing (or appears likely to cause) damage. | Facility is rebuilt or redesigned to standards. |
| | Receiving area over-saturated | Water in receiving area is causing (or has potential of causing) landslide problems. | There is no danger of landslides. |
| **Internal:** | | | |
| **Manhole/chamber** | Worn or damaged post, baffles, side of chamber | Structure dissipating flow deteriorates to ½ of original size or any concentrated worn spot exceeds 1 square foot, which would make structure unsound. | Structure is replaced to design standards. |
| | Other defects | See entire contents of Table 5.5.5 (catch basins). | See entire contents of Table 5.5.5 (catch basins). |

## Table 5.5.8. Maintenance standards for biofiltration swale.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Recommended Maintenance to Correct Problem |
|---|---|---|---|
| **General** | Sediment accumulation on grass | Sediment depth exceeds 2 inches. | 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. |
| | Standing water | Water stands in the swale between storms and does not drain freely. | Any of the following may apply: remove sediment or trash blockages; improve grade from head to foot of swale; remove clogged check dams; add underdrains; or convert to a wet biofiltration swale. |
| | Flow spreader | Flow spreader is uneven or clogged so that flows are not uniformly distributed through entire swale width. | Level the spreader and clean so that flows are spread evenly over entire swale width. |
| | Constant baseflow | Small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom. | Add a low-flow pea gravel drain the length of the swale, or bypass the baseflow around the swale. |
| | Poor vegetation coverage | Grass is sparse or bare, or eroded patches occur in more than 10% of the swale bottom. | Consult with roadside vegetation specialists to determine why grass growth is poor and correct the offending condition. Reseed into loosened, fertile soil or replant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. |
| | Vegetation | Grass becomes excessively tall (greater than 10 inches); nuisance weeds and other vegetation start to take over. | Mow vegetation or remove nuisance vegetation so that flow is not impeded. Grass should be mowed to a height of 6 inches.<br>Mowing is not required for wet biofiltration swales. However, fall harvesting of very dense vegetation after plant die-back is recommended. |
| | Excessive shading | Grass growth is poor because sunlight does not reach swale. | If possible, trim back overhanging limbs and remove brushy vegetation on adjacent slopes. |
| | Inlet/outlet | Inlet/outlet areas are clogged with sediment/debris. | Remove material so there is no clogging or blockage in the inlet and outlet area. |
| | Trash and debris | Trash and debris have accumulated in the swale. | Remove trash and debris from bioswale. |
| | Erosion/scouring | Swale bottom has eroded or scoured due to flow channelization or high flows. | For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with 50/50 mixture of crushed gravel and compost. If bare areas are large (generally greater than 12 inches wide), the swale should be regraded and reseeded. 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. |

## Table 5.5.9. Maintenance standards for vegetated filter strip.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Recommended Maintenance to Correct Problem |
|---|---|---|---|
| **General** | Sediment accumulation on grass | Sediment depth exceeds 2 inches. | Remove sediment deposits. Relevel so slope is even and flows pass evenly through strip. |
| | Vegetation | Grass becomes excessively tall (greater than 10 inches); nuisance weeds and other vegetation start to take over. | Mow grass and control nuisance vegetation so that flow is not impeded. Grass should be mowed to a height of 6 inches. |
| | Trash and debris | Trash and debris have accumulated on the vegetated filter strip. | Remove trash and debris from filter. |
| | Erosion/scouring | Areas have eroded or scoured due to flow channelization or high flows. | For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with a 50/50 mixture of crushed gravel and compost. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the vegetated filter strip should be regraded and reseeded. For smaller bare areas, overseed when bare spots are evident. |
| | Flow spreader | Flow spreader is uneven or clogged so that flows are not uniformly distributed over entire filter width. | Level the spreader and clean so that flows are spread evenly over entire filter width. |

## Table 5.5.10. Maintenance standards for media filter drain.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Recommended Maintenance to Correct Problem |
|---|---|---|---|
| **General** | Sediment accumulation on grass filter strip | Sediment depth exceeds 2 inches or creates uneven grading that interferes with sheet flow. | Remove sediment deposits on grass treatment area of the embankment. When finished, embankment should be level from side to side and drain freely toward the toe of the embankment slope. There should be no areas of standing water once inflow has ceased. |
| | No-vegetation zone/flow spreader | Flow spreader is uneven or clogged so that flows are not uniformly distributed over entire embankment width. | Level the spreader and clean so that flows are spread evenly over entire embankment width. |
| | Poor vegetation coverage | Grass is sparse or bare, or eroded patches are observed in more than 10% of the grass strip surface area. | Consult with roadside vegetation specialists to determine why grass growth is poor and correct the offending condition. Reseed into loosened, fertile soil or compost or replant with plugs of grass from the upper slope. |
| | Vegetation | Grass becomes excessively tall (greater than 10 inches); nuisance weeds and other vegetation start to take over. | Mow vegetation or remove nuisance vegetation so that flow is not impeded. Grass should be mowed to a height of 6 inches. |
| | Media filter drain mix replacement | Water is seen on the surface of the media filter drain mix from storms that are less than a 6-month, 24-hour precipitation event. Maintenance also needed on a 10-year cycle and during a preservation project. | Excavate and replace all of the media filter drain mix contained within the media filter drain. |
| | Excessive shading | Grass growth is poor because sunlight does not reach embankment. | If possible, trim back overhanging limbs and remove brushy vegetation on adjacent slopes. |
| | Trash and debris | Trash and debris have accumulated on embankment. | Remove trash and debris from embankment. |
| | Flooding of media filter drain | When media filter drain is inundated by flood water | Evaluate media filter drain material for acceptable infiltration rate and replace if media filter drain does not meet long-term infiltration rate standards. |

## Table 5.5.11. Maintenance standards for permeable pavement.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Recommended Maintenance to Correct Problem |
|---|---|---|---|
| **General** | Sediment accumulation | Collection of sediment is too coarse to pass through pavement. | Remove sediment deposits with high-pressure vacuum sweeper. |
| | Accumulation of leaves, needles, and other foliage | Accumulation on top of pavement is observed. | Remove with a leaf blower or high-pressure vacuum sweeper. |
| | Trash and debris | Trash and debris have accumulated on the pavement. | Remove by hand or with a high-pressure vacuum sweeper. |
| | Oil accumulation | Oil collection is observed on top of pavement. | Immediately remove with a vacuum and follow up by a pressure wash or other appropriate rinse procedure. |
| **Visual facility identification** | Not aware of permeable pavement location | Facility markers are missing or not readable. | Replace facility identification where needed. |
| **Annual minimum maintenance** | | | Remove potential void-clogging debris with a biannual or annual high-pressure vacuum sweeping. |

## Table 5.5.12. Maintenance standards for dispersion areas (natural and engineered).

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Recommended Maintenance to Correct Problem |
|---|---|---|---|
| **General** | Sediment accumulation on dispersion area | Sediment depth exceeds 2 inches. | Remove sediment deposits while minimizing compaction of soils in dispersion area Relevel so slope is even and flows pass evenly over/through dispersion area. Handwork is recommended rather than use of heavy machinery. |
| | Vegetation | Vegetation is sparse or dying; significant areas are without ground cover. | Control nuisance vegetation. Add vegetation, preferably native ground cover, bushes, and trees (where consistent with safety standards) to bare areas or areas where the initial plantings have died. |
| | Trash and debris | Trash and debris have accumulated on the dispersion area. | Remove trash and debris from filter. Handwork is recommended rather than use of heavy machinery. |
| | Erosion/scouring | Eroded or scoured areas due to flow channelization, or high flows are observed. | For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel/compost mix (see Section 5-4.3.2 for the compost specifications). The grass will creep in over the rock mix in time. If bare areas are large (generally greater than 12 inches wide), the dispersion area should be reseeded. For smaller bare areas, overseed when bare spots are evident. Look for opportunities to locate flow spreaders, such as dispersion trenches and rock pads. |
| | Flow spreader | Flow spreader is uneven or clogged so that flows are not uniformly distributed over entire filter width. | Level the spreader and clean so that flows are spread evenly over entire filter width. |

## Table 5.5.13. Maintenance standards for wet ponds.

| Maintenance Component | Defect or Problem | Condition When Maintenance is Needed | Recommended Maintenance to Correct Problem |
|---|---|---|---|
| **General** | Water level | First cell is empty, doesn't hold water | 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. |
| | Trash and debris | Accumulations exceed 1 cubic foot per 1000 square feet of pond area. | Remove trash and debris from pond. |
| | Inlet/outlet pipe | Inlet/outlet pipe is clogged with sediment or debris material. | Unclog and unblock inlet and outlet piping. |
| | Sediment accumulation in pond bottom | Sediment accumulations in pond bottom exceed the depth of sediment zone plus 6 inches, usually in the first cell. | Remove sediment from pond bottom. |
| | Oil sheen on water | Oil sheen is prevalent and visible. | Remove oil from water using oil-absorbent pads or Vactor truck. Locate and correct source of oil. If chronic low levels of oil persist, plant wetland species such as *Juncus effusus* (soft rush), which can uptake small concentrations of oil. |
| | Erosion | Pond side slopes or bottom show evidence of erosion or scouring in excess of 6 inches and the potential for continued erosion is evident. | Stabilize slopes using proper erosion control measures and repair methods. |
| | Settlement of pond dike/berm | Any part of the pond dike/berm has settled 4 inches or lower than the design elevation, or the inspector determines dike/berm is unsound. | Repair dike/berm to specifications. |
| | Internal berm | Berm dividing cells are not level. | Level berm surface so that water flows evenly over entire length of berm. |
| | Overflow/spillway | Rock is missing and soil exposed at top of spillway or outside slope. | Replace rocks to specifications. |

### 5-5.2.1 Documenting and Preserving Intended Functions

Natural and landscaped areas designated as stormwater management facilities must be identified in the field and documented for future reference. The locations of these areas are documented in the WSDOT GIS Workbench, right of way plans, and as-built plans. During the post-construction meeting, these treatment facilities are identified to maintenance personnel. Note: Specially marked delineators are placed to notify maintenance personnel that a sensitive feature is in the area. The type and placement of this marker must be worked out between the maintenance and design offices.

### 5-5.2.2 Sensitive Area Mapping

State roadways have been surveyed to provide information to WSDOT maintenance crews so that BMPs may be employed to eliminate or reduce the impacts of maintenance activities on streams, wetlands, and water bodies. The primary objective of the survey was to identify all locations where these sensitive areas are within 300 feet of a roadway. A secondary objective was to note those areas that are particularly sensitive or insensitive in order to support appropriate maintenance actions and application of BMPs. This effort does not eliminate the need for detailed biological evaluation of resources during highway project planning. This survey information is located on the GIS Workbench. When wetlands on WSDOT-owned right of way are delineated and new wetlands created, this information must be documented in the GIS Workbench. The GIS Workbench is used to update the Maintenance Roadside Sensitive Area Atlases.

### 5-5.2.3 Stormwater Inventory

The stormwater database can be a valuable tool for design engineers. The stormwater database contains all of the data used to prioritize stand-alone stormwater retrofit projects. In addition to the data used to derive retrofit priorities for each outfall, several hundred complete records contain BMP retrofit recommendations, conceptual design information, BMP cost estimates, drainage basin characteristics, conveyance system information, photographs, field sketches, and preliminary facility sizing calculations. To obtain stormwater database information about specific outfalls, contact the Region Hydraulics and Water Quality offices or the HQ ESO Stormwater & Watersheds Program. Further information is available in Section 3-3.7.

## 5-6 References

API. 1990. Design and operation of oil-water separators. American Petroleum Institute Publication 421, February 1990.

Bureau of Reclamation. 1978. Hydraulic design of stilling basins and energy dissipaters, Publication EM 25. U.S. Bureau of Reclamation.

Cahill Associates. Section 02725 – General porous paving and groundwater infiltration beds. In *General Specifications only: Porous Paving* 02725-1

Cahill, T.H., Adams, M., & Marm, C. (2003, September/October). Porous asphalt: The right choice for porous pavements. *Hot Mix Asphalt Technology, 26-40.*

Chang, G.C. 2000. Review of stormwater manual, sand filtration basins for Department of Ecology, State of Washington. November 5, 2000.

Chollack, Tracy, et al., 2001. Porous Pavement Phase 1 Evaluation Report. Seattle Public Utilities, Report, Seattle, Washington. February 7, 2001.

Chow, V.T. 1959. Open-channel flow. McGraw-Hill, Boston, MA.

City of Austin. 1988. Design guidelines for water quality control basins, environmental criteria manual. June 1988. Austin, Texas.

Claytor and Schueler. 1996. "Design of Stormwater Filtering Systems. Center for Watershed Protection. Chesapeake Research Consortium. Silver Spring, MD.

Daugherty, R.L. and J.B. Franzini. 1977. "Fluid Mechanics with Engineering Applications," McGraw-Hill, New York.

Ecology. 2004. *Stormwater Management Manual for Eastern Washin*gton. Washington State Department of Ecology.

Ecology. 2004. "Washington State Wetland Rating System for Eastern Washington." Revised Ecology Publication # 04-06-15. Washington State Department of Ecology Publication.
www.ecy.wa.gov/programs/sea/wetlandratings/pdf/ 0406015-part1.pdf

Ecology. 2005. *Stormwater Management Manual for Western Washington*. Washington State Department of Ecology.

Ecology. 2005. Washington State Wetland Rating System for Western Washington. Washington State Department of Ecology Publication.
www.ecy.wa.gov/biblio/0406025.html

Federal Highway Administration. 2002. Construction of Pavement Subsurface Drainage Systems. Publication FHWA IF-01-014. Washington, D.C.

FHWA. 1983. Hydraulic design of energy dissipaters for culverts and channels. Hydraulic Engineering Circular No. 14 (HEC-14), FHWA-EPD-86-110. U.S. Department of Transportation, Federal Highway Administration.

FHWA. 1995. Geosynthetic design and construction guidelines. Publication No. FHWA HI-95-038. Federal Highway Administration. May 1995.

FHWA. 2002. Construction of pavement subsurface drainage systems. Publication No. FHWA-IF-01-014, HIPA-20/1-02(500). January 3, 2002. U.S. Department of Transportation, Federal Highway Administration.

*Georgia Stormwater Management Manual*, Section 3.3.5.

Harrison, R.B., M.A. Grey, C.L. Henry and D. Xue. 1997. Field test of compost amendment to reduce nutrient runoff, final report.

Hitchcock, G.L and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Hortus Northwest. 1991. Wetland plants for western Oregon.

Jaisinghani, R.A., et al., 1979. A study of oil/water separation in corrugated plate separators. Journal of Engineering for Industry, November, 1979.

Kadlec, R.H. and R.L. Knight. 1996. Treatment Wetlands. Lewis Publishers, Boca Raton, FL. 893p.

King County. 1998. King County, *Washington Surface Water Design Manual*. King County Department of Natural Resources, Seattle, WA.

Lau, Marsalek, and Rochfort. 2000. Use of a biofilter for treatment of heavy metals in highway runoff. Water Quality Research Journal of Canada 35(3):563–580.

Metro. 1990. Water pollution control aspects of aquatic plants. Municipality of Metropolitan Seattle.

Miller, S. 2000. Criteria for assessing the trace element removal capacity of bio-filtration systems. Spokane County.

Mollick, R.B. et al., 2000. Design, Construction and Performance of New-Generation Open-Graded Friction Courses. National Center for Asphalt Technology. Auburn University, Alabama.

NCHRP. 1994. Long-term performance of geosynthetics in drainage applications. NCHRP Report 367.

Prince George's County. 2001. *The Bioretention Manual*. Prince George's County Programs and Planning Division.

Puget Sound Action Team. 2005. *Low Impact Development Technical Guidance Manual for Puget Sound.*

Schueler, Thomas, Peter Kumble, and Heraty, Anacostia Restoration Team, Metropolitan Washington Council of Governments. 1992. "A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone." Prepared for U.S. Environmental Protection Agency.

Thullen, J.S., J.J. Sartoris, and W.E. Walton. 2002. "Effects of Vegetation Management in Constructed Wetlands Treatment Cells on Water Quality and Mosquito Production." *Ecological Engineering* 18 (2002) 441-457.

U.S. EPA. 1993. "Guidance Specifying Management Measures For Sources of Nonpoint Pollution In Coastal Waters." EPA-840-B-92-002. U.S. Environmental Protection Agency (USEPA), Office of Water, Washington, D.C.

U.S. EPA Technology Fact Sheets. www.epa.gov/owm/mtb/mtbfact.htm

U.S.A.F. Circa 1991. Gravity oil and water separator design criteria. U.S. Air Force.

U.S. COE. 1994. Selection and design of oil and water separators. U.S. Army Corps. of Engineers. August 26, 1994.

UW. 1994. Field test of compost amendment to reduce nutrient runoff. University of Washington, College of Forest Resources, Seattle, WA.

WEF and ASCE. 1998. Urban runoff quality management. Water Environment Federation and American Society of Civil Engineers.

WPCF. 1985. Clarifier Design. Water Pollution Control Federation: Manual of Practice. No. FD-8.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. "Evaluation and Management of Highway Runoff Water Quality." FHWA-PD-96-032, Federal Highway Administration.

# CHAPTER 6

# Temporary Erosion and Sediment Control Design Guidelines and Process

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# Chapter 6 Temporary Erosion and Sediment Control Design Guidelines and Process

## 6.1 Introduction

Comprehensive construction stormwater planning prevents sediment and other pollutants associated with construction activity from impacting soil, air, and water quality. Such impacts are subject to federal, state, and local regulatory requirements and can increase project costs through legal fines and repair of site damage that causes delays to project delivery.

The Washington State Department of Transportation (WSDOT) uses temporary erosion and sediment control (TESC) plans and spill prevention control and countermeasures (SPCC) plans to adequately and systematically identify and minimize project risk during construction projects. Together, the TESC and SPCC plans satisfy the National Pollutant Discharge Elimination System (NPDES) Construction Stormwater General Permit (CSWGP) Stormwater Pollution Prevention Plan (SWPPP) requirements in Washington State. Every TESC plan must include planning information for the 12 elements listed in Section 6-2.1.2. Note that these are the same 12 planning elements as those listed in the CSWGP.

**All projects that disturb soil must comply with the 12 TESC elements** (see Section 6-2.1.2) and must apply best management practices (BMPs) approved by the Washington State Department of Ecology (Ecology). A TESC plan must be prepared if a construction project adds or replaces (removes existing road surface down to base course) more than 2,000 square feet of impervious surface or disturbs more than 7,000 square feet of soil. Projects that do not meet these thresholds must perform erosion control planning by addressing the 12 TESC elements in a written document; however, a stand-alone TESC plan (narrative and plan sheets) is not required.

All WSDOT staff who design or implement TESC plans must attend the Construction Site Erosion and Sediment Control Course (course code BPW). This 8-hour course covers WSDOT procedures for water quality monitoring, sampling and reporting, TESC planning and implementation, basic principles of erosion and sedimentation, and information about BMP selection, installation, and maintenance. Section 6-4 has more information about how this course may be used in the internal Certified Erosion and Sediment Control Lead (CESCL) training program. Contact the Statewide Erosion Control Lead (360-570-6654) for class scheduling and availability, or get on the course request list.

SPCC plans are prepared by the contractor as required in the *Standard Specifications for Road, Bridge, and Municipal Construction* (*Standard Specifications*), Section 1-07.15(1). Instructions for plan preparation are available to contractors at the Headquarters (HQ) Hazardous Materials Program website:
www.wsdot.wa.gov/environment/hazmat/spillprevention.htm

## 6-2 TESC Plan

A good TESC plan clearly establishes when and where specific BMPs will be implemented to prevent erosion and the transport of sediment from a site during construction. Every TESC plan must address the 12 TESC planning elements (the same as the 12 SWPPP elements in the CSWGP), which are described later in this chapter.

**A TESC plan consists of a narrative section and plan sheets.** The narrative section includes a site-specific risk analysis for each TESC element, as well as documentation to explain and justify the pollution prevention decisions made for the project. The TESC plan sheets show the BMP locations and other features, such as topography and sensitive area locations for multiple project stages. Large projects that will be under construction for multiple seasons should create phased TESC plans (or multiple TESC plans for projects that require unique erosion control measures for each phase).

**You must include the following information in the TESC plan narrative:**

- Existing site conditions (such as topography, precipitation, drainage, soils, and vegetation).
- Potential erosion problem areas.
- A risk analysis for the 12 TESC elements, including a list of the BMPs chosen to address those risks. Include a list of applicable Standard Specifications, General Special Provisions (GSPs), and Special Provisions as needed.
- Construction phasing/sequencing plans and a general BMP implementation schedule (to be confirmed at the preconstruction meeting with the contractor).
- A contingency plan or backup plan that describes the actions to be taken if BMP performance goals are not achieved.
- Engineering calculations for ponds.

**The contract plan sheets must include:**

- Direction of north, property lines, existing structures and roads, and impervious surfaces.
- Cut and fill slopes indicating the top and bottom of slope catch lines.
- Approximate slopes, contours (topography), and direction of stormwater flow before and after major grading activities (drainage basins).
- Areas of soil disturbance and areas that will not be disturbed (clearing limits and vegetation protection).
- Stormwater treatment areas, including locations of structural and nonstructural controls (BMPs).
- Locations of off-site material, stockpiles, waste storage, borrow areas, and vehicle/equipment storage areas that are covered under WSDOT permits.

- Locations of all surface water bodies, and receiving waters, including wetlands.
- Locations where stormwater or nonstormwater discharges off-site, into surface waters of the state, into storm sewer systems that drain to waters of the state, or into a surface water body, including wetlands.
- Location(s) of discharge water quality sampling station(s).
- Areas where final stabilization has been accomplished and no further construction-phase permit requirements apply.

WSDOT has a web-based TESC planning tool that helps designers create thorough TESC plan narratives. The TESC planning tool helps the designer review plan requirements, do a risk analysis for the 12 TESC elements, select BMPs, and identify contractual tools to ensure enforcement of TESC plans. The planning tool helps ensure consistency in plan format as it automatically organizes and generates the TESC plan narrative. It also assists in the TESC plan review process. Training will be made available as needed based on the course request list (course code CAY). For further information, contact the Statewide Erosion Control Lead (360-570-6654) at the HQ Environmental Services Office (ESO).

A TESC plan template, which provides information on how to create an effective TESC plan, is available online for non-WSDOT TESC plan designers at the HQ Erosion Control Program website: www.wsdot.wa.gov/environment/waterquality/erosioncontrol.htm

## 6-2.1 Step-by-Step Procedure for Preparing TESC Plans

### 6-2.1.1 Data Collection and Risk Analysis

Before creating a TESC plan, designers should collect site-specific information about the factors that control erodibility (soil, precipitation patterns, topography, drainage patterns, including adjacent areas and the potential for run-on water from off-site areas), groundwater, sensitive areas on or near the site, and vegetated areas). On any given project, designers will be able to control some of these factors, but not others. Evaluating risks associated with each of these factors is a necessary step before designers can determine the level of effort needed to address the 12 TESC elements and begin to select the appropriate BMPs. A successful TESC plan will mitigate risk with proactive planning and appropriate BMP selection.

Most high-risk construction projects discharge to state waters within 300 feet of the project, and they meet at least three of the following four characteristics:

- More than 50% of the site consists of soils in Hydrologic Groups C and D. This information is obtained from Natural Resource Conservation Service (NRCS) county soil surveys.
- The project involves wet-season (October through April west of the Cascades or October through June east of the Cascades) work or lasts more than one year.
- Cut/fill slopes exceed more than 50 feet in length.
- Active seeps or shallow groundwater is present on the project site.

TESC plan designers should use the guidance provided below when preparing to collect and analyze site-specific information for the TESC planning process. The information gathered during this process should be used when creating the TESC plan narrative and shown on the contract plan sheets where feasible.

1. **Soils**

   The proportion of sand, silt, and clay particles in the soil determines soil texture. Soil texture affects the erodibility and cohesiveness of the soil, how quickly the particles will gravity settle, and the amount of infiltration that may occur.

   Knowing the characteristics of on-site soil will help designers select appropriate BMPs. Information on soil texture can be obtained for any given project from several sources, including geotechnical reports/soil boring logs, jar testing, on-site evaluation, and NRCS soil survey reports for individual counties.

   The *Construction Site Erosion and Sediment Control Course Manual* and Chapter 4 (Hydrologic Analysis) provide guidelines for determining soil-related risks, including the methods listed above. Additional WSDOT resources include Region Environmental, Maintenance, and Landscape offices, Region Materials Engineers, and the HQ Erosion Control Program.

2. **Precipitation Patterns**

   The frequency, intensity, and duration of rainfall events affect the potential for water erosion on a site. Frequency and duration of rainfall events influence soil saturation. Once soil becomes saturated, more water will flow over the top of the soil rather than infiltrating, and this can increase the potential for erosion or discharge from the project boundaries. High-intensity rainfall events increase the risk of raindrop or splash erosion. They can also create large or flashy runoff volumes, which need to be managed to prevent damage to slopes, conveyances, drainage features, and downstream properties.

   Knowing the probability of these precipitation patterns at any given location will help designers select appropriate BMPs. This information is vital to the timing and phasing of projects to minimize erosion potential.

   The *Hydraulics Manual* (Chapter 2, Appendix 2-3) contains isopluvial maps for mean annual precipitation, design storm events, and mean annual runoff that can all be used to get a general idea about rainfall patterns in any given part of the state. A design storm event is a storm with a magnitude, rate, and intensity that do not exceed the design load of the storm drainage system on the project.

   The Western Regional Climate Center (WRCC) website has statistical information on precipitation, temperature, and several other climatic measurements for over 200 sampling stations throughout the state. The WRCC website (www.wrcc.dri.edu/summary/climsmwa.html) includes tabular and graphical information as well as interactive probability-graphing capabilities.

3. **Topography**

   The three-dimensional surface of the project terrain will influence the potential for erosion. The potential for erosion increases exponentially with increasing slope length and gradient; as runoff travels faster, it holds more erosive energy. Higher-velocity runoff can form rills and gullies that concentrate erosive flows and energy even further.

   Designers should evaluate the size, slope length, gradient, and stability (soil type or vegetative cover) of planned slopes in the project work area to assess potential risks during construction. Whenever slopes are created with Hydrologic Group C or D soils, there is an increased risk of large slope failures, especially when silt content exceeds 30%. All soil types, regardless of composition, are vulnerable to rapid rill and gully erosion when concentrated flows are not diverted away from slopes. In addition, groundwater seepage greatly increases the potential for slope failures with all soil types.

   Designers should identify areas that can be used to reduce the risk of erosion and turbid water discharges. Closed depressions, upland areas, flat areas, and vegetated areas can be used to disperse or infiltrate runoff, thereby greatly reducing the risk of turbid water discharges. Dispersion, infiltration, and bioinfiltration areas must be labeled on the TESC plan sheets. Flow to these areas must be managed to encourage complete infiltration and avoid discharges whenever possible. Refer to Chapter 4 (Section 4-5) for the Infiltration Design Criteria that should be used when designating and managing infiltration areas.

4. **Drainage Patterns/Adjacent Areas**

   Off-site water that runs onto a project can cause tremendous damage because the contributing area may generate stormwater volumes that far exceed the capacity of designed on-site stormwater conveyance and treatment BMPs such as ponds. Some of WSDOT's largest erosion-related cost overruns and fines in past years were related to off-site water entering construction sites.

   Identify potential sources of off-site water during the TESC planning phase. Off-site water sources may include: natural sheet flow from neighboring facilities; permitted or illicit stormwater outfalls from neighboring buildings and parking lots; overland flow from upland areas outside the project boundary; groundwater seeps; water from neighboring construction projects; or unmapped seasonal drainages.

   Design a TESC strategy for managing overland flow or off-site water as it crosses slopes to reduce the risk of erosion. Slope cover BMPs cannot adequately protect a slope from concentrated runoff. Use top-of-slope BMPs to prevent concentrated flows from reaching cut and fill or exposed slopes.

   Handle off-site water separately from stormwater generated on the site. If off-site water enters project boundaries and comes into contact with construction activity, it becomes the responsibility of the project. Whenever possible, divert off-site stormwater around the site in a lined channel or pipe to prevent erosion

and mixing with on-site stormwater. Redirect diverted flows to the natural drainage location at or before the property boundary and discharge in a manner that does not cause downstream erosion.

Take the following actions to evaluate the potential for off-site stormwater problems:

- When prescribing temporary measures, refer to the Hydraulic Report to quantify the potential for off-site water.
- Consult maintenance personnel to determine drainage patterns and general volumes.
- Visit the site during a rainstorm and confirm runoff patterns.

5. **Groundwater**

Seasonably high groundwater levels affect stormwater infiltration and timing of construction. Expected groundwater levels can usually be determined from the geotechnical survey of the site. County soil surveys also provide general information on groundwater levels, including the seasonality of high water tables. Groundwater levels can fluctuate greatly throughout the year; data from winter (wet season) is the most important to determine the level of risk associated with groundwater.

If groundwater is less than 5 feet below the ground surface, there is a higher potential for discharges to groundwater to occur. Areas with high groundwater shall not be considered for infiltration areas. Refer to Chapter 4 of this manual (Section 4-5) for the Infiltration Design Criteria that should be used when designating and managing infiltration areas.

Evaluate the probability of intercepting groundwater seeps and springs by using geotechnical reports, county soil maps, and on-site field evaluations. To further evaluate project risk, contact WSDOT Project Engineers for information about past projects in the area to determine whether problems were encountered with the seasonality, quantity, treatment, and disposal of groundwater.

6. **Sensitive Areas**

Delineate stream and wetland boundaries in the field and show them with their buffer zones on the plan sheets. Place sediment control BMPs (such as silt fence, wattle, compost berm or sock, or vegetated buffer strips) between the site and downslope of sensitive areas.

Never consider ditched streams or other sensitive areas for dispersion, infiltration, and bioinfiltration activities. Refer to Chapter 4 (Section 4-5) for the Infiltration Design Criteria.

When developing the TESC plan, always refer to environmental studies and permits for the project if they have been completed. These documents often provide an assessment of how sensitive the receiving waters are and specify

measures that are required as conditions of the project. Consult Region Environmental staff if the studies and permits are not yet completed.

7. **Vegetation Preservation/Utilization**

   Preserve vegetation to reduce the potential for erosion. By doing so, downslope sediment treatment areas, such as infiltration ponds, will remain functional longer. Set clearing limits to minimize vegetation removal. Consider phasing vegetation removal when developing plans. Preserved vegetation can be highly effective for dispersing and infiltrating runoff. Label the existing vegetation that will be protected on the TESC plan sheets.

8. **Existing Encumbrances**

   Check for existing encumbrances, such as utilities, wells, or drain fields, to ensure the TESC plan identifies them, protects them from erosion impacts, and addresses any potential erosion risks.

9. **Timing and Duration**

   During the design phase, it is often impossible to know the timing and duration of a project. As timing often depends on funding, permitting, and other issues, and duration varies with contractors and weather conditions, prepare your TESC plans assuming worst-case conditions for timing and duration.

10. **Contingency Plans**

    Identify areas and activities that are at a higher risk for erosion and sediment control issues. Develop some general plans to explain the actions to be taken if BMP performance goals are not achieved. Contingency plans could include using detention tanks for temporary containment of water that does not meet benchmarks or using pumps or plugs to prevent a discharge. If necessary, use approved methods for chemical treatment or neutralization.

### 6-2.1.2 BMP Selection/TESC Elements

For comprehensive descriptions of individual BMPs, see Appendix 6A.

Review the BMP selection information (part 1 below) before selecting appropriate BMPs for each element (part 2 below). **You must include all 12 elements in every TESC plan**. If site conditions render an element unnecessary, clearly justify the exemption in the narrative of the TESC plan.

1. **BMP Selection**

   The three categories of BMPs that exist include *design*, *procedural*, and *physical*. Use a combination of all three to create an effective TESC strategy. Each BMP type is described in detail below.

The priority in selecting BMPs should be to prevent erosion from occurring, rather than simply treating turbid runoff that is the result of erosion. Enhance this effort by maximizing the use of design and procedural BMPs before prescribing physical BMPs. The effectiveness of physical BMPs is limited if you do not properly consider design and procedural BMPs.

### *Design BMPs*

A project design that minimizes erosion risk can greatly reduce complications, both during and after construction. Take all possible measures to minimize clearing and grading that exposes soil to erosion. For example, design projects to integrate existing land contours as much as possible and minimize the gradient and continuous lengths of slopes. Design drainages to convey water generated both on and off the site to infiltrate and flow away from the disturbed areas as much as possible.

### *Procedural BMPs*

How and when a project is built can greatly affect the potential for erosion. Sequence construction to minimize the duration and extent of soil disturbance. Whenever possible, conduct major soil-disturbances in phases to minimize exposed areas. Likewise, limit major grading operations to the dry season whenever feasible. Installing physical sediment control BMPs before grading operations is one of the most important procedural BMPs.

### *Physical BMPs*

Physical BMPs include all approved erosion and sediment control measures installed after all possible design and procedural BMPs have been considered. The *Standard Specifications*, Section 8-01, provides guidance on the installation, inspection, and maintenance of physical BMPs. Appendix 6A and the *Construction Site Erosion and Sediment Control Course Manual* provide more detailed information on physical BMPs.

2. **TESC Elements**

The 12 TESC elements are described below. You must consider all elements and include them in the TESC plan. If site conditions render an element unnecessary, clearly justify the exemption in the narrative of the TESC plan for that element. Common design and procedural BMPs are described for each element, followed by a list of approved physical BMPs, if applicable.

- ***TESC Element 1: Mark Clearing Limits***

  Before conducting land clearing and disturbance activities, mark all clearing limits on the plan sheets and in the field. Retain duff layer, native topsoil, and existing vegetation in an undisturbed state to the maximum extent practicable.

Use high-visibility fencing to define clearing limits (including vegetation to be preserved). Use high-visibility fence to protect sensitive areas and their buffers (orange silt fence should only be used in sensitive areas where turbid runoff is a concern.) Refer to Fencing, BMP 6A-2.11, for additional detail.

PHYSICAL BMPS

- Preserving natural vegetation
- Buffer zones
- Orange silt fence
- High visibility fence

- ***TESC Element 2: Establish Construction Access***

Stabilize access points with a pad of quarry spalls underlaid with geotextile fabric, crushed rock, steel rumble pad or equivalent BMP, per Standard Specification 8-01.3(7) and the *Standard Plans*. Install stabilized construction access points before major grading operations take place. Limit access points to the fewest number possible, using only one when feasible. Whenever practicable, slope entrances downward into the site to prevent discharges onto the roadway. If sediment is tracked off-site, clean roads thoroughly at the end of each day, and more frequently if necessary. Remove sediment from roads by shoveling or sweeping, and transport removed sediment to a controlled disposal area. Sweeping does not remove fine sediment particles from the roadway; therefore, a rain event can still cause a turbid discharge. Do not use sweeping as a substitute for a stabilized construction entrance.

If the stabilized construction entrance is not effective in preventing sediment from being tracked onto roads, install a tire wash on-site per Standard Specification 8-01.3(7). Discharge tire wash-water to a separate on-site treatment system that prevents discharge to surface water, such as a closed-loop recirculation system or upland application, or to a sanitary sewer (with prior local sewer district approval). Do not use an upland application if oil sheen or contaminated soils are present.

Street washing is only allowed after loose sediment is removed from the street. If streets are washed with water, treat the wash-water before discharge.

PHYSICAL BMPS

- Stabilized construction entrance
- Construction road stabilization
- Steel rumble pad
- Street cleaning
- Tire wash

- ***TESC Element 3: Control Flow Rates***

  Protect downstream properties and waterways from erosion by preventing increases in the volume, velocity, and peak flow rate of stormwater runoff from the site during construction. Maintain and treat runoff as sheet flow whenever possible. Minimize soil erosion by controlling stormwater volume and velocity within the site. Control peak flow and discharge rates to minimize erosion at outlets and downstream channels and/or streambanks. Install retention/detention facilities as one of the first steps in grading, for use as infiltration or sedimentation facilities before mass grading and the construction of site improvements. Design sediment ponds and traps using criteria contained in Section 4-3.3 for western Washington or Section 4-4.3 for eastern Washington. Design drainages to account for both on- and off-site water sources. Use vegetated areas that are not identified as wetlands or other sensitive areas/features to disperse and infiltrate water whenever possible, and mark those areas on the TESC plan sheets.

  Control authorized nonstormwater (such as uncontaminated dewatering and water line flushing) discharges to protect downstream properties. When nonstormwater is routed through separate storm sewer systems, control the flow rate to minimize scouring and flushing of sediment trapped in the system.

  PHYSICAL BMPS

  - Temporary sediment pond
  - Detention tank
  - Sediment trap
  - Stormwater infiltration

- ***TESC Element 4: Install Sediment Controls***

  Install sediment control BMPs before soil-disturbing activities to minimize sediment releases from site. Continue to consider site-specific factors, such as changing topography and soil characteristics, during the installation and ongoing maintenance of the TESC plan.

  Install the permanent sediment control facilities to provide flow control as early in the construction process as feasible. Protect infiltration facilities from siltation during the construction phase. Before concentrated stormwater runoff from disturbed areas leaves a construction site or discharges to an infiltration facility, it must pass through sediment-trapping BMPs such as check dams or traps. Direct sheet flow runoff through sediment control BMPs specifically designed to remove sediment from sheet flows, such as filter berms, vegetated filter strips, wattles, or compost socks.

Provide and maintain natural buffers around sensitive areas where feasible. Direct turbid stormwater to upland vegetated areas for infiltration where feasible. Also where feasible, design outlet structures that will withdraw or discharge stormwater from the surface of detained water to avoid discharging sediment that is suspended lower in the detained water column.

PHYSICAL BMPS

- Silt fence
- Check dam
- Outlet protection
- Surface roughening
- Inlet protection
- Wattle
- Vegetated filter strip
- Filter berm (gravel, wood chip, or compost)
- Construction stormwater filtration
- Temporary sediment pond or trap
- Street cleaning
- Level spreader
- Portable storage water tanks
- Stormwater chemical treatment*
- Preserving natural vegetation

*Contact Region Environmental when planning to use stormwater chemical treatment as a TESC strategy.

- ***TESC Element 5: Stabilize Soils***

  Stabilize all exposed and unworked soils by applying effective BMPs that protect the soil from wind, raindrops, and flowing water. Selected soil stabilization measures must be appropriate for the time of year, site conditions, estimated duration of use, and the water quality impacts that stabilization BMPs may have on downstream waters or groundwater. Consider site-specific factors such as climate patterns, topography, and soil characteristics when choosing products like erosion control blankets or hydraulically-applied mulches.

  Minimize the amount of soil exposed during construction. Minimize disturbance of steep cut-and-fill slopes. Minimize soil compaction in areas that will be permanently vegetated and, unless infeasible, preserve topsoil.

  Stabilize and address construction activity, including equipment staging areas, material storage areas, and borrow areas that are within WSDOT's project limits, in the TESC plan.

  Stockpiles and cut-and-fill slopes are especially vulnerable to slumping when they become saturated. Stabilize or protect all stockpiles and cut-and-fill slopes that are not actively being worked. Depending on the soil type, plastic may be the best option on stockpiles, as it is the only BMP that can prevent soil saturation (unless the stockpile is located under a covered area). Locate stockpiles away from storm drain inlets, waterways, and drainage channels where possible.

In western Washington, you must cover exposed soil that is not being worked by hand or machinery (walking or driving over exposed soil is not considered working an area)—whether at final grade or not—within the following time limits, using approved soil cover practices:

| | |
|---|---|
| **October 1 through April 30** | **2 days maximum** |
| **May 1 through September 30** | **7 days maximum** |

Maximum time limits for all soil cover practices are defined in calendar days. A calendar day is a period of 24 consecutive hours starting at midnight and ending the following midnight.

In eastern Washington, cover exposed soil that is not being worked by hand or machinery (walking or driving over exposed soil is not considered working an area)—whether at final grade or not—within the following time limits, using approved soil cover practices:

| | |
|---|---|
| **July 1 through September 30** | **10 days** |
| **October 1 through June 30** | **5 days** |

In the Central Basin region of eastern Washington (areas receiving 12 inches or less of annual rainfall), cover exposed soil that is not being worked by hand or machinery (walking or driving over exposed soil is not considered working an area)—whether at final grade or not—within the following time limits, using approved soil cover practices. For precipitation maps:
www.wsdot.wa.gov/design/hydraulics/

| | |
|---|---|
| **July 1 through September 30** | **30 days** |
| **October 1 through June 30** | **15 days** |

If any portion of the project lies in areas that receive more than 12 inches of annual precipitation, follow the soil coverage time limits for eastern Washington, not for the Central Basin. (Contact the Region Hydraulics Office staff to confirm average annual rainfall.)

Expose no more soil than can be covered within the above time limits. Construction activities should never expose more erodible earth than the amounts shown below for the specified locations (without written approval by the Engineer).

| Area | Date | Location |
|---|---|---|
| 17 Acres | April 1 – October 31 | East of the Summit of the Cascade Range |
| | May 1 – September 30 | West of the Summit of the Cascade Range |
| 5 Acres | November 1 – March 31 | East of the Summit of the Cascade Range |
| | October 1 – April 30 | West of the Summit of the Cascade Range |

PHYSICAL BMPS

- Preserving vegetation
- Temporary mulching
- Soil binding using polyacrylamide*
- Placing erosion control blanket
- Placing compost blanket
- Placing plastic covering
- Seeding and planting
- Long-term mulch
- Sodding
- Check dam**
- Wattle**
- Gravel base
- Stabilized construction entrance
- Construction road stabilization
- Dust control BMPs
- Moderate-term mulch

*While polyacrylamide (PAM) alone does help stabilize soils, using it in conjunction with mulch provides more protection for disturbed soil.

**Check dams and wattles alone do not stabilize soils. Use these BMPs in conjunction with other soil stabilization BMPs.

- ***TESC Element 6: Protect Slopes***

  Design and construct cut-and-fill slopes to minimize erosion by (1) reducing continuous length of slopes with terracing and diversions, (2) reducing slope steepness, and (3) roughening slope surfaces, considering the soil type and its potential for erosion. In addition, protect all soil from concentrated flows through temporary conveyances such as top of slope diversions and pipe slope drains.

  Manage overland flow to prevent erosion on slopes. Ensure concentrated flows running off overhead structures do not hit slopes. If flow is exclusively surface water, use the design criteria contained in Section 4-3.3 for western Washington or Section 4-4.3 for eastern Washington. If flow is from seeps or groundwater, use your best professional judgment in consultation with the Region Materials Engineer (RME) when sizing slope drains.

  Use a solid lining for conveyances exceeding a 10% slope. To capture sediment and runoff when cutting trenches, place excavated soil on the uphill side of the trench (when consistent with safety and space considerations).

Place check dams at regular intervals (see the *Standard Plans*) within constructed channels that are cut down a slope.

PHYSICAL BMPS

- Channel lining (riprap, grass)
- Temporary pipe slope drain
- Temporary curb
- Interceptor dike and swale
- Subsurface drains
- Level spreader
- Live fascines
- Gradient terraces
- Physical BMPs listed under TESC Element 5 (with the exception of stabilized entrance and road stabilization)

- ***TESC Element 7: Protect Drain Inlets***

  Protect all operable storm drain inlets from sediment with approved inlet BMPs. These inlet protection devices must be capable of being maintained and must be inspected and maintained often. These devices clog easily and overflow; therefore, the priority should always be to prevent turbid water from reaching inlets using source control BMPs. Wherever feasible, use inlet covers or plugs.

  PHYSICAL BMPS

  - Inlet protection devices (above/below grate and grate covers)
  - Compost sock
  - Check dam

- ***TESC Element 8: Stabilize Channels and Outlets***

  Design, construct, and stabilize all temporary conveyance channels to prevent erosion. Use the design criteria contained in Section 4-3.3 for western Washington or Section 4-4.3 for eastern Washington.

  Provide stabilization methods, including armoring material, adequate to prevent erosion at the outlets of all conveyance systems. Common outlet locations include areas where ponds, culverts, or pipe slope drains discharge. Plastic covering increases flow rates; stabilize outlet areas where water is running off plastic.

  Use a solid lining for conveyances exceeding a 10% slope.

  Place check dams at regular intervals based on the grade of the conveyance (see the *Standard Plans*).

PHYSICAL BMPS

- Channel lining (riprap, grass)
- Level spreader
- Check dam
- Temporary seeding and planting
- Erosion control blanket
- Sodding
- Outlet protection
- Quarry spalls

- ***TESC Element 9: Control Pollutants***

  Handle and dispose of all pollutants, including construction materials, waste materials, and demolition debris, in a manner that does not cause contamination of stormwater. Describe your methods for controlling nonhazardous pollutants in the TESC plan.

  Apply fertilizers and other chemicals in a manner and at application rates that will not result in loss of chemicals to stormwater runoff. Follow manufacturers' label requirements.

  Discharge tire wash wastewater to a separate on-site treatment system that prevents discharge to surface waters, such as a closed-loop recirculation system or upland application. Do not use upland application if oil sheen or contaminated soils are present. You may use the sanitary sewer with prior local sewer district approval.

  Concrete spillage or concrete wastewater discharge to waters of the state is prohibited. Wash out concrete trucks in designated concrete washout areas only. Wash concrete truck chutes, pumps, and hand tools in formed areas actively awaiting installation of concrete or asphalt. When no formed areas are available, dispose of wash water and leftover product in a lined container or designated area that is designed and maintained to prevent discharge to surface waters of the state. Return unused concrete to the originating batch plant for recycling. Do not wash out concrete trucks near storm drains, open ditches, streets, natural or constructed stormwater conveyances, or streams. Refer to BMP 6A-2.33 for more information.

  Stormwater or groundwater that has come into contact with curing concrete or other pH-modifying substances may be allowed to discharge if correct monitoring and treatment methods are used. (See water quality monitoring protocols in Section 6-8 for pH monitoring and sampling procedures). Do not allow high-pH stormwater or groundwater to discharge into surface waters of the state. Infiltrate high-pH stormwater or groundwater in designated areas or neutralize prior to discharge. Refer to Chapter 4 (Section 4-5) for the Infiltration Design Criteria when designating appropriate infiltration areas.

Headquarters has created a GSP for controlling high-pH stormwater or dewatering water:
www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/8-01.3(1)a.opt1.gr8.pdf

Describe methods for controlling pollutants that can be considered hazardous materials, such as petroleum products and chemicals, in the contractor's SPCC plan. Provide cover, containment, and protection from vandalism for all hazardous materials. Include secondary containment for on-site fueling tanks. Secondary containment means placing fueling tanks within an impervious structure capable of containing 110% of the volume contained in the largest tank. Double-walled tanks and tanks with sufficient built-in secondary containment do not require additional secondary containment. The SPCC plan shall be consistent with Standard Specification 1.07.15(1) and Ecology's standards as described in WSDOT SPCC Plan Preparation Instructions and Spill Plan Reviewers Protocols:
www.wsdot.wa.gov/environment/hazmat/spillprevention.htm

- ***TESC Element 10: Control Dewatering***

  When groundwater is encountered in an excavation or other area, control, treat, and discharge it as described in Standard Specification 8-01.3(1)C.

  Uncontaminated dewatering water is an authorized nonstormwater discharge. If dewatering water comes into contact with pH-modifying substances, monitor and sample before discharge to surface waters of the state to ensure high-pH groundwater is not discharged into surface waters of the state. Infiltrate in designated areas or neutralize before discharge.

  Headquarters has created a GSP for controlling high-pH dewatering water:
  www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/8-01.3(1)a.opt1.gr8.pdf

- ***TESC Element 11: Maintain BMPs***

  A Certified Erosion and Sediment Control Lead (CESCL) must inspect BMPs per Standard Specification 8-01.3(1)B to ensure the BMPs perform their intended function properly until the Project Engineer determines that final stabilization is achieved. Final stabilization means completing all soil-disturbing activities and establishing a permanent vegetative cover or equivalent permanent stabilization measures (such as riprap) that prevent erosion.

  Maintain BMPs in accordance with Standard Specification 8-01.3(15). When the depth of accumulated sediment and debris reaches approximately one-third the height of the device, the contractor must remove the deposits. Stabilize uncontaminated sediments on-site in a controlled disposal area approved by the Project Engineer. Document BMP implementation and maintenance in the site log book.

Remove temporary BMPs within 30 days after final stabilization is achieved or after the BMPs are no longer needed. BMPs that are biodegradable and manufactured to be left in place and not interfere with maintenance or land use do not need to be removed.

- ***TESC Element 12: Manage the Project***

  Apply the following actions on all projects:

  (1) Preserve vegetation and minimize disturbance and compaction of native soil, except as needed for building purposes.

  (2) Phase development projects to minimize the amount of soil exposed at any one time and prevent the transport of sediment from the site during construction.

  (3) Time sediment control BMP installation in accordance with TESC Element 4.

  (4) To minimize erosion, follow soil cover timing requirements and exposure limits in TESC Element 5 and Standard Specification 8-01.3(1). Projects that infiltrate all runoff may not be required to obtain coverage under the CSWGP and therefore may be exempt from the above restrictions. Individual contract Special Provisions and Project Engineer directives may be more stringent, based on specific location characteristics or changing site and weather conditions.

  (5) Coordinate the work of utility contractors and subcontractors to meet requirements of both the TESC and SPCC plans.

  (6) Maintain a site log book that contains a record of the implementation of the TESC plan and related permit requirements, including the installation and maintenance of BMPs, site inspection reports, and stormwater monitoring information for all discharge locations.

  (7) Ensure site inspections are being performed as specified in Standard Specification 8-01.3(1)B and in accordance with TESC Element 11. Site inspections may be reduced to one per month on temporarily stabilized inactive sites (sampling must continue weekly if there is a discharge). Keep complete site inspection forms in the site log book.

  (8) Weekly discharge sampling must be done in accordance with Section 6-4 to ensure compliance. Sampling data must be kept in the site log book.

  (9) Ensure that the CESCL is on-site or on-call at all times and is identified in the TESC plan or site log book. Maintain current contact information so that the contractor's CESCL can be reached by Ecology or others as necessary.

Keep a copy of the current CESCL card in the site log book for any contractor staff responsible for performing site inspections and for the WSDOT staff responsible for collecting discharge samples.

(10) Keep the TESC and SPCC plans on-site or within reasonable access to the site. The TESC plan is a flexible document that should be modified (or adapted) when field conditions change. Modify the plan when inspections and/or monitoring reveal that the BMPs identified in the TESC plan are inadequate due to the actual or potential discharge of pollutants. Modify the plan as appropriate as soon as possible, but within 7 days. Fully implement and maintain BMPs as soon as possible, but within 10 days. Most of these updates can be drawn onto the plans sheets. The plan must also be updated whenever there are changes in the project design or in construction methods that could affect the potential for erosion or spills.

### 6-2.1.3 Schedule

The contractor must provide a construction schedule per Standard Specification 8-01.3(1)A. The schedule should specify TESC plan implementation to effectively reduce erosion risks. Include the following in the schedule:

- Install perimeter control and detention BMPs before soil-disturbing activities take place.
- Phase and time clearing, grubbing, and grading. Where feasible, phase and time work to minimize soil exposed at any one time and to prevent transport of sediment from the site during construction.
- Apply interim BMP strategies when construction activities interfere with the placement of final-grade BMPs.
- Discuss how temporary BMPs are to be transitioned into permanent BMPs.
- Implement an erosion control inspection and maintenance schedule.

The following is a general schedule guideline for implementing TESC BMPs during construction of a project:

1. Before any work on-site, WSDOT verifies:
    - The contractor has obtained permits for off-site staging/storage/borrow areas (per CSWGP requirement S1.C.2). Include staging/storage/borrow areas within WSDOT right of way in the TESC plan for the project.
    - The point(s) at which site stormwater runoff and authorized nonstormwater (such as dewatering water) leave the project boundary and enter surface water.
    - Locations where off-site stormwater can enter the project so that it can be diverted or tight-lined around the site, if applicable.

- Clearing limits.
- Appropriate infiltration areas within WSDOT's right of way (nonsensitive areas) or to neighboring properties with written permission. Label these areas on the TESC plan sheets as dispersion/infiltration areas.

2. Before any soil-disturbing activities, the contractor installs:
   - Storm drain inlet protection BMPs.
   - Perimeter control BMPs (such as construction entrances, silt fences, or clearing limit fences).
   - Diversion measures for off-site water, if applicable.
3. Before any other grading activities, excavate temporary sediment/detention ponds (or detention tanks installed) and pond stabilize or otherwise protect embankments against erosion per Standard Specification 8-01.3(1)E. Phase site clearing and grading so that runoff from exposed areas flows through stabilized conveyances to functioning sediment control BMPs.
4. Major construction excavation begins only after TESC measures are in place.
5. The contractor must provide weekly Look-Ahead Schedules per Standard Specification 1-08.3(2)D. Use this weekly schedule to proactively plan and coordinate upcoming TESC needs.
6. Install additional erosion and sedimentation control facilities, as needed, throughout construction. These additional methods are called adaptive management and must be drawn onto the TESC plan sheets to reflect actual field conditions per Standard Specification 8-01.3(1)B.
7. Maintain BMPs as necessary per Standard Specification 8-01.3(15).
8. Replace temporary BMPs with permanent BMPs as construction allows per Standard Specification 8-01.3(16).
9. Once all permanent construction is completed and permanent BMPs are functioning properly, remove the remaining temporary BMPs in accordance with Standard Specification 8-01.3(16). Remove temporary BMPs within 30 days after you achieve final stabilization. BMPs that are biodegradable and manufactured to be left in place and not interfere with maintenance or land use do not need to be removed.

### 6-2.1.4 Narrative and Plan Sheets

Show the physical BMPs specified in the narrative section of the TESC plan on the plan sheets where feasible. Include provisions for interim project conditions in the narrative section, not just the final configuration as shown on the plan sheets. The *Plans Preparation Manual* provides more information on plan sheet preparation.

1. **Scoping and Budgeting**

   The scope of a TESC plan includes all phases of construction. Include each phase of a construction project in the risk analysis and evaluation effort. Account for intermediate site configurations in the TESC scope; the process of staging requires multiple applications of BMPs. For example, a short-duration project may be scheduled and completed during the dry season, whereas a multi-year project may need soil cover BMPs for each wet season encountered. Consider inspecting and maintaining BMPs in scoping and budgeting, as well as repairing or replacing inadequate or malfunctioning BMPs.

   Even with the best planning and risk assessment, there is still an inherent risk associated with each project. For example, you may encounter groundwater where it is not expected, soil conditions are often worse than anticipated, and construction is sometimes delayed into the wet season in western Washington. In addition, low-probability storm events, such as high-intensity rainfall in mid-August, sometimes cannot be avoided. Even after completing a thorough risk assessment, scheduling a project to take advantage of optimum conditions, and incorporating a full range of BMPs, include extra materials and funds in the budget (force account) to provide for BMP adaptive management and contingency plans.

   Budgeting methods for erosion control are not as well developed as for more predictable construction activities. Additionally, erosion control overlaps with numerous other construction activities. The budgeting tools described below are intended to help when calculating the cost to install and maintain physical BMPs. One of the most accurate methods for calculating a TESC budget is to consult with technical personnel and specialists. Consultation with WSDOT personnel with experience on similar projects is recommended to confirm cost estimates for anticipated/selected BMPs.

2. **Cost-Based Estimate**

   Costs can be calculated from the labor and materials costs for individual items. This method can be time consuming; however, it is the only method available for many of the newer TESC products.

3. **Bid-Based Estimate**

   The HQ Design Office has some very useful tools for making bid-based estimates. The UnitBid Analysis and Standard Item Table (www.wsdot.wa.gov/biz/contaa) can be used to view per-unit costs for specific standard bid items on past WSDOT projects. This method can quickly provide a price range for most common erosion control bid items.

4. **Construction Contract Information System**

   The HQ Construction Office maintains the Construction Contract Information System (CCIS), which contains cost information from past projects. This database can be used to estimate future erosion control costs. If a project is being built in an area with a history of erosion challenges, the designer can query the database to view how much was estimated under the line items for Water Pollution Prevention/Erosion Control and other commonly used TESC BMPs versus how much was actually spent. For instance, on some state routes and on some project types, WSDOT consistently pays more than it estimates for erosion control. If the erosion control costs in an area are consistently greater than the estimates, consult the construction offices that experienced the cost overruns. Ask what factors caused the overruns, and incorporate extra measures into the erosion budget and the TESC plan to address problems and prevent or reduce such overruns on the upcoming project. WSDOT staff should contact their local help desk or workstation support personnel to obtain access to CCIS.

## 6-2.2 Contracting

The ability to enforce provisions in the TESC plan is directly tied to the contract. Contracts must be written to ensure all 12 TESC elements are addressed throughout construction. The contractual tools for ensuring the plan is properly enforced include the *Standard Specifications*, statewide and region-specific GSPs, Special Provisions, and erosion control plans in the *Standard Plans*. The TESC plan narrative itself will only be contractually enforceable if it is included in the contract.

Revisions are regularly made to the erosion control specifications in the *Standard Specifications* to do a better job of meeting the 12 elements within a TESC plan. However, in some cases they must be supplemented with GSPs or Special Provisions to ensure site-specific issues concerning erosion control are addressed in the contract language.

GSPs or Special Provisions should be prepared whenever the *Standard Specifications* do not address the specific needs of a project. Such provisions may involve limiting earthwork in the wet season, timing of pond installation, or requiring specific products. GSPs and Special Provisions have been written for many common erosion problems and can be pulled from existing libraries. The statewide library for GSPs and Special Provisions is provided on the HQ Design Office website: www.wsdot.wa.gov/design/projectdev/

Some regions also have their own libraries of regional GSPs that can be accessed by contacting the Region Plans Office. If there is no suitable provision, one must be written. Staff within design, construction, and environmental offices can often help and should be consulted.

## 6-3 Spill Prevention Control and Countermeasures Plan

A Spill Prevention Control and Countermeasures (SPCC) plan is required on all projects in order to prevent and minimize spills that may contaminate soil or nearby waters of the state. The contractor prepares the plan as a contract requirement and submits the plan to the Project Engineer before starting on-site construction activities. For further information, refer to Standard Specification 1-07.15(1).

The Hazardous Materials and Solid Waste Program provides online guidance to contractors for preparing SPCC plans, and provides training to WSDOT staff for reviewing an SPCC plan to ensure compliance with the following required elements:

- Site information and project description
- Spill prevention and secondary containment
- Spill response procedures
- Standby on-site material and equipment requirements
- Reporting information
- Program management
- Plans to contain preexisting contamination, if necessary
- Equipment for work below the ordinary high water line
- Attachments, including a site plan and Spill and Incident Report forms

SPCC plans are required to be project/site specific. When contractors write the SPCC plan in coordination with key WSDOT project staff, the plan must ensure the contractor:

- Handles all pollutants in a manner that does not cause contamination of stormwater.
- Covers, contains, and protects all materials from vandalism so that, if spilled, the materials would not pose an immediate risk to surface waters or groundwater.
- Maintains and repairs heavy equipment using spill prevention measures such as drip pans and, if necessary, cover.
- Applies fertilizers and herbicides following manufacturers' recommendations, to protect runoff water quality.
- Manages materials that modify pH, such as cement, concrete, kiln dust, fly ash, cement grindings, and cement wash-water to prevent contamination of runoff.

Additional SPCC guidance is available at:
www.wsdot.wa.gov/environment/hazmat/spillprevention.htm

## 6-4 Water Quality Sampling and Reporting Procedures

WSDOT has developed the following procedures to document compliance with local, state, and federal permit conditions. Use these procedures to evaluate the effectiveness of BMPs.

All water quality sampling required under the CSWGP must be performed by individuals who have received formal training in the water quality sampling procedures listed in this chapter (course code BPW). These individuals must understand the purpose and intent of the sampling procedures and be capable of performing these procedures in the field.

**Certified Erosion and Sediment Control Lead (CESCL) certification is required for all individuals performing these sampling procedures.** Ecology maintains a list of approved providers for the 2-day certification (and the 1-day renewal) training:
www.ecy.wa.gov/programs/wq/stormwater/cescl.html

Individuals who have completed the initial 2-day CESCL training (classroom day and field day) must renew the certification every three years. Certifications must be renewed within 6 months after the expiration date. The 1-day WSDOT Construction Site Erosion and Sediment Control course (course code BPW) will renew CESCL certifications for WSDOT staff only. Individuals attending this course specifically for certification renewal must bring a current CESCL card to class. Individuals who do not renew certifications within 6 months after the expiration date must take the 2-day CESCL training again.

All projects with 1 acre or more of soil disturbance, with the potential to discharge construction stormwater to surface waters of the state, are required to seek coverage under the NPDES Construction Stormwater General Permit (CSWGP). Projects smaller than 1 acre, but part of a larger common plan of development or sale that will ultimately disturb 1 acre or more and discharge stormwater to surface waters of the state, must also seek coverage under the CSWGP. Projects that are deemed significant contributors of pollutants or reasonably expected to cause a violation of any water quality standard must also seek coverage under the CSWGP. Stormwater discharges from federal projects or from projects on federal land or within an Indian reservation (except Puyallup) within the state of Washington are not covered by the Washington State CSWGP issued by Ecology, but are instead covered by an NPDES CSWGP overseen by the U.S. Environmental Protection Agency.

Sampling procedures for meeting Washington State CSWGP requirements can be found in Section 6-8.

Projects covered under a CSWGP that will discharge to segments of a water body listed as impaired by the state of Washington under Section 303(d) of the Clean Water Act for turbidity, fine sediment, high pH, or phosphorus must sample discharge and measure compliance in accordance with Section S8 of the CSWGP. Similarly, projects covered under a CSWGP that will discharge to segments of a water body subject to a Total Maximum Daily Load (TMDL) for turbidity, fine sediment, high pH, or phosphorus must sample discharges and measure compliance in accordance with Section S8 of the CSWGP.

Projects that require additional permit conditions or sampling requirements, such as those for 303(d) or TMDL-listed water bodies or contaminated sites, should contact Region Environmental and the HQ ESO for assistance with incorporating additional sampling parameters and procedures into these protocols. Contact the TMDL Lead (360-570-6649) for assistance with 303(d) and TMDL permit conditions.

## 6-5 Standard Sampling Procedures

1. **Sampling Equipment**

   It is recommended that WSDOT regions use the following sampling equipment for instructional consistency purposes. Functionally equivalent turbidimeters, pH meters, and wide range pH test strips are allowed. Sampling equipment was selected for the purpose of legal compliance and should be maintained according to manufacturers' guidelines.

| Conditions/Procedures | Sampling Equipment |
|---|---|
| Turbidity | Hach Model 2100P portable turbidimeter with sampling bottles |
| pH and temperature | ▪ Hach Model IQ125 miniLab pH meter<br>▪ HQ11D pH meter<br>▪ Wide range pH strips for nonbuffered solutions |
| Water sampling | Extendable rod & cup, scoop for collecting sheet flow, clean sample bottles or containers |
| Rain measurement | Gage – Tru-Check brand or equivalent installed on-site |
| Field observations | Field notebook/recording equipment/camera |

| Company | Product | Approximate Cost |
|---|---|---|
| Hach Company*<br>(970) 669-3050<br>www.hach.com/ | ▪ 2100P Turbidimeter<br>▪ 2100Q Tubidimeter<br>▪ IQ125 miniLab pH meter or HQ11D pH Meter with pHC301 liquid-filled pH electrode | $850<br>$930<br>$240<br>$500 |
| Fisher Scientific*<br>www.fishersci.com | ▪ ColorpHast Strips S60169 or similar | $20 per pack |
| Grainger*<br>www.grainger.com | ▪ EMD ColorpHast Strips 4YMV9 or similar | $20 per pack |

(*or any major scientific supply distributor)

2. **Equipment Calibration**

   Calibrate all equipment according to manufacturers' recommendations and specified schedules. Follow the calibration frequency in the manufacturers' recommendations, at a minimum, for data to be legally defensible. Perform additional calibrations immediately if data appear suspect. Keep an equipment calibration log in a convenient location (for example, in the site log book) so it can be updated and referred to as needed.

   Use product instruction manuals to determine calibration methods. Contact product manufacturers if further assistance is needed. Hach provides technical assistance and calibration training for Hach products. Check class availability at: www.hach.com/training

   Other key factors to remember when using sampling equipment:

   - Clean sample vials with distilled water.
   - Dry or wipe vials with Kimwipes® or special cloth (other material may scratch vials, leading to inaccurate measurements).
   - Keep pH meter probes submerged in storage fluid when not in use so they do not dry out.

3. **Field Equipment Checklist**

   - Clean sampling bottles/containers
   - Extendable sampling rod, scoop, or hip waders as needed
   - Calibrated turbidity sampling equipment (check batteries)
   - Calibrated pH equipment (check batteries)
   - Distilled water for cleaning sampling equipment
   - Long survey stakes, hammer, and marking pen (initial set-up only)
   - Rain gage at project site for daily precipitation measurements
   - WSDOT-approved safety vest and hardhat
   - Camera
   - Weather-proof field notebook or data sheet for recording sampling data and field conditions. Data sheets are available at: www.wsdot.wa.gov/environment/waterquality/erosioncontrol.htm
   - Cellular phone and contact phone numbers
   - Pre-Activity Safety Plan (PASP)

4. **Sampling Location Setup**

   When setting up sampling location stations:

   - Mark all sampling locations with clearly labeled survey stakes.
   - Photograph each sampling station for future reference and to ensure consistent reporting procedures. Pictures should show a good relationship between the project, the sampling station, and the surrounding environment.
   - If sampling outside WSDOT right of way, ensure survey stake locations are within WSDOT right of way with direction and distance labels to the exact sampling point locations. Record the exact sampling location in the field notebook and the TESC plan.
   - If new sampling locations arise as construction progresses, follow the steps listed above to create new sampling stations.

5. **Create Base/Site Map**

   Develop a small-scale map depicting the project, sampling locations, and major water, land, and road characteristics. Keep the map in the site log book so that other staff can identify the locations and access the sampling stations. Include all monitoring locations in the TESC plan sheets; draw new locations onto the TESC plan sheets as they arise.

6. **Recording Sampling Information in the Field**

   Record the following information in a field notebook (or on data recording sheets) for each sampling event:

   - Date, time, and location of the sample
   - Project name and contract number
   - Name(s) of personnel who collected the sample
   - Amount of rainfall in the last 24 hours
   - Field conditions (such as weather, temperature, pertinent construction activities, and any prior disturbance of the water body)
   - Testing results for measured parameters
   - Date and time of the last calibration of sampling equipment
   - Notes summarizing (among others) critical activities, unusual conditions, corrective actions, and whether or not photographs were taken as supporting documentation

7. **Standard Sampling Procedures**

   Use the following sampling procedures:

   - Use clean sampling bottles/containers/cups/scoops.
   - Collect samples that are representative of the flow and characteristic of the discharge. Use a sampling rod or scoop if necessary.
   - Take pH samples as soon as possible and before turbidity testing, as temperature changes affect pH.
   - Use approved calibrated sampling equipment or devices. Follow the manufacturers' recommendations for equipment operations and calibrations (typically, at least once every three months).
   - Make sure sample vials are clear of fingerprints or other residue before inserting into a turbidity meter, use Kimwipes® or special cloth to clean as needed.
   - Invert the sample vial (resuspend particulates) before inserting the sample vial into the turbidity meter.

## 6-6 Office Data Recording and Analysis

WSDOT has developed a Construction Water Quality Monitoring (CWQM) database application that all WSDOT projects must use to enter all water quality sampling and monitoring data for WSDOT-owned permits. For projects with CSWGPs, the database provides a data entry field for discharge sample values, which automatically calculates exceedances of benchmarks and the phone reporting trigger. For permits or certifications that require in-stream sampling, the application automatically calculates water quality standards based on the receiving water body classification. Noncompliant events are flagged, prompting the user to confirm that the Environmental Compliance Assurance Procedure (ECAP) has been initiated. If it is determined that the sample event did not require an ECAP to be initiated, a note should be added to explain. For a brief training, contact Region Environmental staff or the Statewide Erosion Control Lead (360-570-6654).

## 6-7 Reporting Sampling Results and Compliance Issues

The CSWGP requires that water quality sampling and monitoring data be collected weekly and submitted/reported monthly for all projects with active permits. Monthly reporting must occur even if the project is inactive or has no active discharge locations. The HQ ESO Erosion Control Program will report data to Ecology monthly by using the data entered into the CWQM application. **All projects with CSWGPs should enter sample data as it is collected. All data must be entered no later than the end of the month in which the samples were collected**.

**Sample data collected during in-water work projects, on projects covered under NPDES Individual permits, or those covered under any permit with 303(d) or Total Maximum Daily Load (TMDL) requirements must be entered into CWQM. This data must be reported directly to resource agencies by the project office staff; the HQ ESO does not submit the data to Ecology. The CWQM database can generate an Excel document for all data entered, which may help project offices report to regulatory agencies.**

ECAP should be initiated as soon as possible after a noncompliant event is identified. Recording sample data into CWQM is not the same as filing ECAP. There is an additional process for reporting an ECAP event. Recording an ECAP event in the Commitment Tracking System (CTS) is not the same as entering the sample data into CWQM; all sample data must be entered into CWQM. ECAP procedure information can be found in the *Construction Manual*, Section 1-2.2K.

### *Additional Project Water Quality Sampling*

Construction-related discharges to impaired waters may require additional pre-project planning and/or discharge monitoring (refer to Section 8 of the CSWGP). If construction stormwater will be discharging to a 303(d)-listed water body or a water body with a TMDL requirement, or if there is an NPDES Individual permit that requires additional sampling, contact Region Environmental personnel and the TMDL Lead (360-570-6649).

If a project chooses to monitor any pollutants more frequently than required by these protocols, the data must be reported to Ecology per a requirement of the CSWGP. Section 6-8, WSDOT's water quality monitoring protocols, is designed to meet the CSWGP requirements. Contact Region Environmental or the Statewide Erosion Control Lead (360-570-6654) if additional sampling will be performed.

**Enter all water quality data into CWQM,** regardless of which permit or regulatory program the project is under. Data submitted for the CSWGP with no additional sampling requirements will be reported to Ecology through the HQ ESO Erosion Control Program. **Project offices or Region Environmental Office support staff must directly submit data collected for all NPDES Individual permits, 401 Water Quality Certifications, or data collected during in-water work, and CSWGPs with TMDL or 303(d) sampling requirements, to the appropriate resource agency contact**.

## 6-8 NPDES Construction Stormwater General Permit Sampling Procedures

All project water quality monitoring forms, maps, and pictures of sampling locations must be kept in the site log book, along with copies of the contractors' inspection reports. The site log book must be kept on-site. Before conducting water quality sampling in the field, the responsible WSDOT personnel must perform the following procedures:

## 6-8.1 Review Important Project Information and Assess Risk

Review project maps, project scope, and schedule to understand when and where construction-related discharges are likely to occur.

1. **Projects that Require Turbidity Monitoring and Sampling**

   Any WSDOT project covered under a CSWGP with potential discharge to surface waters of the state or to a storm sewer system that drains to surface waters of the state. It is not necessary to sample stormwater on portions of the site undisturbed by construction activity (areas of native vegetation that will not be disturbed) or if soil-disturbing activities have not begun yet (prior to breaking ground).

2. **Projects that Require pH Monitoring and Sampling**

   Any WSDOT project covered under a CSWGP with potential discharge to surface waters of the state or to a storm sewer system that drains to surface waters of the state and involves any of the following:

   - Greater than 1,000 cubic yards of poured concrete over the life of a project (monitoring and sampling must begin as soon as the first cubic yard of concrete is poured).
   - Greater than 1,000 cubic yards of recycled concrete used on-site.
   - Soils amended or engineered with cement, fly ash, or kiln dust.

3. **Establish Sampling Locations**

   Sites with multiple discharge locations or stream crossings may require numerous sampling locations. The status of sampling locations may change as construction progresses; establish new sampling locations as needed. Never discharge into a water body or section of a water body not covered by the issued permit. All sampling location should be assigned unique names, which must be used consistently for reporting purposes.

   Sampling locations should be identified on the TESC plan sheets and marked in the field according to the following criteria:

   Establish sampling locations where stormwater or authorized nonstormwater is expected to:

   - Leave the project boundary; or
   - Discharge to surface waters of the state; or
   - Discharge to a storm sewer system that drains to waters of the state.

   If water discharges the site through a traditional treatment BMP, such as a pond, sampling should occur at the outlet of that BMP to ensure data accurately represent the treatment that has occurred.

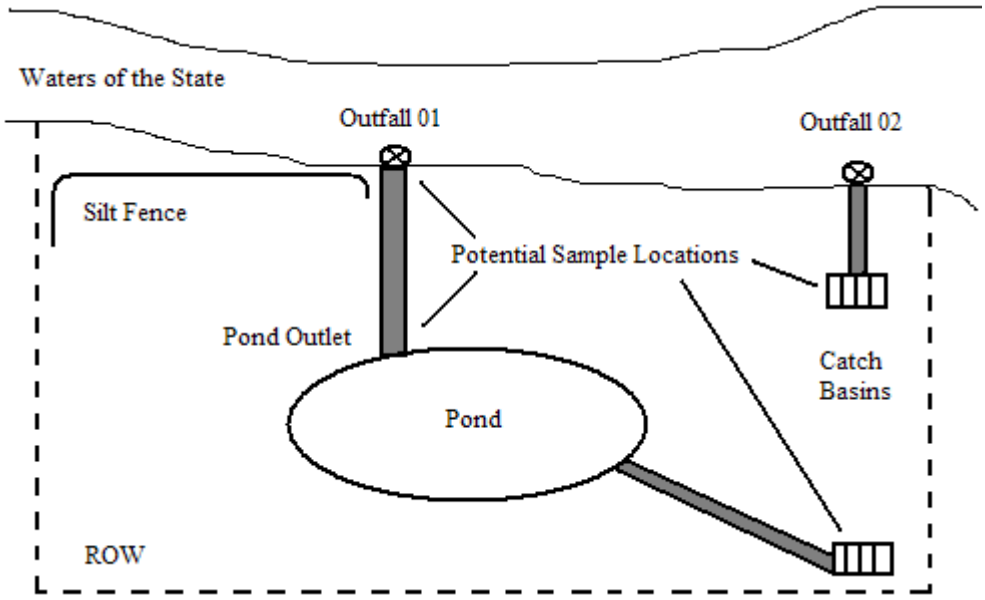


**Figure 6-5.1 General layout of NPDES Construction Stormwater General Permit water quality sampling locations.**


Examples of common stormwater discharge locations where the person monitoring would potentially take stormwater samples.

**Top left:** Stormwater catch basin.

**Top right:** Stormwater discharging from a pipe outlet.

**Bottom left:** Stormwater discharging over the top of silt fence into a ditch. This should not be a long-term discharge point. BMP maintenance should take place.

4. **Establish Turbidity Sampling Schedule**

   Establish a sampling schedule to ensure sampling is conducted consistently and according the procedures in this chapter. A sampling schedule can be documented in the event that someone not familiar with the project needs to perform the sampling.

5. **Follow the Turbidity Sampling Schedule**

   All WSDOT projects covered under a CSWGP must collect samples at least once every calendar week, and within 24 hours of a storm event, when there is a discharge of stormwater or authorized nonstormwater (such as dewatering water or groundwater) from the site. All active sampling locations must be reported on weekly, even if there is no discharge.

   Samples must be representative of the flow and characteristics of the discharge being sampled.

   Sampling is not required:

   - In areas where construction has not started.
   - In areas that have been confirmed as fully stabilized and have no discharge.
   - For discharges that are sent directly to sanitary sewer systems (separate sewer discharge permit requirements apply and must be approved before discharges can occur).
   - When there is no discharge during a calendar week.
   - Outside normal working hours.
   - During unsafe conditions (include a note in CWQM and the on-site SWPPP or site plan about why a sample was not collected).

   Contact the Statewide Erosion Control Lead (360-570-6654) for guidance on sampling and inspection requirements during temporary suspension of construction.

### *Turbidity Benchmark Values*

Benchmark and trigger values represent pollutant concentrations above which Ecology has determined signify a level of concern. The turbidity benchmark value is 25 nephelometric turbidity units (NTU) and the phone reporting trigger value is 250 NTU. The benchmark and phone reporting trigger values indicate how BMPs are functioning. They are not limitations or water quality standards. Discharge samples are compared to these values to determine the level of required action.

Discharges from construction sites sampling at less than 25 NTU indicate that BMPs are functioning well. Discharges between 25.1 and 249.9 NTU indicate that the TESC plan or BMPs are not functioning as well as they should be and action is required (follow step "a" below). Discharges of 250 NTU or greater indicate the TESC plan and BMPs are not functioning; immediate action is required (follow step "b" below).

a. If a discharge sample has a value greater than 25 NTU, but less than 250 NTU:

   i. Review the TESC plan and make appropriate revisions within 7 days of the discharge that exceeded the benchmark; and

   ii. Fully implement and maintain the BMPs as soon as possible, but within 10 days of the discharge that exceeded the benchmark, and document in the site log book. If installation of necessary treatment BMPs is not feasible within 10 days, Ecology may approve additional time when an extension is requested by a permittee within the initial 10-day response period.

b. If a discharge sample has a value of 250 NTU or greater:

   i. Initiate the internal ECAP process. Ecology must be notified by phone within 24 hours of a discharge that is 250 NTU or more. Only one person should make this call. The person designated to make this call must follow the High Turbidity Reporting instructions on Ecology's website: www.ecy.wa.gov/programs/wq/stormwater/construction/

   ii. Review the TESC plan and make appropriate revisions within 7 days of the discharge that exceeded the benchmark; and

   iii. Fully implement and maintain the BMPs as soon as possible, but within 10 days of the discharge that exceeded the benchmark, and document in the site log book. If installation of necessary treatment BMPs is not feasible within 10 days, Ecology may approve additional time when an extension is requested by a permittee within the initial 10-day response period.

   iv. Collect a sample to document when the discharge meets the 25 NTU benchmark (contingency sampling). Contingency sample information needs to be entered into the CWQM database so it can be reported to Ecology. Contingency sample information is also used in the ECAP report. Contingency sampling is not required if the discharge stops or is eliminated (this detail must be documented in the ECAP report and in the CWQM database). If the discharge is not below the 25 NTU benchmark by the end of the workday, then:

   v. Continue to sample the discharge (contingency sampling) daily until:

      1. Turbidity is 25 NTU or lower; **or**

      2. The discharge is confirmed as stopped or eliminated.

6. **Establish pH Monitoring and Sampling Schedule**

   A pH monitoring and sampling period begins when:

   - Concrete is first poured (or recycled concrete is used) and exposed to precipitation and must continue at least once per week throughout and after the pour and curing period until stormwater pH is in the range of 6.5 to 8.5; **or**
   - Soil amendments (or engineered soil) are first exposed to precipitation and should continue at least once per week until runoff from the area of amended soils complies with the pH benchmark (6.5 to 8.5 range) or the area is covered.

   **pH monitoring** is intended as proactive management for stormwater that has the potential to discharge but has not yet discharged. This "predischarge" monitoring can be done by simply dipping wide range pH indicator paper into affected collection areas. Monitoring data must be reported as predischarge in CWQM or in the notes section as supplemental data, but do not report it as a discharge sample if the water is not actively discharging from the site.

   **pH sampling** must occur weekly in all locations where stormwater from the pH-affected areas drains to surface waters of the state or to a storm sewer system that drains to surface waters of the state. pH discharge sample values should always be accompanied with a turbidity sample value.

   Do not allow stormwater or authorized nonstormwater with a pH outside of the 6.5 to 8.5 range to discharge into waters of the state.

7. **Follow the pH Sampling Schedule**

   All WSDOT projects covered under a CSWGP must collect samples at least once every calendar week when there is a discharge of stormwater or authorized nonstormwater (such as dewatering water) from the site. All active sampling locations must be reported on weekly, even if there is no discharge.

   Samples must be representative of the flow and characteristics of the discharge being sampled.

   pH sampling is not required:

   - In areas where construction has not started.
   - In areas not affected by pH-modifying substances.
   - For discharges that are sent directly to sanitary sewer systems (separate sewer discharge permit requirements apply and must be approved by the owner of the sewer system before discharges can occur).
   - When there is no discharge during a calendar week.
   - Outside normal working hours.
   - During unsafe conditions (include a note in CWQM about why a sample was not collected).

8. **pH Benchmark Range Values**

The benchmark values for pH are measured by a range; pH-affected water can only be discharged if it is within 6.5 to 8.5 standard units (su). Whenever sampling indicates that pH is outside of this range:

- Prevent the pH-contaminated water (outside of the 6.5 to 8.5 su range) from entering storm sewer systems or surface waters of the state; and
- If necessary, adjust or neutralize the pH using approved methods.

6.5 to 8.5 su are the points of compliance, which means that sample values of 6.5 and 8.5 are in compliance, but sample values 6.49 or lower and 8.51 or higher would be exceedances. If fluctuating pH values become evident, develop a contingency plan for managing pH water and preventing pH water outside of the 6.5 to 8.5 su range from discharging. Contact Region Environmental staff or the HQ ESO for additional guidance about neutralizing pH water with dry ice or $CO_2$ sparging. Using unapproved methods for neutralizing pH is prohibited without prior approval from Ecology; some methods may cause pH to drop below 6.5 su. All discharged water must be within the range of 6.5 to 8.5 su.

9. **Contingency Sampling**

- Conduct contingency sampling if visual observations suggest that pH and turbidity benchmark values may have been breached.
- Contingency sampling is required if a discharge sample breaches the phone reporting trigger value for turbidity (250 NTU). Contingency sampling is used to determine and document the duration and magnitude of the exceedance event. Once discharge samples are in compliance with the turbidity benchmark value (25 NTU or less), or the discharge stops or is eliminated, the project shall return to its normal sampling schedule. Contingency samples shall also be included in the ECAP report and in CWQM for reporting purposes.

***Reporting Contingency Samples***

- If contingency samples are collected during the same day of an exceedance event, the contingency samples are required to be reported as supplemental data for that exceedance event. Therefore, these samples should be included in the notes section of the CWQM application for reporting purposes.
- If contingency samples are collected in subsequent days following an exceedance event, the contingency samples are considered new events in CWQM. Therefore, these samples should be entered as separate events in the CWQM application for reporting purposes.
- For assistance with how to collect or report contingency samples, contact the Statewide Erosion Control Lead (360-570-6654).

# APPENDIX 6A

# Best Management Practices

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# Best Management Practices

## 6A-1 Introduction

Read Chapter 6 before applying best management practices (BMPs) to projects.

The following descriptions are provided to aid in the selection of appropriate BMPs for temporary erosion and sediment control (TESC) plans. *Standard Specifications for Road, Bridge, and Municipal Construction* (*Standard Specifications*) exist for most, but not all, BMPs. The *Standard Specifications* associated with each BMP are referenced in this section; *Standard Plans for Road Bridge, and Municipal Construction (Standard Plans)* are referenced when applicable.

General Special Provisions (GSP) and Special Provisions must be used to ensure the other BMPs are effectively employed. Prior to writing a Special Provision, check the statewide library for existing GSPs and Special Provisions that can be used to satisfy project needs: www.wsdot.wa.gov/design/projectdev/specifications.htm. Regional GSP libraries may also provide useful provisions. Contact Region Environmental staff or the Statewide Erosion Control Lead for assistance in identifying resources when preparing Special Provisions.

The Washington State Department of Ecology's (Ecology's) Stormwater Management Manuals for Western Washington (SMMWW) and Eastern Washington (SMMEW) also contain BMP specifications: http://www.ecy.wa.gov/programs/wq/stormwater/construction/resourcesguidance.html. Ecology maintains a list of BMPs approved as equivalent to the ones listed here and in Ecology's manuals: www.ecy.wa.gov/programs/wq/stormwater/newtech/equivalent.html

## 6A-2 Best Management Practices

### 6A-2.1 Temporary Seeding

*WSDOT Standard Specification*
8-01.3(2) – Seeding, Fertilizing, and Mulching
9-14.2 – Seed

1. Definition

   *The establishment of a vegetative cover on disturbed areas by seeding with plants. Temporary seeding is used in areas where permanent cover is not necessary or appropriate (such as stockpiles or over-wintering of incomplete grades). Permanent seeding is intended to restore and provide perennial vegetative cover to disturbed areas.*

2. Purpose

   By protecting bare soil from raindrop impact and binding the soil with its roots, a well-established vegetative cover is one of the most effective methods of reducing erosion.

3. Additional Information/Guidance

   Soil surfaces shall be prepared for seeding per Standard Specification 8-01.3(2)A, Preparation For Application.

   The application of agricultural chemicals to promote grass establishment must be conducted in a manner and at application rates that will not result in loss of chemicals to stormwater runoff. Manufacturers' recommendations for application rates and procedures must be followed.

   *To determine the optimal seed/fertilizer/mulch mixes and application specifications for a project, contact the Headquarters (HQ) Roadside and Site Development Section. Additional information can be found in the Roadside Manual, Chapter 800 – Vegetation ~ Seed, Fertilizer, and Mulch.*

## 6A-2.2 Mulching

*WSDOT Standard Specifications*
8-01.3(2)D – Mulching
9-14.4 – Mulch and Amendments

1. Definition

   *The application of organic material to protect bare soil from raindrop and sheet erosion and enhance seed germination.*

2. Purpose

   Mulch provides immediate temporary protection from erosion. Mulch also enhances plant establishment by conserving moisture; holding fertilizer, seed, and topsoil in place; and moderating soil temperatures. There are numerous mulches that can be used, such as weed-free straw, wood chips (hog-fuel), hydraulically applied mulch products, and coarse compost.

3. Additional Information/Guidance

   Table 6A-1 provides additional information on some types of mulch material, including application rates.

## Table 6A-1 Mulch standards and guidelines.

| Mulch Standards and Guidelines | | |
|---|---|---|
| **Mulch Material** | **Application Rates** | **Remarks** |
| Straw | 2"–3" thick | Straw mulch material must meet Standard Specification 9-14.4(1). Cost-effective temporary protection when applied with adequate thickness. Hand application generally requires greater thickness than blown straw. The thickness of straw may be reduced by half when used in conjunction with seeding. Hand-spread straw is less likely to be displaced by wind or runoff because of its weight and length. Erosion blankets/netting or tackifiers are available to prevent displacement of mulch by wind and rain. Straw often introduces and/or encourages the propagation of weed species and it has no significant long-term benefits. It should also not be used within the ordinary high-water elevation of surface waters (due to flotation). |
| Short-Term Mulch | Approx. 1,500–2,000 lbs per acre | Shall be applied with a hydromulcher. This mulch contains a tackifier. |
| Moderate-Term Mulch | Approx. 3,000–4,000 lbs per acre: per the manufacturer's recommendation | Shall be applied with a hydromulcher. May be used as temporary erosion control mulch prior to the seeding window. Requires a 24–48 hour curing time before rain. Under normal circumstances will last 3–6 months. Soil must be completely covered. Can be combined with seed and fertilizer during the seeding window. |
| Long-Term Mulch | Approx. 3,000–4,000 lbs per acre: per the manufacturer's recommendation | Shall be applied with a hydromulcher. May be used as temporary erosion control mulch prior to the seeding window. Physically bonds with top layer of soil. Requires drying time before rains. Soil must be completely covered. Under normal circumstances will last up to 12 months. Can be combined with seed and fertilizer during the seeding window. |
| Compost | 2" minimum thickness | Compost material used for erosion control must meet Standard Specification 9-14.4(8) for Coarse Compost. Excellent mulch for protecting final grades until landscaping because it can be directly seeded or tilled into soil as an amendment. Also, see Standard Specification 9 14.4(8)A, Compost Approval, and 9-14.4(8)B, Compost Acceptance. |
| Chipped Site Vegetation | 2" minimum thickness | This is a cost-effective way to dispose of debris from clearing and grubbing. If seeding is expected shortly after mulch, the decomposition of the chipped vegetation can create a nitrogen deficiency in the soil, making it difficult for plants to grow well. Generally, it should not be used on slopes above approx. 10% because of its tendency to be transported by runoff. It is not recommended within 200 feet of surface waters. Wood chip mulch is also a suitable material for stabilizing entrances and haul roads that are not heavily used by construction vehicles. |
| Wood-Based Mulch | 2" thick; approx. 100 tons per acre (approx. 800 lbs per cubic yard) | Bark or wood chip material must meet Standard Specification 9-14.4(3). This material is often called "hog or hogged fuel." Hog fuel is also a suitable material for stabilizing entrances and haul roads that are not heavily used by construction vehicles. The use of mulch ultimately improves the organic matter in the soil. Special caution is advised regarding the source and composition of wood-based mulches. Its preparation typically does not provide any weed seed control, so evidence of residual vegetation in its composition or known inclusion of weed plants or seeds should be monitored and prevented (or minimized). |

## 6A-2.3 Blankets

*WSDOT Standard Specifications*
8-01.3(3) – Placing Erosion Control Blanket
9-14.5(2) – Erosion Control Blanket

*WSDOT Standard Plans*
I-60.10-00 – Erosion Control Blanket Placement on Slope
I-60.20-00 – Erosion Control Blanket Placement in Channel

1. Definition

   *A blanket made of natural plant material or synthetic fibers that is rolled out and fastened to the soil surface to protect soil from raindrop and sheet erosion.*

2. Purpose

   Erosion control blankets (rolled erosion control products) protect soil from raindrop and sheet erosion until permanent vegetation is established. Organic blankets are made of jute, straw, wood shavings, coconut fiber (coir), or various combinations of each. Product longevity ranges from 6 months to 5 years, depending on the composition of the blanket and environmental conditions. Synthetic blankets often contain materials that resist ultraviolet light and last more than 5 years and should not be used under most circumstance for temporary erosion control. Considerations must be made for soil type, climate, and slope/conveyance gradient when choosing a product. Follow manufacturer's recommendations for product placement.

3. Additional Information/Guidance

   - Slopes must be prepared (smooth) prior to blanket installation so that the blanket makes contact with the entire soil surface when secured.

   - Blankets must be anchor trenched at the top of the slope to prevent water from undercutting the blanket, and upslope sections must be placed over downslope sections like shingles on a roof.

   - Use anchoring staples that are appropriate for the soil type. Follow manufacturer's recommendation for staple placement.

## 6A-2.4 Plastic Covering

*WSDOT Standard Specifications*
8-01.3(5) – Placing Plastic Covering
9-14.5(3) – Clear Plastic Covering

1. Definition

   *The covering with plastic sheeting of bare areas that need immediate protection from erosion.*

2. Purpose

   The primary uses for plastic are:

   - Coverage of slopes and stockpiles.
   - Temporary coverage of active work areas.
   - Short-term coverage where mulch or blankets are not an option.
   - Protection of seed from cold weather to encourage early growth of vegetation.

3. Additional Information/Guidance

   - Plastic provides 100% protection of the soil; however, it collects 100% of the rain and transfers the erosion potential elsewhere. Energy dissipation downslope of the plastic, as well as conveyance of runoff, should be anticipated and addressed appropriately with other BMPs. Prevent clean concentrated flows from plastic from hitting bare soil.
   - Plastic prevents infiltration and soil saturation.
   - Plastic must be anchored at the top of the slope to prevent water from going under the plastic, and upslope sheets must be placed over downslope sheets like shingles on a roof.
   - The average cost per square yard of installed plastic is often greater than the cost of many erosion control blankets, especially when maintenance, removal, and disposal costs are added.
   - Plastic is maintenance intensive, and it becomes brittle over time and develops holes and tears.
   - Plastic can easily be blown off in wind and become a safety hazard for the traveling public.

## 6A-2.5 Polyacrylamide for Soil Erosion Protection

*WSDOT Standard Specification*
8-01.3(2)E – Tacking Agent and Soil Binders/Soil Binding Using Polyacrylamide
9-14.5(1) - Polyacrylamide

1. Definition

   *Polyacrylamide (PAM) is a long-chain polymer developed to clarify drinking water. It can be used in erosion and sediment control applications because of its ability to flocculate fine suspended sediments in stormwater runoff, thereby*

*accelerating the sediment deposition process. PAM also increases infiltration rates in soils by preventing surface sealing.*

2. Purpose

   Applying PAM to bare soil in advance of a rain event reduces erosion and controls sediment transport. PAM binds soil particles together and reduces the effects of raindrop and sheet erosion. Stormwater infiltration increases because soil pore volume is not clogged with fine sediments. Stormwater pond and other sediment control BMP performance is enhanced because sediment that reaches these BMPs contains PAM and will gravity settle faster.

3. Additional Information/Guidance

   - PAM products must meet ANSI/NSF Standard 60 for drinking water treatment and be anionic and linear (non-cross-linked) per Standard Specification 9-14.5(1).
   - PAM must not be applied directly to water without prior approval from Ecology.
   - Runoff from PAM-treated soil must not discharge directly into waters of the state. If less than 5 acres of soil have been treated with PAM, all runoff from treated areas must drain to a sediment control BMP that will allow enough time for sediment to settle out. For example, runoff must pass through three check dams per acre treated, prior to discharge. If 5 acres or more of soil have been treated with PAM, all of the runoff from the treated area must drain to a pond prior to discharge.
   - PAM has infinite solubility in water, but dissolves very slowly. Pre-measure the area where PAM is to be applied and calculate the amount of product and water necessary to provide coverage at the specified application rate (not more than 2/3 lb per 1,000 gal water per acre). Always add PAM to mixing water; never add water to measure the PAM. Mechanical mixing will help the PAM dissolve completely.
   - PAM must be used in conjunction with other BMPs.

   *PAM should be used in combination with mulch per Standard Specification 8-01.3(2)E.*

   - For small areas that need coverage, PAM can be applied at the dry application rate (5 lbs per acre) using a hand-held "organ grinder" seed spreader.
   - Depending on site conditions, PAM remains in the soil 3 to 6 months from the date of application. Extreme weather and heavy traffic (if used on haul roads) shorten the lifespan. These conditions require more frequent application.
   - PAM may be reapplied on actively worked areas after a 48-hour period.
   - Refer to Ecology's SMMWW, Volume II, for more information on PAM.

## 6A-2.6 Moderate- and Long-Term Mulch

*WSDOT Standard Specification*
8-01.3(2)E – Tacking Agent and Soil Binders
9-14.4(9) – Moderate-Term Mulch
9-14.4(10) – Long-Term Mulch

1. Definition

   *Moderate-Term Mulch: A combination of organic fiber and organic or synthetic tackifier that can be mixed with seed and applied hydraulically. Requires at least a 48-hour cure time and should not be used on saturated soils with groundwater seeps.*

   *Long-Term Mulch: A combination of organic fiber, organic or synthetic tackifiers, and cross-linking fibers or polymers that can be mixed with seed and applied in advance of precipitation and on saturated soil.*

2. Purpose

   Soil stabilization BMPs that form a permeable crust over disturbed soils to protect from raindrop impacts. They are not meant to prevent erosion where there are channelized flows. Both products provide better protection than Short-Term Mulch. They can be applied with seed or as a stand-alone BMP.

3. Additional Information/Guidance

   WSDOT's Qualified Products List (QPL) contains approved vendors of Moderate-Term and Long-Term Mulch products.

## 6A-2.7 Preserving Natural Vegetation

*WSDOT Standard Specifications*
1-07.16(2) – Vegetation Protection and Restoration
1-07.16(2)A – Wetland Sensitive Area Protection

1. Definition

   *Minimizing exposed soils by clearing only where construction will occur or preserving an undisturbed strip of natural vegetation or preserving an established suitable planting between sensitive areas and land-disturbing activities.*

2. Purpose

   Vegetation provides the following benefits:

   - Rainfall impact (energy) absorption
   - Reduction of runoff volumes and velocities

- Sediment trapping
- Root stabilization of soil

Preserving natural vegetation reduces the need to spend money on BMPs that try to mimic these natural benefits. Vegetation surrounding sensitive areas (buffer zones) provides critical habitat and assists in controlling erosion, especially on unstable steep slopes.

3. Additional Information/Guidance

   Buffer zones must be identified and protected with fencing around wetlands, streams, and other sensitive areas. These areas should not be used as sediment filters. Check with the local jurisdiction or WSDOT environmental permitting staff.

## 6A-2.8 Sodding

*WSDOT Standard Specification*
9-14.6(8) – Sod

1. Definition

   *Stabilizing fine-graded disturbed areas by establishing permanent grass stands with sod.*

2. Purpose

   To establish permanent turf for immediate erosion protection or to stabilize drainageways where concentrated overland flow will occur.

3. Additional Information/Guidance

   - Sod may be more expensive than other permanent-cover BMPs, but because the grass is already established, instant protection is provided.
   - In swales, placing sod strips perpendicular to the flow of water increases the ability to resist shear stress.
   - Staggering sod strips produces a more stable soil cover.
   - For maintenance information, refer to WSDOT Standard Specification 8-01.3 (15), Maintenance.

## 6A-2.9 Topsoiling

*WSDOT Standard Specifications*
8-02.3(4) – Topsoil
9-14.1 – Soil

1. Definition

   *Preserving or importing topsoil to promote vegetation establishment in nutrient-poor soils.*

2. Purpose

   To provide a suitable growth medium for final site stabilization.

## 6A-2.10 Conveyance Channel Stabilization

*WSDOT Standard Specification*
For flexible liners, the information below can be used to select appropriate materials. Materials and installation Standard Specifications already exist for these liner types.

If it is determined that a rigid liner is necessary, contact the WSDOT HQ Design Office, Hydraulics Branch. No WSDOT Standard Specification exists for solid liners; therefore, a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *Temporary conveyance channels must be designed, constructed, and stabilized to prevent erosion. Materials used to stabilize channels against erosion are categorized as flexible and rigid. Flexible channel liners include vegetation, blankets, gravel, and small- to medium-sized riprap. Rigid materials used for conveyance systems include PVC/concrete/metal pipe, asphalt, and large rock.*

2. Purpose

   To stabilize the conveyance feature sufficiently to prevent erosion up to the design storm flow.

3. Additional Information/Guidance

   Channels should be sized to convey expected flows. Use the design criteria contained in Section 4-3.3 for western Washington or Section 4-4.3 for eastern Washington.

   *Always be sure to use the most recent guidance material when designing channels. The following guidance comes from the Hydraulic Engineering Circular No. 15 – Design of Roadside Channels with Flexible Linings, Federal Highways Department publication No. FHWA-IP-87-7.*

   The following principles must be considered when designing stable channels:

   - Bare soil has very little resistance to erosion when subjected to concentrated flows. Channels must be protected to withstand expected erosive forces.
   - Flow velocities should be limited, if necessary, to prevent damage to channel liners.
   - Flexible liners are not as strong as rigid liners, but are able to conform to changes in channel shape while maintaining the overall lining integrity. As a general guideline, only rigid liners should be used in channels with shear stresses exceeding 8 lb/ft$^2$ or on slopes exceeding 10%, unless using

properly sized riprap. Table 6A-2 summarizes the advantages and disadvantages of the two liner types.

The potential for erosion is based on the shear stress of flow, which is the force required to pull or peel (erode) material off the bottom or sides of a ditch. Shear stress can be calculated using the following formula:

Shear Stress = WHG where:
W = Weight of water (62.4 lb/ft$^3$)
H = Height of water in feet
G = Channel gradient in ft/ft

Note: Channel gradient and water height in this formula assume an unobstructed flow of water in the ditch.

- Using shear stress to determine effective liner types:

  Table 6A-3 indicates the maximum shear stresses that several types of flexible liner materials can withstand. As a general guideline when rock lining is used, multiply the expected maximum shear stress by 3 to apply a 30% safety factor, to obtain the mean diameter of rock or riprap needed to stabilize the ditch. Manufacturers provide the shear strength ratings for erosion control blankets.

  Selection of liner material should be based on the maximum shear stress that products or specified rock sizes can withstand.

- Sample calculation and product selection process:

  What flexible liner materials are adequate to stabilize a ditch with a 3% slope and an expected flow depth of 1.5 feet?

  Shear stress = (62.4 lb/ft$^3$)(1.5 ft)(.03) = 2.81 lb/ft$^2$

  If rock is used, stone size should be a minimum mean stone size of at least 8.4 inches, because (2.81)(3.0 conversion factor) = 8.4.

  Numerous erosion control blankets made of coir and synthetic turf reinforcement products could be substituted for rock with potentially significant cost savings. A well-established healthy stand of grass could also withstand the expected shear stresses in the ditch and help purify the runoff.

  Consider coupling other BMPs with the channel lining to ensure channel stability. Check dams can greatly reduce the velocity of flowing water, thereby reducing shear stress. Check dams can prevent erosion until the permanent grass liner is established. Temporary slope drains provide rigid lined conveyances until the permanent rigid or flexible lined channels are completed.

## Table 6A-2 Flexible versus rigid lined conveyances.

| Flexible | Rigid |
|---|---|
| *Advantages*<br>▪ Inexpensive to install and maintain (grass-lined ditches are self-healing)<br>▪ Provide runoff treatment<br>▪ Allow some infiltration<br>▪ Cause less increase in peak flows | *Advantages*<br>▪ Maximize conveyance capacity using limited space<br>▪ Fully effective immediately (no need to wait for grass to grow)<br>▪ Can be designed to withstand any level of shear stress |
| *Disadvantages*<br>▪ Excessive flows can cause erosion<br>▪ Vegetation requires time to become established<br>▪ Require more space<br>▪ Not to be used in channels where shear stress exceeds 8 lb/ft$^2$ or slopes exceed 10% (except riprap) | *Disadvantages*<br>▪ Expensive to build, maintain, and repair<br>▪ Increased peak discharge rates more likely to cause downstream erosion<br>▪ Minimal, if any, infiltration<br>▪ No runoff treatment |

## Table 6A-3 Maximum permissible shear stresses for flexible liners.

| Liner Category | Liner Type | Permissible Shear Stress (lbs/ft$^2$) |
|---|---|---|
| Bare soil – No liner | Noncohesive soil<br>Cohesive soil | 0.01-0.04<br>up to 0.1 (noncompacted)/<br>up to 0.8 (compacted) |
| Erosion control blankets (temporary/permanent)* | Jute<br>Curlex wood or straw<br>Coir<br>Organic, synthetic, or mix | 0.45-1.0<br>1.0-2.5<br>2.0-4.0<br>10.0-12.0 |
| Vegetative** | Uncut stand<br>Cut grass | 2.1-3.7<br>0.6-1.0 |
| Gravel/riprap | 1-inch<br>2-inch<br>6-inch<br>12-inch | 0.33<br>0.67<br>2.0<br>4.0 |

* Permissible shear stresses based on products chosen at random to give a general idea of blanket strengths by material type. This table does not reflect the full range of permissible shear stresses for each product type.

** Varies with type and density of grass stand.

## 6A-2.11 Fencing

*WSDOT Standard Specifications*
1-07.16(2) – Vegetation Protection and Restoration
8-01.3(1) – General
9-14.5(8) – High Visibility Fencing

*WSDOT Standard Plans*
I-10.10-01 – High Visibility Construction Fencing

A Special Provision must be prepared if a particular fencing design or material is necessary. For instructions on preparing Special Provisions, see the Introduction (6A-1). *Project Delivery Memo #04-04,* dated August 11, 2004, addresses high-visibility construction fencing. Regions should adapt the Special Provision to best fit their methods of presentation while retaining the intent.

1. Definition

   *Installing a visual and physical barrier to delineate a project boundary or protect a sensitive feature.*

2. Purpose

   Fencing restricts clearing to approved limits, prevents disturbance of sensitive areas, and limits construction traffic to designated roads and entrances.

3. Additional Information/Guidance

   - High-visibility fence should be installed in advance of clearing and grubbing to delineate sensitive areas. Orange silt fence should only be used in sensitive areas where turbid runoff is a concern.
   - Maintenance – Refer to WSDOT Standard Specification 8-01.3(15), Maintenance.

## 6A-2.12 Stabilized Construction Entrance

*WSDOT Standard Specification*
8-01.3(7) – Stabilized Construction Entrance

*WSDOT Standard Plan*
I-80.10-00 – Miscellaneous Erosion Control Details

1. Definition

   *A temporary stone-stabilized pad located at points of vehicular ingress and egress on a construction site.*

2. Purpose

   To reduce the amount of sediment track-out or transport onto public roads by vehicles or runoff.

3. Additional Information/Guidance

   - Paved areas and steel rumble plates can be used to stabilize construction entrances.
   - A stabilized rock pad can be implemented for all staging and employee parking areas for the project.
   - For maintenance, refer to WSDOT Standard Specification 8-01.3(15), Maintenance.
   - If a stabilized construction entrance fails to prevent sediment track-out or transport, it must be maintained or enhanced. A tire wash facility or sweeping can be used to limit track-out.

## 6A-2.13 Tire Wash

*WSDOT Standard Specification*
8-01.3(7) – Stabilized Construction Entrance

1. Definition

   *A system using sump and spray equipment and tire flexing devices to remove sediment from vehicles during site egress.*

2. Purpose

   A tire wash is used when a stabilized construction entrance does not prevent sediment from being tracked onto off-site pavement. An effective tire wash will prevent sediment track out.

3. Additional Information/Guidance

   - Effective function requires participation by and communication with vehicle drivers to ensure all vehicles leaving the site pass through the tire wash at a slow enough speed to remove sediment (usually about 30–45 seconds depending on soil type).
   - Effective tire washes will include the following features:
     - □ Stabilized approach (paved, quarry spall pad, or rumble plates) that is maintained clear of excess soil.
     - □ Appropriately sized wash deck based on soil type (minimum of one complete tire revolution; more revolutions will be required for more cohesive soil types).

- Multiple angled spray patterns (must reach all tires and undercarriage).
- High-volume, moderate-pressure spray.
- Rinse water maintained at reasonable clarity.
- Collection of overspray and drip out.
- Stabilized egress (paved, quarry spall pad, or rumble plates) that is maintained clear of excess soil.

- Wash-water shall be discharged to a separate on-site treatment system, such as closed-loop recirculation or upland application, or discharged to a sanitary sewer, if allowed by a local sewer district permit. Upland application will not be allowed if oil sheen or other contaminants are present in the wash water.
- Local jurisdictions may require a tire wash as a permit condition.

## 6A-2.14 Construction Road Stabilization

*WSDOT Standard Specification*
Standard Specifications exist for road stabilization materials, but a Special Provision must be written describing when, where, and how much material is to be used. For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *The temporary stabilization of access roads and other on-site vehicle transportation routes immediately after grading.*

2. Purpose

   To reduce erosion of temporary roadbeds by construction traffic during wet and dry weather. Construction road stabilization eliminates the need for regrading of permanent road beds between the time of initial grading and final stabilization and reduces dust emissions.

3. Additional Information/Guidance

   - If the area will not be used for permanent roads, parking areas, or structures, a 6-inch depth of hog fuel may also be used (but this is likely to require more maintenance). Whenever possible, construction roads and parking areas are placed on a firm, compacted subgrade.
   - On areas that will receive asphalt as part of the project, install the first lift as soon as possible.
   - A 6-inch depth of 2- to 4-inch crushed rock, gravel base, or crushed surfacing base course can be applied immediately after grading or utility installation. A 4-inch course of asphalt treated base (ATB) may also be used, or the road/parking area may be paved. It may also be possible to use cement or calcium chloride for soil stabilization. If cement or cement

kiln dust is used for roadbase stabilization, pH monitoring and other BMPs are necessary to evaluate and minimize the impact on stormwater.

- Roadways must be carefully graded to drain effectively. Drainage ditches are required on each side of the roadway in the case of a crowned section or on one side in the case of a super-elevated section. Drainage ditches should be directed to a sediment control BMP.
- Rather than relying on ditches, it may also be possible to grade the road so that runoff sheet-flows into a heavily vegetated area with well-developed topsoil. If the vegetated area has at least 50 feet of vegetation, it is generally preferable to use the vegetation, rather than a sediment pond or trap, to treat runoff.
- Storm drain inlets receiving runoff from temporary construction roadways must be protected to prevent sediment-laden water from entering the storm drain system.
- Inspect stabilized areas regularly, especially after large storm events.
- Crushed rock, gravel base, hog fuel, and so forth, should be added as required to maintain a stable driving surface and to stabilize any areas that have eroded.

## 6A-2.15 Dust Control

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *Reducing the movement of dust during land-disturbing, demolition, and construction activities.*

2. Purpose

   To prevent movement of dust where on-site and off-site impacts to roadways, drainage ways, or surface waters are likely.

3. Additional Information/Guidance

   - Vegetate or mulch areas that will not receive vehicle traffic. In areas where planting, mulching, or paving is impracticable, apply gravel or landscaping rock.
   - Limit dust generation by clearing only those areas where immediate activity will take place.
   - Construct natural or artificial windbreaks or windscreens.

- Spray the site with water until the surface is wet. Repeat as needed. To prevent mud being carried onto adjacent streets, install a Stabilized Construction Entrance and/or a Tire Wash as necessary.
- Spray exposed soil areas with a dust palliative, following the manufacturer's instructions and cautions regarding handling and application. Used oil is prohibited as a dust suppressant. Local governments may approve other dust palliatives (such as calcium chloride or PAM).
- Techniques that can be used for unpaved roads and lots include:
  - Lower speed limits.
  - Upgrade the road surface strength by improving particle size, shape, and mineral types that make up the surface and base materials.
  - Add surface gravel to reduce the source of dust emission. Limit the amount of fine particles (those passing a #200 screen) to 10% to 20%.
  - Use geotextile fabrics to increase the strength of new roads or roads undergoing reconstruction.
  - Encourage the use of alternative, paved routes, if available.
  - Restrict use by tracked vehicles and heavy trucks to prevent damage to the road surface and base.
  - Apply chemical dust suppressants using the admix method: blending the product with the top few inches of surface material. Suppressants may also be applied as surface treatments.
  - Pave permanent roads and other high-traffic areas.
  - Use vacuum street sweepers.
  - Remove mud and other dirt promptly so it does not dry and turn into dust.
  - Limit dust-causing work on windy days.
- Contact the local air pollution control authority for guidance and training on other dust control measures. Compliance with the local air pollution control authority constitutes compliance with this BMP.

## 6A-2.16 Surface Roughening

*WSDOT Standard Specification*
8-01.3(2)A – Preparation for Application

1. Definition

   *Creating longitudinal depressions perpendicular to the natural flow of runoff by using a cleated roller, crawler tractor, or similar equipment.*

2. Purpose

   To aid in the establishment of vegetative cover by reducing runoff velocity, increasing infiltration, and providing for sediment trapping.

3. Additional Information/Guidance

   There are different methods for achieving a roughened soil surface on a slope; the selection of an appropriate method depends on the type of slope. Roughening methods include stairstep grading, grooving, contour furrows, and track walking. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

   - Disturbed areas that will not require mowing may be stairstep graded, grooved, or left rough after filling.
   - Stairstep grading is particularly appropriate in soils containing large amounts of soft rock. Each step catches material that sloughs from above and provides a level site where vegetation can become established. Stairs should be wide enough to work with standard earth-moving equipment. Stairsteps must be on contour or gullies will form on the slope.
   - Areas that will be mowed (these areas should have slopes less steep than 3H:1V) may have small furrows left by disking, harrowing, raking, or seed-planting machinery operated on the contour.
   - Graded areas with slopes greater than 3H:1V, but less than 2H:1V, should be roughened before seeding. This can be accomplished in a variety of ways, including track walking or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.

## 6A-2.17 Pipe Slope Drains

*WSDOT Standard Specification*
8-01.3(14) – Temporary Pipe Slope Drain

1. Definition

   *A pipe extending from the top to the bottom of a slope and discharging into a stabilized water course, a sediment-trapping device, or a stabilized outfall.*

2. Purpose

   To carry concentrated runoff down slopes without causing the formation of rills and gullies and to minimize saturation of slide-prone soils.

3. Additional Information/Guidance

   - If flow is exclusively surface water, use the design criteria contained in Section 4-3.3 for western Washington or Section 4-4.3 for eastern Washington.

- If flow is from seeps or groundwater, use best professional judgment in consultation with the Region Materials Engineer (RME) when sizing slope drains.
- Pipe slope drains can be used when a temporary or permanent stormwater conveyance is needed to move the water down a slope to prevent erosion.
- Pipe slope drains can be used at bridge ends to collect runoff and pipe it to the base of the fill slopes along bridge approaches. These can be designed into a project and included as bid items.
- Another use on road projects is to collect runoff from pavement and pipe it away from side slopes. This is useful because there is generally a time lag between installation of the first lift of asphalt and installation of curbs, gutters, and permanent drainage.
- Water can be collected and channeled to pipe slope drain inlets with sand bags, triangular silt dikes, berms, or other material.
- Use temporary drains on new slopes.
- Compact the soil around and under the pipe and entrance section to prevent undercutting.
- Securely connect prefabricated flared inlet sections to the slope drain pipe.
- Securely fasten multiple slope drain sections together, or use gasketed watertight fittings.
- If 90º bends cannot be avoided in the drain pipe, install thrust blocks constructed from sandbags; "t" posts and wire; or ecology blocks to anchor the bends. For pipe slope drains that are to remain as permanent features, the thrust block materials must be capable of lasting for the expected life of the pipe.
- Secure pipe along its full length to prevent movement. This can be done with steel "t" posts and wire. Posts are installed on each side of the pipe and the pipe is wired to them. This should be done approximately every 10–20 feet of pipe length, depending on the size of the pipe and quantity of water to be diverted.
- Pipe slope drains can be used to convey water collected by interceptor dikes. Ensure the height of the dike is at least 1 foot higher at all points than the top of the inlet pipe.
- The area at the outlet must be stabilized with an energy-dissipating material (such as riprap).
- If the pipe slope drain is conveying sediment-laden water, direct all flows into a sediment-trapping facility.

## 6A-2.18 Level Spreader

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *A slightly elevated structure made of wood, sandbags, pipe, wattles, compost or compost sock, gravel, or compacted earth that spans an area and converts concentrated runoff into sheet flow.*

2. Purpose

   To reduce shear stress by converting concentrated runoff to sheet flow, resulting in less erosion.

3. Additional Information/Guidance

   - Use when a concentrated flow of water needs to be dispersed over a large area with existing stable vegetation.
   - Use only where the slopes are gentle, the water volume is relatively low, and the soil will absorb most of the low-flow events.
   - Use above areas that are stabilized by vegetation.
   - If the level spreader has any low points, flow will concentrate, creating channels and possibly causing erosion.
   - Design the level spreader so that runoff does not reconcentrate after release unless intercepted by another downstream measure.
   - Level spreaders consisting of gravel or organic material should have a minimal amount of fine particles that could negatively influence turbidity.
   - The spreader should span the full width of the channel. Use multiple spreaders for higher flows.
   - The depth of the spreader, as measured from the lip, should be uniform across the entire width.
   - Level spreaders should be set back from the property line unless there is an easement for flow.

## 6A-2.19 Interceptor Dike and Swale

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1). The design criteria shown in Table 6A-4 apply.

1. Definition

   *A ridge of compacted soil with a parallel swale placed on a slope. These structures may or may not be vegetated. They differ from water bars in that they are of greater scale and complexity.*

2. Purpose

   To intercept runoff and/or groundwater from drainage areas on slopes and direct it to a stabilized outlet.

3. Additional Information/Guidance

   Use the dike and swale to intercept the runoff from unprotected areas and direct it to areas where erosion can be controlled. This can prevent runoff from entering the work area or sediment-laden runoff from leaving the construction site.

   - When placed horizontally across a disturbed slope, the dike and swale reduces the amount and velocity of runoff flowing down the slope.
   - Stabilization of the dike and swale with temporary or permanent vegetation depends on soil characteristics and gradient. Low-gradient, highly-porous soils may not require a higher level of protection, because much of the water infiltrates the ground, reducing erosion potential.
   - Steeper grades require swale protection, check dams, or level spreaders.
   - Provide energy dissipation measures at swale outlet.
   - Sediment-laden runoff must be released to a sediment-trapping facility.
   - Minimize construction traffic over temporary dikes. Use temporary cross culverts for channel crossing.

**Table 6A-4 Design criteria.**

| | |
|---|---|
| **Interceptor dikes meet the following criteria:** | |
| Top width | 2 feet (600 mm) minimum. |
| Height | 18 inches (450 mm) minimum. Measured from upslope toe and at a compaction of 90% ASTM D698 standard proctor. |
| Side slopes | 3H:1V or flatter. |
| Grade | Topography dependent, except that dike is limited to grades between 0.5 and 1.0%. |
| Horizontal spacing of interceptor dikes | Slopes <5% = 300 feet (90 m)<br>Slopes 5–10% = 200 feet (60 m)<br>Slopes 10–40% = 100 feet (30 m) |
| Stabilization | Slopes = <5%. Seed and mulch applied within 5 days of dike construction.<br>Slopes = 5–40%. Dependent on runoff velocities and dike materials. Stabilization, using either sod or riprap, should be done immediately to avoid erosion. |
| Outlet | The upslope side of the dike must provide positive drainage to the dike outlet. No erosion can occur at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment-trapping facility. |
| Other | Minimize construction traffic over temporary dikes. |
| **Interceptor swales meet the following criteria:** | |
| Bottom width | 2 feet (600 mm) minimum; the bottom is level. |
| Depth | 1 foot (300 mm) minimum. |
| Side slope | 3H**:**1V or flatter. |
| Grade | Maximum 5%, with positive drainage to a suitable outlet (such as a sediment trap). |
| Stabilization of swale bottom and side slopes | Seed per Standard Specification 8-01.3(2)<br>Temporary seeding, or riprap 12 inches (300 mm) thick, pressed into the bank and extending at least 8 inches (200 mm) vertical from the bottom. |
| Swale spacing | Slope of disturbed area: <5% = 300 feet (90 m)<br>5–10% = 200 feet (60 m)<br>10–40% = 100 feet (30 m) |
| Outlet | Level spreader or riprap to stabilized outlet/sedimentation pond. |

## 6A-2.20 Stormwater Infiltration

*WSDOT Standard Specification*
8-01.3(1)D – Dispersion/Infiltration

1. Definition

   *The process of treating water in engineered infiltration ponds, naturally occurring closed depressions, and vegetated areas with soils or duff that can absorb stormwater.*

2. Purpose

   To treat turbid stormwater that would otherwise not meet water quality standards if discharged to a surface water body. If a standard BMP is not providing sufficient treatment prior to discharge, additional treatment may include dispersion into WSDOT-owned vegetated strips and grass-lined channels that can be expected to infiltrate runoff or reduce turbidity prior to discharging from a site. Prior written authorization must be obtained from adjacent landowners before water can be dispersed onto adjacent non-WSDOT properties. Dispersion, infiltration, and bioinfiltration areas will be labeled on the TESC plan sheets, and visual inspections must be completed daily to verify that they function as intended. Flow to such areas will be controlled to encourage complete infiltration and avoid discharges whenever possible. If discharges occur, however, runoff will be sampled at the dispersion area discharge point in accordance with permit conditions. Inspection frequency will increase (daily inspections during dispersion operations) whenever there are discharges or whenever weather conditions are likely to limit the capacity or effectiveness of treatment areas. Use of dispersion areas will immediately cease if they stop providing improved treatment compared to direct discharges from traditional BMPs.

   Ditched stream channels and other sensitive areas shall never be considered for dispersion, infiltration, or biofiltration activities. Dispersion and infiltration in Critical Aquifer Recharge Areas will not be allowed in areas identified in the Geotechnical Report as having less than 5 feet between the ground surface and the seasonal high groundwater table. (Refer to Section 4-5 for the Infiltration Design Criteria when identifying appropriate infiltration areas.) Roadside ditches shall only be used when they can reasonably be expected to prevent runoff or fine sediments from reaching receiving streams based on field observations and soils information. (Note: WSDOT maintenance personnel are an excellent resource, with many years of observations about flow under wet weather conditions.) Check dams and other BMPs shall be installed where necessary to enhance the effectiveness of the dispersion and biofiltration BMPs. The BMPs will be maintained and deposited sediment will be removed if necessary to eliminate the possibility of sediment resuspension during future rain events. If present, deposited sediment shall be stabilized or removed at the end of the project.

   This method can often be employed to create a zero discharge site, thereby eliminating the possibility of impacting surface waters.

3. Additional Information/Guidance

   - Infiltration ponds work best on highly porous soils. Silt and clay deposits reduce infiltration capacity. Upslope erosion/sediment control BMPs, especially sediment traps/basins, are essential to ensure consistent performance of infiltration facilities, whether used as temporary or permanent water quality/quantity BMPs.
   - Infiltration rates are usually higher in undisturbed, vegetated areas.

- Infiltration rates are limited on most sites, so creative methods are often required to meet infiltration needs.
- Infiltration can be maximized by spreading water over the largest possible area, discharging water at a slow and constant rate, and using vegetated areas whenever possible.
- If an area becomes saturated, give it a rest period and try again later.
- Design infiltration areas to empty between storm events.
- Monitor infiltration areas and nearby surface waters. Infiltrating water on slopes may destabilize the slope, causing structural failure.
- Always consult with and get approval from the Project Engineer before dispersing or infiltrating water.

## 6A-2.21 Check Dams

*WSDOT Standard Specifications*
8-01.3(6) – Check Dams
9-13.6 – Quarry Spalls
9-14.5(4) – Geotextile-Encased Check Dam
9-14.5(5) – Wattles
9-14.5(6) – Compost Sock
9-14.5(7) – Coir Log

*WSDOT Standard Plans*
I-50.10-00 – Geotextile-Encased Check Dam Installation
I-50.20-00 – Check Dams

1. Definition

   *Small dams constructed across a swale or drainage ditch. Suitable materials include quarry spalls, riprap, washed gravel, sandbags, and prefabricated structures.*

2. Purpose

   To reduce the velocity of concentrated flows, reduce erosion of the swale or ditch, and cause some suspended sediment to settle in ponded areas upstream of check dams.

3. Additional Information/Guidance

   - Check dams should be perpendicular to the flow of water and spaced at maximum so that the toe of the upstream dam is at the same elevation as the spill point of the downstream dam.

- Check dams should be a maximum of 2 feet at center (spill point) and the center should be at least 12 inches lower than the outer edges.
- Whatever material is used, the cross section of the dam crest should form a triangle. This prevents undercutting at the downstream toe, as water flows over the face of the dam rather than falling directly onto the ditch bottom.
- The material used to fill sand bags should be selected so that it does not contribute to turbid runoff (for example, use washed rock or pea gravel instead of silty sand).
- Keep the center of the check dam lower than the outer edges at natural ground elevation to prevent flooding of roads, dikes, or other structures.
- Placing rock, geotextile, or erosion control blankets in the conveyance channel reduces or eliminates scouring.

## 6A-2.22 Triangular Silt Dike (Geotextile-Encased Check Dam)

*WSDOT Standard Specifications*
8-01.3(6)A – Geotextile-Encased Check Dam
9-14.5(4) – Geotextile-Encased Check Dam

*WSDOT Standard Plan*
I-50.10-00 – Geotextile-Encased Check Dam Installation

1. Definition

   *A prefabricated check dam consisting of a urethane foam core encased in geotextile material.*

2. Purpose

   To reduce the velocity of concentrated flows, reduce erosion of the swale or ditch, and cause some suspended sediment to settle in ponded areas upstream of check dams. A triangular silt dike can be mobilized and placed quickly. If they are taken care of, triangular silt dikes can be reused.

3. Additional Information/Guidance

   - The flexibility of the materials in triangular silt dikes allows them to conform to all channel configurations.
   - Triangular silt dikes can be fastened to soil with staples or rock and to pavement with adhesives.
   - Triangular silt dikes have been used to build temporary sediment ponds, diversion ditches, concrete wash-out facilities, curbing, water bars, level spreaders, and berms.

## 6A-2.23 Outlet Protection

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1). The Region Hydraulics Office should be consulted whenever shear stresses require solid liners.

1. Definition

   *A protective barrier of rock, erosion control blankets, vegetation, or sod constructed at a conveyance outlet.*

2. Purpose

   To prevent erosion and scour at drainage conveyance outlets and minimize the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

3. Additional Information/Guidance

   - Common locations for outlet protection include discharge points for ponds, pipes, ditches, or other conveyances.
   - Size the scale of the outlet protection based on expected flow volumes and velocities.
   - Refer to the *Hydraulics Manual* for guidance in choosing appropriate-sized rock outlet protection or alternative materials.

## 6A-2.24 Vegetated Strip

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *A strip of dense vegetation adjacent to a land-disturbing activity.*

2. Purpose

   To reduce the transport of sediment from a construction site by providing a physical barrier that reduces runoff velocities.

3. Additional Information/Guidance

   Vegetated strips may be used downslope of all disturbed areas. The strips are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Any concentrated flows must be conveyed through the drainage system to a sediment pond or a comparable BMP. The only circumstance in which overland sheet flow can be treated solely by a strip, rather than by a sediment pond or comparable BMP, is when the criteria shown in Table 6A-5 are met.

Ideally, vegetated strips consist of undisturbed native growth with a well-developed soil that allows for infiltration of runoff.

**Table 6A-5 Vegetated strips.**

| Average Slope | Slope Percent | Flowpath Length |
|---|---|---|
| 1.5H:1V or less | 67% or less | 100 feet |
| 2H:1V or less | 50% or less | 115 feet |
| 4H:1V or less | 25% or less | 150 feet |
| 6H:1V or less | 16.7% or less | 200 feet |
| 10H:1V or less | 10% or less | 250 feet |

## 6A-2.25 Wattles

*WSDOT Standard Specification*
8-01.3(10) – Wattles
9-14.5(5) – Wattles

*WSDOT Standard Plan*
I-30.30-00 – Wattle Installation On Slope

1. Definition

   *Temporary erosion and sediment control barriers consisting of any plant material that is wrapped in biodegradable fiber, tubular plastic, or similar encasing material. Wattles are greater than 5 inches in diameter and 25 to 30 feet in length.*

2. Purpose

   The two main purposes of wattles are to reduce slope length and to trap sediment. Cutting a slope length in half reduces erosion potential by a factor of four. Wattles also trap sediment, whether used on a slope or as a perimeter control device.

3. Additional Information/Guidance

   - Wattles can also be used as temporary curbs for conveying water to catch basins, check dams, and pipe slope drain inlets.

## 6A-2.26 Compost Sock

*WSDOT Standard Specification*
8-01.3(12) – Compost Sock
9-14.5(6) – Compost Sock

*WSDOT Standard Plan*
I-30.40-00 – Compost Sock

1. Definition

   *Temporary erosion and sediment control barriers consisting of a bio- or photodegradable fabric tube filled with compost.*

2. Purpose

   The main purpose of a compost sock is as a perimeter control device to trap sediment and slow down runoff. Compost socks can be used in place of silt fence in some areas where low stormwater flows are expected. They are especially useful near sensitive areas where soil disturbance should be kept to a minimum.

3. Additional Information/Guidance

   - Compost socks do not need to be trenched in like silt fence or wattles.

## 6A-2.27 Silt Fence

*WSDOT Standard Specification*
8-01.3(9)A – Silt Fence

*WSDOT Standard Plans*
I-30.10-01 – Silt Fence with Backup Support
I-30.15-00 – Silt Fence
I-30.20-00 – Erosion Control at Culvert Ends
I-40.10-00 – Temporary Silt Fence for Inlet Protection in Unpaved Areas

1. Definition

   *A temporary sediment barrier consisting of a geotextile fabric stretched across and attached to supporting posts, which are entrenched. Adding rigid wire fence backing can strengthen silt fence.*

2. Purpose

   To reduce the transport of sediment from a construction site by providing a temporary barrier to sediment and reducing the runoff velocities of sheet flow.

3. Additional Information/Guidance

   - Place fence below disturbed areas subject to sheet and rill erosion.
   - Place fence on contour to maximize sediment-trapping performance.

## 6A-2.28 Filter Berm

*WSDOT Standard Specification*
8-01.3(9)B – Gravel Filter, Wood Chips, or Compost Berm
9-14.4(3) – Bark or Wood Chips
9-14.4(8) – Compost

*WSDOT Standard Plan*
I-80.10-00 – Miscellaneous Erosion Control Details

1. Definition

   *A berm consisting of gravel, wood chips, or compost.*

2. Purpose

   Filter berms have two main functions: to prevent concentrated flows from damaging exposed cut/fill slopes and to provide perimeter containment of sediment at the toe of a slope.

3. Additional Information/Guidance

   - Construction vehicles and equipment can easily damage filter berms, so traffic must be routed around them.
   - To prevent blowouts, pipe slope drains may be needed to convey water that accumulates along the filter berm.

## 6A-2.29 Storm Drain Inlet Protection

*WSDOT Standard Specification*
8-01.3(9)D – Inlet Protection (below inlet grate, above inlet grate, and inlet grate cover)

*WSDOT Standard Plan*
I-30.40-00 – Compost Sock
I-40.10-00 – Temporary Silt Fence for Inlet Protection in Unpaved Areas
I-40.20-00 – Storm Drain Inlet Protection

1. Definition

   *A device or mechanism (internal or external) for trapping sediment within or immediately adjacent to a catch basin. Prefabricated devices are available for both situations.*

2. Purpose

   To prevent sediment from entering an enclosed drainage system where the material can be readily washed downstream. Inlet protection is often the last opportunity to minimize sediment impact to a receiving water body.

3. Additional Information/Guidance

   - There is a difference in how internal and external inlet protection devices function.
   - Internal devices tend to consist of a nonwoven material that is semiporous. Larger sediments are trapped, but silt and clay-sized particles pass through. They are most appropriate in situations where roadway flooding is a concern or construction traffic will damage an external device.
   - External devices may be prefabricated or assembled in the field using silt fence. Both types trap sediment by creating a ponding area surrounding the inlet. The reduced velocities allow sediment to settle. This process allows external devices to be more efficient at trapping greater volumes of smaller-sized sediment.
   - In an emergency, berms of sand bags or washed gravel can be placed around the inlet.

## 6A-2.30 Sediment Trap

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1).

*WSDOT Standard Plan*
I-80.10-00 – Miscellaneous Erosion Control Details

1. Definition

   *A small, temporary detention basin using a natural depression or constructed area.*

2. Purpose

   To aid in the settling of suspended sediments from concentrated flows.

3. Additional Information/Guidance

   - Intended for use on sites where the tributary drainage area is less than 3 acres, with no unusual drainage features and with a projected build-out time of six months or less.
   - Trap efficiency is enhanced when runoff is passed through multiple sediment control BMPs.
   - Sediment traps are limited to removing silt/larger-sized sediment particles.
   - Trap effectiveness increases with trap size.

4. Sizing Procedure

   - To determine the sediment trap geometry, first calculate the design surface area (SA) of the trap, measured at the invert of the weir. Use the following equation:

     $$SA = FS(Q/V_S)$$

     where:

     $Q$ = Design inflow based on criteria contained in Section 4-3.3 for western Washington or Section 4-4.3 for eastern Washington.

     $Vs$ = The settling velocity of the soil particle of interest. The 0.02 mm (medium silt) particle with an assumed density of 2.65 g/cm$^3$ has been selected as the particle of interest and has a settling velocity ($V_S$) of 0.00096 ft/sec.

     $FS$ = A safety factor of 2 to account for non-ideal settling.

     Therefore, the equation for computing surface area becomes:

     $SA$ = 2 x $Q_2$/0.00096 or
     2080 square feet per cfs of inflow

     Note: Even if permanent facilities are used, they must still have a surface area that is at least as large as that derived from the above formula. If they do not, the pond must be enlarged.

   - To aid in determining sediment depth, all sediment traps shall have a staff gage with a prominent mark 1 foot above the bottom of the trap.
   - Sediment traps may not be feasible on utility projects due to the limited work space or the short-term nature of the work. Portable tanks may be used in place of sediment traps for utility projects.
   - Sediment shall be removed from the trap when it reaches 1 foot in depth.
   - Any damage to the pond embankments or slopes shall be repaired.

## 6A-2.31 Temporary Sediment Pond

*WSDOT Standard Specification*
8-01.3(1)E – Detention/Retention Pond Construction

1. Definition

   *A basin with a controlled stormwater release structure. Temporary sediment ponds are usually located where the permanent detention facilities are built. In such cases, more stringent permanent facility-sizing criteria are used to size temporary sediment ponds. All design criteria for permanent detention facilities should be applied to temporary ponds unless no permanent pond is to remain or be built.*

2. Purpose

   To collect stormwater runoff and detain it long enough to trap sediment.

3. Additional Information/Guidance

   - The use of infiltration facilities for sedimentation basins clogs the soils and reduces infiltration capacity.
   - Use sediment traps as pretreatment devices to minimize the need for pond maintenance and prevent soil clogging. If pretreatment is not possible, install a permeable rock divider within the pond.
   - Pond outlets must be designed to provide flow control. WSDOT does not yet have a standard temporary pond outlet design. Design outlets in accordance with Figure 6A-1. Contact the Region Hydraulics Office if site conditions warrant any modification of the figures.
   - Structures having a maximum storage capacity at the top of the dam of 10 acre-ft (435,600 $ft^3$) or more are subject to the Washington Dam Safety Regulations (Chapter 173-175 WAC).
   - If permanent runoff control facilities are part of the project, consider using them for sediment retention during construction, if possible. The surface area requirements of the sediment basin must be met. This may require enlarging the permanent basin to comply with the surface area requirements. If a permanent control structure is used, it may be advisable to partially restrict the lower orifice with gravel to increase residence time while still allowing dewatering of the basin.

4. Sizing Procedure

   - Determine the surface area (*SA*) of the sediment pond at the top of the riser pipe. Use the equation:

     $SA = 2 \times Q/0.00096$ or
     2080 square feet per cfs of inflow

     For more information on the derivation of the surface area calculation, see Section 6A-2.31. Design inflow (*Q*) based on criteria contained in Section 4-3.3 for western Washington or Section 4-4.3 for eastern Washington.

   - The basic geometry of the pond can now be determined using the following design criteria:

     - Minimum 3.5-foot depth from top of riser to bottom of pond.
     - Maximum 3H:1V interior side slopes and maximum 2H:1V exterior slopes. The interior slopes can be increased to a maximum of 2H:1V if fencing is provided at or above the maximum water surface.
     - One foot of freeboard between the top of the riser and the crest of the emergency spillway.
     - Flat bottom.

- Minimum 1-foot-deep spillway.
- Length-to-width ratio between 3:1 and 6:1.

- Sizing of Discharge Mechanisms
  - The outlet for the basin consists of a combination of principal and emergency spillways. These outlets must pass the peak runoff expected from the contributing drainage area for a 100-year storm. If, due to site conditions and basin geometry, a separate emergency spillway is not feasible, the principal spillway must pass the entire peak runoff expected from the 100-year storm. However, an attempt to provide a separate emergency spillway should always be made. The runoff calculations should be based on the site conditions during construction. The flow through the dewatering orifice cannot be utilized when calculating the 100-year storm elevation because of its potential to become clogged; therefore, available spillway storage must begin at the principal spillway riser crest.

  - The principal spillway designed by the procedures contained in this standard will result in some reduction in the peak rate of runoff. However, the riser outlet design will not adequately control the basin discharge to the predevelopment discharge limitations as stated in Minimum Requirement 6, Flow Control. However, if the basin for a permanent stormwater detention pond is used for a temporary sedimentation basin, the control structure for the permanent pond can be used to maintain predevelopment discharge limitations. The size of the basin, the expected life of the construction project, the anticipated downstream effects and the anticipated weather conditions during construction should be considered to determine the need of additional discharge control. (See Figure FC.03.5 for riser inflow curves.)

    **Principal Spillway:** Determine the required diameter for the principal spillway (riser pipe). The diameter shall be the minimum necessary to pass the site's 10-year, 15-minute peak flow ($Q_{10}$). For western WA, $Q_{10}$ is the 10-year, 1-hour flow for the developed (unmitigated by flow control facilities) site, multiplied by a factor of 1.6. Use Figure FC.03.5 to determine this diameter (h = 1 foot). Note: A permanent control structure may be used instead of a temporary riser.

    **Emergency Overflow Spillway:** Determine the required size and design of the emergency overflow spillway for the developed 100-year peak flow using the method contained in Chapter 4.

    **Dewatering Orifice:** Determine the size of the dewatering orifice(s) (minimum 1-inch-diameter) using a modified version of the discharge equation for a vertical orifice and a basic equation for the area of a circular orifice. Determine the required area of the orifice with the following equation:

$$A_o = \frac{A_s (2h)^{0.5}}{0.6 \text{x} 3600 \pi g^{0.5}}$$

where:

$A_O$ = orifice area (square feet)
$A_S$ = pond surface area (square feet)
$h$ = head of water above orifice (height of riser in feet)
$T$ = dewatering time (24 hours)
$g$ = acceleration of gravity (32.2 feet/second$^2$)

Convert the required surface area to the required diameter *D* of the orifice:

$$D = 24x\sqrt{\frac{A_o}{\pi}} = 13.54x\sqrt{A_o}$$

The vertical perforated tubing connected to the dewatering orifice must be at least 2 inches larger in diameter than the orifice to improve flow characteristics. The size and number of perforations in the tubing should be large enough so that the tubing does not restrict flow. The orifice should control the flow rate.

- Additional Design Specifications
  - The **pond shall be divided** into two roughly equal volume cells by a permeable divider that will reduce turbulence while allowing movement of water between cells. The divider shall be at least one-half the height of the riser and a minimum of 1 foot below the top of the riser. Wire-backed, 2-to 3-foot-high, extra-strength filter fabric supported by treated 4x4s can be used as a divider. If the pond is more than 6 feet deep, a different mechanism must be proposed. A riprap embankment is one acceptable method of separation for deeper ponds. Other designs that satisfy the intent of this provision are allowed as long as the divider is permeable, structurally sound, and designed to prevent erosion under or around the barrier.
  - To aid in determining sediment depth, **1-foot intervals** shall be prominently marked on the riser.
  - If an **embankment** of more than 6 feet is proposed, the pond must comply with the criteria contained in BMP FC.03 regarding dam safety for detention BMPs.
- The most common structural failure of sedimentation basins is caused by piping. Piping refers to (1) water seeping through fine-grained soil, eroding the soil grain by grain and forming pipes or tunnels, and (2) water under pressure flowing upward through a granular soil with a head of sufficient magnitude to cause soil grains to lose contact and capability for support.
- The most critical construction sequences to prevent piping will be:
  - Tight connections between riser and barrel and other pipe connections.
  - Adequate anchoring of riser.
  - Proper soil compaction of the embankment and riser footing.

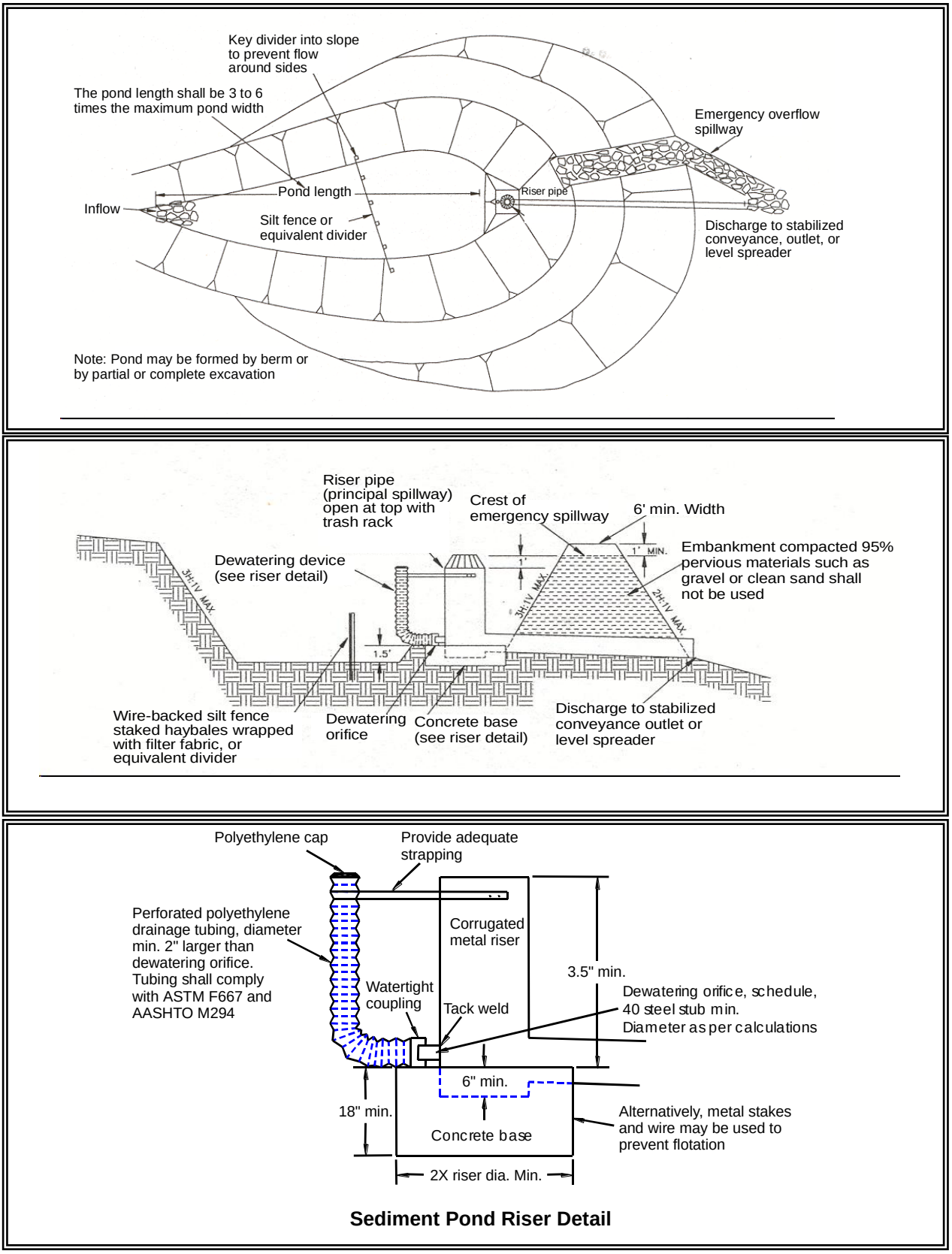


**Figure 6A-1 Temporary sediment pond details.**

## 6A-2.32 Concrete Handling

*WSDOT Standard Specifications*
1-07.5(1) – Environmental Regulations
1-07.15 – Temporary Water Pollution/Erosion Control
5-01.3(11) – Concrete Slurry
8-01.3(1)C – Water Management

WSDOT has created a GSP for preventing stormwater contamination during concrete work, which is located at: www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/8-01.3(1)a.opt1.gr8.pdf. In situations where the GSP does not appear adequate, contact Region Environmental staff or the HQ Environmental Services Office (360-570-6654) for more information or additional guidance for situations where neutralizing the high pH water with dry ice or $CO_2$ sparging may be necessary.

1. Definition

   *A BMP designed to control concrete wastes and concrete leachate.*

2. Purpose

   Concrete work can generate process water and slurry that have a high pH and contain fine particles (turbidity). These byproducts are prohibited from entering waters of the state. Management practices shall be utilized to reduce the impact of fresh concrete on regulated water bodies that results from concrete work, including sawing, grinding, and resurfacing.

3. Additional Information/Guidance

   - Concrete truck chutes, pumps, and hand tools shall be washed in formed areas actively awaiting installation of concrete or asphalt.
   - Unused concrete remaining in the truck and pump shall be returned to the concrete batch plant or disposed of in a formed area actively awaiting concrete or asphalt.
   - When no formed areas are available, wash water and leftover product shall be contained in a lined container or designated area.
   - Designated areas shall never drain to natural or constructed stormwater conveyances. Designated areas shall not be allowed in areas with high groundwater or within 200 feet of any waterway, including wetlands. Designated areas shall be covered with plastic in advance of storms.
   - Designated areas must be inspected daily during use and maintained to prevent a violation of water quality standards and to prevent stormwater from mixing with waste material and discharging.
   - Stormwater inlet protection measures shall be placed around all catch basins in the vicinity of concrete work.
   - Phase larger pours during the dry season when feasible.

- BMPs designed for spill prevention and containment can be used to eliminate the risk of discharging concrete runoff to receiving waters.

## 6A-2.33 High pH Neutralization

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For additional information, contact Region Environmental staff or the HQ Environmental Services Office (360-570-6654). For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *The process of neutralizing stormwater when pH is over 8.5 pH units prior to discharge to waters of the state.*

2. Purpose

   When pH levels in stormwater rise above 8.5, it is necessary to lower the pH levels to the acceptable range of 6.5 to 8.5 prior to discharge to waters of the state. This process is called pH neutralization. Neutralized stormwater may be discharged to surface waters under the General Construction NPDES permit.

   Process water includes wastewaters such as concrete truck wash-out, hydrodemolition, or saw-cutting slurry. Neutralized process water cannot be discharged to surface waters under the General Construction NPDES permit. Contact the Region or HQ Environmental Office for more information.

3. Additional Information/Guidance

   High pH stormwater can be treated by infiltration; dispersion in vegetation or compost (see Section 6A-2.20); pumping to a sanitary sewer; disposal at a permitted concrete batch plant; or dry ice or carbon dioxide sparging (see methods below).

   Methods for $CO_2$ sparging:

   - Every effort should be made to isolate the high-pH water in order to treat it separately from other stormwater on-site.
   - Transfer water to be treated to the treatment structure (baker tank). Ensure treatment structure size is sufficient to hold the amount of water to be treated.
   - Sample the pH of the water. As a general rule, less $CO_2$ is needed for clearer water.

- In the pH adjustment structure (baker tank), add $CO_2$ until the pH drops as close to 7 as practicable. Compressed carbon dioxide gas should be introduced using a carbon dioxide diffuser located near the bottom of the tank.
- Release water, making sure that deposited sediment does not discharge in the process.
- Discharge water in a manner (such as dispersion, infiltration, or dilution in a pond or drainage system) that maximizes treatment potential prior to entering waters of the state.
- Dispose of sludge as concrete waste. If several batches of water are undergoing pH treatment, sludge can be left in the treatment structure. Dispose of sludge as necessary to ensure adequate storage volume and effective treatment.
- Operator Records: Include a diagram of the monitoring and treatment equipment and a description of the pumping rates and capacity the treatment equipment is capable of treating. Keep a record in the Site Log Book of the volume of water treated daily; the pH of untreated water; the amount of $CO_2$ needed to adjust water to as close to a pH of 7 as feasible; the pH of treated water; and the discharge point location and description.
- Refer to Ecology's SMMWW, Volume II, BMPs C252 and C253, for more information on neutralizing high pH.

## 6A-2.34 Construction Stormwater Chemical Treatment

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. Region Environmental staff and the HQ Environmental Services Office (ESO) must be notified of the intent to use chemical treatment to determine whether it is necessary. For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *The use of a chemical to encourage flocculation of fine sediments entrained in construction site runoff.*

2. Conditions of Use

   Chemical treatment must be approved by Ecology. Notify Region Environmental staff to ensure the environmental offices can:

   - Provide input on whether or not chemical treatment is necessary or appropriate.
   - Provide technical assistance.

- Ensure Ecology is properly notified.
- Track usage, effectiveness, and cost/benefit information.

Once written approval from Ecology is obtained, the chemical treatment system must be included in the TESC plan.

3. Purpose

   Polymers improve the removal of fine sediment that would not normally settle out through gravity alone. Their usage is only warranted when:

   - Large volumes of highly-turbid water cannot possibly be prevented due to unusual circumstances (such as projects requiring large dewatering/ horizontal drilling operations or slides), and there is no reasonable possibility of effectively employing any standard sediment control BMP or dispersal/infiltration technique.
   - Chemical treatment system costs enable the recovery of costs by other means, such as accelerated construction rates.

4. Additional Information/Guidance

   - This process is sometimes used in conjunction with stormwater filtration (refer to BMP 6A-2.36 below, Construction Stormwater Filtration).
   - Refer to Ecology's SMMWW, Volume II, BMP C250, for more information on Chemical Treatment.

## 6A-2.36 Construction Stormwater Filtration

*WSDOT Standard Specification*
No WSDOT Standard Specification exists, so a Special Provision must be written. For instructions on preparing Special Provisions, see the Introduction (6A-1).

1. Definition

   *The process of pumping construction stormwater through a series of filters—primarily sand. Filters remove sediment from construction site stormwater by trapping sediment on or in filter media. Many of these systems are mobile and can be set up on any construction site.*

2. Purpose

   To remove sediment from construction site stormwater ponds that cannot be removed through other conventional means.

3. Additional Information/Guidance

   - Unlike chemical treatment, the use of construction stormwater filtration does not require approval from Ecology.

- Two types of filtration systems may be applied to construction stormwater treatment: rapid and slow. Rapid sand filters are typically used for water and wastewater treatment. They can achieve relatively high hydraulic flow rates, on the order of 2 to 20 gallons per minute per square foot of filter area (gpm/sf), because they have automatic backwash systems to remove accumulated solids. In contrast, slow sand filters have very low hydraulic flow rates, on the order of 0.02 gpm/sf, because they do not have backwash systems. To date, slow sand filtration has generally been used to treat stormwater. Slow sand filtration is mechanically simple in comparison to rapid sand filtration, but requires a much larger filter area.
- Filtration Equipment – Sand media filters are available with automatic backwashing features that can filter to 50 µm particle size. Screen or bag filters can filter down to 5 µm. Fiber-wound filters can remove particles down to 0.5 µm. Filters should be sequenced from the largest to the smallest pore opening. Sediment-removal efficiency is related to particle size distribution in the stormwater.
- Treatment Process Description – Stormwater is collected at interception point(s) on the site and diverted to a sediment pond or tank for removal of large sediment and storage of the stormwater before it is treated by the filtration system. The stormwater is pumped from the trap, pond, or tank through the filtration system in a rapid sand filtration system. Slow sand filtration systems are designed as flow-through systems using gravity.
- If large volumes of concrete are being poured, pH adjustment may be necessary.
- Filtration may also be used in conjunction with polymer treatment in a portable system to ensure capture of the flocculated solids.
- Refer to Ecology's SMMWW, Volume II, BMP C251, for more information on Chemical Treatment.

# GLOSSARY OF TERMS

**alignment** Horizontal and vertical geometric elements that define the location of a roadway.

**anadromous fish species** Fish that are born and reared in freshwater, migrate to the ocean to grow to maturity, and return to freshwater to reproduce (such as salmon and steelhead).

**anoxic** Devoid of oxygen.

**antecedent moisture conditions** The degree of wetness of a watershed or the soil at the beginning of a storm.

**antiseepage collar** A device constructed around a pipe or other conduit and placed through a dam, levee, or dike for the purpose of reducing seepage losses and piping failures.

**aquifer** A geological stratum containing groundwater that can be withdrawn and used for human purposes.

**arid** Excessively dry; having insufficient rainfall to support agriculture without irrigation.

**arterial** A road or street intended to move high volumes of traffic over long distances at high speed, with partial control of access, having some intersections at grade. A *major arterial* connects an interstate highway to cities and counties. A *minor arterial* connects major arterials to collectors. A *collector* connects an arterial to a neighborhood (a collector is not an arterial). A *local access road* connects individual residences to a collector.

**as-built drawings** Engineering plans that have been revised to reflect all changes to the plans that occurred during construction.

**average daily traffic (ADT)** The volume of traffic passing a point on a highway in both directions during an average day of the year (or design year). ADT counts must be estimated using *Trip Generation*, published by the Institute of Transportation Engineers, or using a traffic study prepared by a professional engineer or transportation specialist with expertise in traffic volume estimation. ADT counts can be used to forecast future volumes for the design life of a particular project. For project sites with seasonal or varied use, the highest period of expected traffic impacts is evaluated.

**backwater** Water upstream from an obstruction that is deeper than it would normally be without the obstruction.

**baffle** A device to check, deflect, or regulate flow.

**base flood** A flood having a 1% chance of being equaled or exceeded in any given year (also called the 100-year flood).

**base flow** The portion of stream flow that is not attributable to storm runoff and is supported by groundwater seepage into a channel.

**basic (water quality) treatment** (versus *enhanced water quality treatment*) The Washington State Department of Ecology's performance goal is to achieve 80% removal of total suspended solids for influent concentrations that are greater than 100mg/l, but less than 200mg/l. For influent concentrations greater than 200mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100mg/l, the facilities are intended to achieve an effluent goal of 20mg/l total suspended solids.

**basin** The area of land drained by a river and its tributaries that drains water, organic matter, dissolved nutrients, and sediments into a lake or stream (see *watershed*). Basins typically range in size from 1 to 50 square miles.

**basin plan** A plan that assesses, evaluates, and proposes solutions to existing and potential future impacts on the physical, chemical, and biological properties and beneficial uses of waters of the state within a drainage basin. A plan should include but not be limited to recommendations for the following elements:

- Stormwater requirements for new development and redevelopment
- Capital improvement projects
- Land use management through identification and protection of critical areas, comprehensive land use and transportation plans, zoning regulations, site development standards, and conservation areas
- Source control activities, including public education and involvement, and business programs
- Other targeted stormwater programs and activities, such as maintenance, inspections, and enforcement
- Monitoring
- An implementation schedule and funding strategy

A basin plan that is adopted and implemented must have the following characteristics:

- Adoption by legislative or regulatory action of jurisdictions with responsibilities under the plan
- Recommended ordinances, regulations, programs, and procedures that are in effect or scheduled to go into effect
- An implementation schedule and funding strategy in progress

**bench** A relatively level step excavated into earth material on which fill is to be placed.

**beneficial uses** Those water uses identified in state water quality standards that must be achieved and maintained as required under the federal Clean Water Act. "Beneficial use" and "designated use" are often used interchangeably.

**berm** A constructed barrier of compacted earth, rock, or gravel. In a stormwater facility, a berm may serve as a vertical divider, typically built up from the bottom.

**best available science** The best available scientific knowledge and practices.

**best management practices (BMPs)** The structural devices, maintenance procedures, managerial practices, prohibitions of practices, and schedules of activities that are used singly or in combination to prevent or reduce the detrimental impacts of stormwater, such as pollution of water, degradation of channels, damage to structures, and flooding.

**biodegradable** Capable of being readily broken down by biological means, especially by microbial action. Microbial action includes the combined effects of bacteria, fungi, flagellates, amoebae, ciliates, and nematodes. Degradation can be rapid or may take many years, depending on such factors as available oxygen and moisture.

**bioengineering** The combination of biological, mechanical, and ecological concepts (and methods) to control erosion and stabilize soil through the use of vegetation alone or in combination with construction materials.

**biofilter** A designed treatment facility using a combined soil and vegetation system for filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater when runoff flows over and through it. Vegetation growing in these facilities acts as both a physical filter that causes gravity settling of particulates by regulating velocity of flow, and as a biological sink when direct uptake of dissolved pollutants occurs. The former mechanism is probably the most important in western Washington, where the period of major runoff coincides with the period of lowest biological activity.

**biofiltration** The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials, such as vegetation.

**bioinfiltration** The process of reducing pollutant concentrations in water by infiltrating the polluted water through grassy vegetation and soils into the ground.

**biological assessment** A document prepared under the direction of a federal agency to determine whether a proposed action involving major construction activities is likely to (1) adversely affect species protected under the Endangered Species Act or their designated critical habitats, (2) jeopardize the continued existence of species that are proposed for listing as threatened or endangered, or (3) adversely modify proposed critical habitat.

**biological evaluation** A document that contains exactly the same information as a biological assessment, evaluating the impacts of a proposed action on listed and proposed species and habitat. In the case of projects without federal involvement, the biological evaluation determines whether the proposed action would violate Section 9 of the Endangered Species Act. The biological evaluation can evolve into a biological assessment if formal or informal consultation is required with the federal agencies.

**bioretention** The removal of stormwater runoff pollutants using the chemical, biological, and physical properties afforded by a natural terrestrial community of plants, microbes, and soil. The typical bioretention system is set in a depressional area and consists of plantings, mulch, and an amended planting soil layer underlain with more freely draining granular material.

**bituminous surface treatment (BST)** A thin, protective wearing surface that is applied to a pavement or base course (also known as a seal coat or chip seal).

**bollard** A post (which may or may not be removable) used to prevent vehicular access.

**borings** Cylindrical samples of a soil profile used for analysis of soils or determination of infiltration capacity.

**borrow area** A source of earth fill material used in the construction of embankments or other earth fill structures.

**buffer** The zone contiguous with a sensitive area that is required for the continued maintenance, function, and structural stability of the sensitive area. The critical functions of a riparian buffer (those associated with an aquatic system) include shading; input of organic debris and coarse sediments; uptake of nutrients; stabilization of banks; interception of fine sediments; overflow during high water events; protection from disturbance by humans and domestic animals; maintenance of wildlife habitat; and room for variation of aquatic system boundaries over time due to hydrologic or climatic effects. The critical functions of terrestrial buffers include protection of slope stability, attenuation of surface water flows from stormwater runoff and precipitation, and erosion control.

**bypass** A channel or conveyance constructed to divert water around a stormwater facility or series of stormwater facilities.

**capital costs** Nonrecurring costs required to construct infrastructure, including costs of right of way, facilities, drainage systems, utilities, and associated administrative and design costs, as well as financing charges during construction.

**capital improvement project *or* program (CIP)** A project prioritized and scheduled as a part of an overall construction program or the actual construction program.

**catch basin** A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

**catch basin insert (CBI)** A device installed under a storm drain grate to provide runoff treatment through filtration, settling, or adsorption (also called *inlet protection*).

**catchment** Surface area associated with pavement drainage design.

**cation exchange capacity (CEC)** The amount of exchangeable cations that a soil can adsorb at pH 7.0, typically expressed in units of milliequivalents per 100 grams of dry soil.

**channel** A feature that conveys surface water and is open to the air.

**channel erosion** The widening, deepening, and headward cutting of small channels and waterways resulting from erosion caused by moderate-to-large floods.

**channel stabilization** Erosion prevention and stabilization of velocity distribution in a channel using vegetation, jetties, drops, revetments, or other measures.

**check dam** A small dam constructed in a ditch, gully, grass swale, or other small watercourse to decrease the stream flow velocity, enhance infiltration, minimize channel scour, and promote deposition of sediment; or a log or gabion structure placed perpendicular to a stream to enhance aquatic habitat.

**clearing** The removal and disposal of all unwanted natural material from the ground surface such as trees, brush, and downed timber by manual, mechanical, or chemical methods.

**closed depression** A low-lying area that has either no surface water outlet or such a limited surface water outlet that, during storm events, the area acts as a retention basin.

**coir** Coconut fiber used for erosion control blankets and wattles.

**compaction** The densification, settlement, or packing of soil in such a way that its permeability is reduced. Compaction effectively shifts the performance of a hydrologic group to a lower-permeability hydrologic group. Compaction may also refer to the densification of a fill by mechanical means.

**compost** Organic residue, or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus. The Washington State Department of Ecology's *Interim Guidelines for Compost Quality* (1994) defines compost as "the product of composting; it has undergone an initial, rapid stage of decomposition and is in the process of humification (curing)." Compost to be used should meet specifications shown in Standard Specification 9-14.4(8).

**concentrated flow** Water flowing in a channel as opposed to a thin sheet.

**constructed stormwater treatment wetland** A wetland intentionally created on a site that is not a wetland, for the primary purpose of wastewater or stormwater treatment. Constructed wetlands are normally considered part of the stormwater collection and treatment system.

**Construction Contract Information System (CCIS)** A WSDOT database managed by the HQ Construction Office to track contract costs.

**construction staging area** A site used temporarily during construction for materials or equipment storage, assembly, or other temporary construction activities.

**context sensitive design (CSD)** A collaborative, interdisciplinary approach that involves all stakeholders in developing a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources while maintaining safety and mobility (also known as "context sensitive solutions" and "thinking beyond the pavement").

**converted pervious surface** Land cover changed from native vegetation to lawn, landscape, or pasture areas. (See also *pollution-generating impervious surface*.)

**conveyance** A mechanism for transporting water from one point to another, including pipes, ditches, and channels.

**conveyance system** The drainage facilities, both natural and constructed, that collect, contain, and provide for the flow of surface water and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. Constructed elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/ detention facilities.

**critical areas** At a minimum: areas that include wetlands; areas with a critical recharging effect on aquifers used for potable water; fish and wildlife habitat conservation areas; frequently flooded areas; geologically hazardous areas, including unstable slopes; and associated areas and ecosystems.

**culvert** A pipe or concrete box structure that drains open channels, swales, or ditches under a roadway or embankment. Typically, a culvert is not connected to a catch basin or manhole along its length. Various types of culverts are listed in the *Hydraulics Manual*.

**cut-and-fill** The process of moving earth by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

**cut slope** A slope formed by excavating overlying material to connect the original ground surface with a lower ground surface created by the excavation. A cut slope is distinguished from a bermed slope, which is constructed by importing soil to create the slope.

**dangerous waste** Any discarded, useless, unwanted, or abandoned substances, including (but not limited to) certain pesticides, or any residues or containers of such substances that are disposed of in such quantity or concentration as to pose a substantial current or potential hazard to human health, wildlife, or the environment (RCW 70.105.010). These wastes may have short-lived, toxic properties that may cause death, injury, or illness; may have mutagenic, teratogenic, or carcinogenic properties; may be corrosive, explosive, or flammable; or may generate pressure through decomposition or other means. (See also *hazardous waste*.)

**dead storage** The volume of water in a pond, reservoir, or infiltration facility that is stored below the elevation of the lowest outlet or operating level of the structure; the volume available in a depression in the ground below any conveyance system, surface drainage pathway, or outlet invert elevation that could allow the discharge of surface and stormwater runoff.

**demonstrative approach** (versus *presumptive approach*) See Sections 1-1.3 and 5-3.5.3.

**depression storage** The amount of precipitation trapped in depressions on the surface of the ground.

**design flow rate** The maximum flow rate to which certain runoff treatment BMPs are designed for required pollutant removal. Biofiltration swales, vegetated filter strips, and oil/water separators are some of the runoff treatment BMPs that are sized based on a design flow rate.

**design storm** A rainfall event of specified size and return frequency that is used to calculate the runoff volume and peak discharge rate to a stormwater facility. A prescribed hyetograph and total precipitation amount (for a specific duration recurrence frequency) are used to estimate runoff for a hypothetical storm for the purposes of analyzing existing drainage, designing new drainage facilities, or assessing other impacts of a proposed project on the flow of surface water. (A hyetograph is a graph of percentages of total precipitation for a series of time steps representing the total time during which the precipitation occurs.)

**design storm frequency** The anticipated period in years that will elapse before a storm of a given intensity or total volume will recur, based on the average probability of storms in the design region. For instance, a 10-year storm can be expected to occur on the average once every 10 years. Facilities designed to handle flows that occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

**design volume** For western Washington, the water quality design volume is the 91st percentile, 24-hour runoff volume indicated by MGSFlood or an approved continuous runoff model (see Table 3-3). In eastern Washington, the water quality design volume is the volume of runoff predicted from a 24-hour storm with a 6-month return frequency (see Table 3-4).

**detention** The temporary storage of stormwater runoff in a stormwater facility, which is used to control the peak discharge rates and provide gravity settling of pollutants; the release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, with the difference held in temporary storage.

**detention facility** An aboveground or below-grade ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater.

**dewatering** Removing water by pumping, drainage, or evaporation.

**discharge** Runoff leaving a new development or redevelopment via overland flow, built conveyance systems, or infiltration facilities; a hydraulic rate of flow, specifically fluid flow; or a volume of fluid passing a point per unit of time, commonly expressed in cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or millions of gallons per day.

**dispersion** Release of surface water and stormwater runoff in such a way that the flow spreads over a wide area and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.

**displacement** A property encroachment that requires full acquisition of a parcel in order to build and operate public transportation facilities.

**ditch** A long, narrow excavation dug in the earth for drainage, having a top width less than 10 feet at design flow.

**drainage easement** A legal encumbrance placed against a property's title to reserve specified privileges for the users and beneficiaries of the drainage facilities contained within the boundaries of the easement.

**drawdown** The gradual reduction in water level in a pond due to the combined effects of infiltration and evaporation; the lowering of the water surface (in open-channel flow), the water table, or the piezometric surface (in groundwater flow) resulting from a withdrawal of water.

**drop structure** A structure for dropping water to a lower level and dissipating its surplus energy (a fall). A drop may be vertical or inclined.

**dry pond** A facility that provides stormwater quantity control by containing excess runoff in a detention basin, then releasing the runoff at allowable levels.

**dry vault *or* tank** A facility that provides stormwater quantity control by detaining runoff in underground storage units and then releasing reduced flows at established standards.

**drywell** A well completed above the water table so that its bottom and sides are typically dry except when receiving fluids. Drywells are designed to disperse water below the land surface and are commonly used for stormwater management in eastern Washington. (See also *underground injection control [UIC] well.*)

**duff** The naturally-occurring layer of dead and decaying plant material that develops on the ground surface under established plant communities.

**easement** The legal right to use a parcel of land for a particular purpose. It does not include fee ownership, but may restrict the owner's use of the land.

**eastern Washington high-use road** Eastern Washington roadways with ADT >30,000.

**Ecology** Washington State Department of Ecology.

**ecology embankment** See *media filter drain*.

**effective impervious surface** For determining whether a particular TDA has exceeded Minimum Requirement 6 (Flow Control), the net-new impervious surfaces plus any applicable replaced impervious surfaces minus those new and applicable replaced impervious surfaces that are flowing into an existing dispersion area (noneffective new impervious surfaces and noneffective replaced impervious surfaces).

**effective impervious surface = net new impervious surface + applicable replaced impervious surface – noneffective new impervious surface – noneffective replaced impervious surface**

**effective pollution-generating impervious surface (PGIS)** For determining whether a particular TDA has exceeded Minimum Requirement 5 (Runoff Treatment), the new PGIS plus applicable replaced PGIS minus those new PGIS areas and applicable replaced PGIS areas that are flowing into an existing dispersion area (noneffective new PGIS and noneffective replaced PGIS).

**effective PGIS = new PGIS + applicable replaced PGIS – noneffective new PGIS – noneffective replaced PGIS**

**embankment** A structure of earth, gravel, or similar material raised to form a pond bank or foundation for a road.

**emergency overflow spillway** A vegetated earth or rock-lined channel used to safely convey flood discharges in excess of the capacity of the principal spillway.

**emergent plants** Aquatic plants that are rooted in the sediment but whose leaves are at or above the water surface. These wetland plants often have high habitat value for wildlife and waterfowl and can aid in pollutant uptake.

**emerging BMP technologies** BMP technologies that have not been evaluated using approved protocols, but for which preliminary data indicate they may provide a desirable level of stormwater pollutant removal. In some instances, an emerging technology may have already received a *pilot use* or *conditional use designation* from the Washington State Department of Ecology, but does not have a *general use designation*.

**endangered species** Any species in danger of extinction throughout all or a significant portion of its range (other than pest insects).

**Endangered Species Act (ESA) of 1973** An act *"To provide for the conservation of endangered and threatened species of fish, wildlife, and plants, and for other purposes."*

**energy dissipater** A means by which the total energy of flowing water is reduced, such as rock splash pads, drop manholes, concrete stilling basins or baffles, and check dams. In stormwater design, an energy dissipater is usually a mechanism that reduces velocity prior to or at discharge from an outfall in order to prevent erosion.

**engineering and economic feasibility (EEF)** An assessment of whether a project will experience practical limitations in fully meeting certain minimum requirements, particularly runoff treatment and flow control, within the project right of way. Limitations may be infrastructural, geographical, geotechnical, hydraulic, environmental, or benefit/cost-related. (Chapter 2 provides further discussion of EEF, and Appendix 2A includes the EEF Checklist, which is designed to identify the critical limiting factors that may inhibit or preclude construction of stormwater management facilities in a project right of way).

**enhanced runoff treatment, enhanced water quality treatment** (versus *basic water quality treatment*) The use of runoff treatment BMPs designed to capture dissolved metals at a higher rate than basic treatment BMPs.

**ephemeral stream** A stream or portion of a stream that flows in direct response to precipitation, receiving little or no water from groundwater or snowmelt (also known as a seasonal stream).

**equivalent area** An impervious surface area equal in size, located in the same drainage basin (threshold discharge area), and having similar use characteristics (for example, similar average daily traffic) to the impervious surface. The equivalent area concept generally applies to *engineered dispersion* areas and may apply to *natural dispersion* areas, as described in the following: The existing site currently collects runoff in a ditch or pipe and discharges to a surface water. By changing this condition to natural dispersion (BMP FC.01), a surface discharge is eliminated, resulting in a flow control improvement. Equivalent area trades for natural dispersion are allowed for this specific case.

**erosion** The detachment and movement of soil or rock fragments by water, wind, ice, or gravity.

**erosion control blanket** A blanket made of natural plant material or synthetic fibers that is rolled out and fastened to the soil surface to protect soil from raindrop and sheet erosion.

**erosion and sedimentation control (ESC)** Any temporary or permanent measures taken to reduce erosion, trap sediment, and ensure sediment-laden water does not leave the site.

**estuarine wetland** Generally, an eelgrass bed, salt marsh, or rocky sand flat or mudflat intertidal area where freshwater and saltwater mix (specifically, a tidal wetland with salinity greater than 0.5 parts per thousand, usually partially enclosed by land, but with partially obstructed or sporadic access to the open ocean).

**eutrophication** The addition of nutrients, especially nitrogen and phosphorus, to a body of water, resulting in high organic production rates that may overcome natural self-purification processes. Frequently resulting from pollutant sources on adjacent lands, eutrophication produces undesirable effects, including algal blooms, seasonally low oxygen levels, and reduced survival opportunities for fish and invertebrates.

**evapotranspiration** The collective term for the processes of evaporation and plant transpiration by which water is returned to the atmosphere.

**exfiltration** The downward movement of runoff through the bottom of an infiltration facility into the soil layer, or the downward movement of water through soil.

**existing land cover/existing site conditions** The conditions (ground cover, slope, drainage patterns) of a site as they existed on the first day the project entered the design phase.

**existing roadway prism** The limit of embankment or excavation work required to construct the roadway. This limit is further defined as the catch point of a cut or fill with the existing ground.

**feasibility** See *engineering and economic feasibility*.

**fill slope** An embankment made of earthen material placed by artificial means that is especially vulnerable to erosion**.**

**filter berm** A berm of compost, mulch, or gravel to detain and filter sediment from sheet flow.

**filter fabric** A woven or nonwoven water-permeable material, typically made of synthetic products such as polypropylene, used in stormwater management and erosion and sediment control applications to trap sediment or to prevent fine soil particles from clogging the aggregates.

**filter strip** A grassy area with gentle slopes that treats stormwater runoff from adjacent paved areas before it can concentrate into a discrete channel.

**fish-bearing stream** According to WAC 222-16-030: Type S, F, and Np waters are fish habitat streams. Until fish habitat water type maps are available, an interim water-typing system applies (see WAC 222-16-031). Type 1, 2, 3, and 4 waters are fish habitat streams.

**flood** An overflow or inundation that comes from a river or any other source, including but not limited to streams, tides, wave action, storm drains, or excess rainfall; any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream.

**flood control project** A structural system installed to protect land and improvements from floods by the construction of dikes, river embankments, channels, or dams.

**flood frequency** The frequency at which the flood of interest may be expected to occur.

**flood peak** The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.

**floodplain** The total area subject to inundation by a flood, including the flood fringe and floodway.

**flood stage** The stage at which overflow of the natural banks of a stream begins.

**floodway** The channel of the river or stream and those portions of the adjoining floodplains that are reasonably required to carry and discharge the base flood flow. The "reasonably required" portion of the adjoining floodplains is defined by flood hazard regulations.

**flow control** (formerly called *water quantity treatment* or *detention*)

**flow control facility** A drainage facility (BMP) designed to mitigate the impacts of increased surface water and stormwater runoff flow rates generated by development. Flow control facilities are designed to either hold water for a considerable length of time and then release it by evaporation, plant transpiration, or infiltration into the ground, or to hold runoff for a short period of time and then release it to the conveyance system at a controlled rate.

**flow duration** The aggregate time that peak flows are equal to or above a particular flow rate of interest. For example, the amount of time that peak flows are equal to or above 50% of the 2-year peak flow rate for a period of record.

**flow frequency** The inverse of the probability that the flow will be equaled or exceeded in any given year (the exceedance probability). For example, if the exceedance probability is 0.01 or 1 in 100, that flow is referred to as the 100-year flow.

**flow path** The route that stormwater runoff follows between two points of interest.

**flow rate** The amount of a fluid passing a certain point in a given amount of time. In stormwater applications it is usually expressed in cubic feet per second or gallons per minute.

**flow splitter** A device with multiple outlets, each sized to pass a specific flow rate at a given head.

**flow spreader** A device with a wide enough outlet to efficiently distribute concentrated flows evenly over a large area, having common components such as trenches, perforated pipes, and berms.

**forebay** An easily maintained extra storage area provided near an inlet of a stormwater facility to trap incoming sediments before they accumulate in a pond or wetland.

**freeboard** The vertical distance between the design water surface elevation and the elevation of the barrier that contains the water.

**functions, wetland** The ecological (physical, chemical, and biological) processes or attributes of wetlands without regard for their importance to society. Wetland functions include food chain support; provision of ecosystem diversity and fish and wildlife habitat; flood flow alteration; groundwater recharge and discharge; water quality improvement; and soil stabilization.

**gabion** A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used as a protection or revetment against erosion. Soft gabions, often used in streams and ponds to stabilize banks or change flow patterns, are made of geotextiles filled with soil, with cuttings placed between.

**gage *or* gauge** A device for registering precipitation, water level, discharge, velocity, pressure, or temperature. Also, a measure of the thickness of metal (for example, diameter of wire or wall thickness of steel pipe).

**geologically hazardous areas** Areas that, because of their susceptibility to erosion, sliding, earthquakes, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns.

**geologist** A person who has earned a degree in geology from an accredited college or university (or who has equivalent educational training) and has at least five years of experience as a practicing geologist or four years of experience in practice and at least two years of post-graduate study, research, or teaching. The practical experience must include at least three years working in applied geology and landslide evaluation, in close association with qualified practicing geologists or geotechnical professional/civil engineers.

**geotextile** Durable synthetic fabrics used to reinforce soils and construct temporary sediment control BMPs for detaining runoff and trapping sediment.

**GIS Workbench** An ArcView geographic information system tool maintained by the WSDOT HQ Geographic Services Office and the HQ Office of Information Technology to provide staff with access to comprehensive, current, and detailed environmental and natural resource management data.

**gore area** The tapering paved area between two lanes, on which travel is not allowed.

**grade** The slope of a road, channel, or natural ground; the finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; or any surface prepared for the support of construction such as paving or the laying of a conduit.

**gradient terrace** A terrace cut horizontally into a sloe, designed according to criteria that consider slope, length, and height.

**groundwater** Water in a saturated zone or stratum beneath the land surface or a surface water body.

**groundwater recharge** Inflow to a groundwater reservoir.

**groundwater table** The free surface of the groundwater, which is subject to atmospheric pressure under the ground and is seldom static, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions.

**grubbing** The removal and disposal of all unwanted vegetative matter from underground, such as sod, stumps, roots, buried logs, or other debris.

**gully** A channel caused by the concentrated flow of surface and stormwater runoff over unprotected erodible land.

**habitat** The specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide all the basic requirements for life and should be protected from harmful biological, chemical, and physical alterations.

**hardpan** A cemented or compacted and often clay-like layer of soil that is impenetrable by roots (also known as glacial till).

**hazardous substance** Any liquid, solid, gas, or sludge, including any material, substance, product, commodity, or waste, regardless of quantity, that exhibits any of the characteristics or criteria of hazardous waste (RCW 70.105.010). (See also *dangerous waste*.)

**hazardous waste** All dangerous and extremely hazardous waste, including substances having radioactive or hazardous components (RCW 70.105.010). (See also *dangerous waste*.)

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

**heavy metals** Metals of high specific gravity, present in municipal and industrial wastes, that pose long-term environmental hazards. Such metals include cadmium, chromium, cobalt, copper, lead, mercury, nickel, and zinc.

**high-use roadway and parking area** Roadways and parking areas that the Washington State Department of Ecology presumes will generate concentrations of oil that need to be managed. With respect to oil control, absorptive BMPs (CAVFS, bioinfiltration pond) should be used on these high-use roads and parking areas. Examples of high-use roadways and parking areas include the following:

- Rest areas with an expected trip end count greater than or equal to 300 vehicles per day
- Eastern Washington roads with ADT > 30,000

**high-use site, high-use intersection** A site that the Washington State Department of Ecology presumes will generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil. Examples of high-use sites include the following:

- An intersection where either ≥15,000 vehicles (ADT) must stop to cross a roadway with ≥25,000 vehicles (ADT) or vice versa

- Maintenance facilities that park, store, or maintain 25 or more vehicles (trucks or heavy equipment) that exceed 10 tons gross weight each

**highway** A main public road connecting towns and cities.

**historic land cover** The native vegetation and soils that existed at a site prior to the influence of Euro-American settlement. The predeveloped condition shall be assumed to be forested land cover unless reasonable historic information is provided that indicates the site was prairie prior to settlement.

**hog fuel** Wood residues processed through a chipper or mill to produce coarse chips. Residues may include bark, sawdust, planer shavings, wood chunks, and small amounts of mineral material.

**hydraulic conductivity** The quality of saturated soil that enables water or air to move through it (also known as permeability coefficient).

**hydraulic gradient** Slope of the potential head relative to a fixed datum.

**hydraulic residence time** The time required for a slug of water to move through a system. In the most simplistic situation, once inflows to a water body cease, the hydraulic residence time is equal to the volume of the water body divided by the discharge rate (assuming no short-circuiting of the system).

**hydrograph** A graph of runoff rate, inflow rate, or discharge rate past a specific point over time.

**Hydrological Simulation Program–Fortran (HSPF)** A continuous simulation hydrologic model that transforms an uninterrupted rainfall record into a concurrent series of runoff or flow data by means of a set of mathematical algorithms that represent the rainfall-runoff process at some conceptual level.

**hydrologic cycle** The circuit of water movement from the atmosphere to the earth and returning to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

**hydrologic soil groups** A soil characteristic classification system defined by the U.S. Soil Conservation Service in which a soil may be categorized into one of four soil groups (A, B, C, or D) based upon infiltration rate and other properties (based on *Water Quality Prevention, Identification, and Management of Diffuse Pollution* by Vladimir Novotny and Harvey Olem; Van Nostrand Reinhold, New York, 1994, page 109). Soil groups include:

- **Type A** – Low runoff potential. Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well-drained to

excessively-drained sands or gravels. These soils have a high rate of water transmission.

- **Type B** – Moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
- **Type C** – Moderately high runoff potential. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
- **Type D** – High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential; soils with a permanent high water table; soils with a hardpan, till, or clay layer at or near the surface; soils with a compacted subgrade at or near the surface; and shallow soils or nearly impervious material. These soils have a very slow rate of water transmission.

**hydrology** The science of the behavior of water in the atmosphere, on the surface of the earth, and below ground.

**hydroperiod** A seasonal occurrence of flooding or soil saturation; it encompasses the depth, frequency, duration, and seasonal pattern of inundation.

**hyetograph** A graph of percentages of total precipitation for a series of time steps representing the total time during which the precipitation occurs.

**illicit discharge** All nonstormwater discharges to stormwater drainage systems that cause or contribute to a violation of state water quality, sediment quality, or groundwater quality standards, including but not limited to sanitary sewer connections, industrial process water, interior floor drains, car washing, and gray-water systems.

**impaired waters** Water bodies not fully supporting their beneficial uses, as defined under the federal Clean Water Act, Section 303(d). (See the Washington State Department of Ecology 303(d) list at: www.ecy.wa.gov/programs/wq/303d/.)

**impervious surface** A hard surface area that either prevents or retards the entry of water into the soil mantle as occurs under natural conditions (prior to development) and from which water runs off at an increased rate of flow or in increased volumes. Common impervious surfaces include but are not limited to rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, gravel roads, packed earthen materials (such as compact dirt), and oiled or macadam surfaces. Open, uncovered retention/detention facilities are not considered impervious surfaces for the purpose of determining whether the thresholds for application of minimum requirements are exceeded. Open, uncovered retention/detention facilities are considered impervious surfaces for the purpose of runoff modeling.

**Implementing Agreement** The Implementing Agreement between the Washington State Department of Ecology and the Washington State Department of Transportation Regarding Compliance with the State of Washington Surface Water Quality Standards (also abbreviated as WQIA: Water Quality Implementing Agreement).

**impoundment** A natural or constructed containment for surface water.

**improvement** Streets (with or without curbs or gutters), sidewalks, crosswalks, parking lots, water mains, sanitary and storm sewers, drainage facilities, street trees, and other appropriate items.

**infiltration** The downward movement of water from the surface to the subsoil.

**infiltration facility *or* system** A drainage facility designed to use the hydrologic process of surface and stormwater runoff soaking into the ground (commonly called percolation), to dispose of surface and stormwater runoff.

**infiltration pond** A facility that provides stormwater quantity control by containing excess runoff in a detention facility, then percolating that runoff into the surrounding soil.

**infiltration rate** The rate, usually expressed in inches per hour, at which water moves downward (percolates) through the soil profile. Short-term infiltration rates may be inferred from soil analysis or texture or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration facility.

**inlet** A form of connection between the surface of the ground and a drain or sewer for the admission of surface and stormwater runoff.

**interception (hydraulic)** The process by which precipitation is caught and held by foliage, twigs, and branches of trees, shrubs, and other vegetation. Often used to mean interception loss or the amount of water evaporated from the precipitation intercepted.

**interceptor dike** A soil berm used to intercept and redirect stormwater runoff to a treatment facility.

**interflow** That portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface; for example, in a roadside ditch, wetland, spring, or seep. Interflow is a function of soil system depth, permeability, and water-holding capacity.

**intermittent stream *or* channel** A stream or portion of a stream that flows only in direct response to precipitation; receives little or no water from springs and no continual supply from melting snow or other sources; and is dry for a large part of the year, ordinarily more than three months.

**invert** The lowest point on the inside of a sewer or other conduit.

**invert elevation** The vertical elevation of a pipe or orifice in a pond that defines the water level.

**isopluvial map** A map with lines representing constant depth of total precipitation for a given return frequency.

**lake** An area permanently inundated by water in excess of two meters deep and greater than 20 acres in size as measured at the ordinary high water marks.

**land-disturbing activity** Any activity that results in a movement of earth or a change in the existing soil cover (both vegetative and nonvegetative) or the existing soil topography, including but not limited to clearing, grading, filling, and excavation. Compaction that is associated with stabilization of structures and road construction is also considered a land-disturbing activity. Vegetation maintenance practices are not considered land-disturbing activities.

**landslide hazard areas** Those areas subject to a severe risk of landslide.

**leachate** Liquid that has percolated through soil and contains substances in solution or suspension.

**level pool routing** The basic technique of storage routing used for sizing and analyzing detention storage and determining water levels for ponding water bodies. The level pool routing technique is based on the continuity equation: inflow – outflow = change in storage.

**level spreader** A temporary erosion and sedimentation control device used to distribute stormwater runoff uniformly over the ground surface as sheet flow (not through channels), in order to enhance infiltration and prevent concentrated, erosive flows.

**live storage** The volume of the flow control BMP that is released over a long period of time.

**local government, local jurisdiction** Any county, city, town, or special-purpose district having its own incorporated government for local affairs.

**low-impact development (LID)** An evolving approach to land development and stormwater management that uses a site's natural features and specially designed BMPs to manage stormwater; it involves assessing and understanding the site, protecting native vegetation and soils, and minimizing and managing stormwater at the source. Low-impact development practices are appropriate for a variety of development types.

**low-permeability liner** A layer of compacted till or clay or a geomembrane.

**Manning's equation** An equation used to predict the velocity of water flow in a pipeline or an open channel:

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

where:

V = the mean velocity of flow in feet per second

R = the hydraulic radius in feet

S = the slope of the energy gradient or, for assumed uniform flow, the slope of the channel in feet per foot

n = Manning's roughness coefficient or retardance factor of the channel lining

**media filter** A filter that includes material for removing pollutants (such as compost, gypsum, perlite, zeolite, or activated carbon).

**media filter drain (previously known as the ecology embankment)** A stormwater treatment facility typically constructed in the pervious shoulder area of a highway, consisting of a no-vegetation zone, a grass strip, a filter media mix, and a drain component that keeps the facility free draining.

**mitigated area** The drainage area from which stormwater runoff is to be detained or treated.

**mitigation** Measures to reduce adverse impacts on the environment, in the following order of preference:

1. Avoid the impact altogether by not taking a certain action or part of an action.
2. Minimize the impact by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts.
3. Rectify the impact by repairing, rehabilitating, or restoring the affected environment.
4. Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action.
5. Compensate for the impact by replacing, enhancing, or providing substitute resources or environments.

**mitigation wetland** A wetland that is created, enhanced, restored, or preserved to offset the unavoidable environmental impacts of development actions on natural wetlands.

**monitoring** The collection of data by various methods for the purposes of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures imposed as conditions of development.

**National Pollutant Discharge Elimination System (NPDES)** The part of the federal Clean Water Act that requires point source dischargers to obtain permits, called NPDES permits, which in Washington State are administered by the Washington State Department of Ecology.

**native growth protection easement (NGPE)** An easement granted for the protection of native vegetation within a sensitive area or its associated buffer. The easement should be recorded on the appropriate documents of title and filed with the county records division.

**native vegetation** Vegetation consisting of plant species other than noxious weeds that are indigenous to the region and that could be reasonably expected to occur naturally on the site.

**Natural Resources Conservation Service (NRCS) curve number** A number that describes the runoff characteristics of a particular soil type.

**new impervious surfaces** Those surfaces that receive direct, run-on, or blow-in of rainfall and (1) expand the existing roadway prism or (2) are upgraded from gravel to bituminous surface treatment (BST), asphalt, or concrete pavement. Note that existing gravel surfaces are considered impervious surfaces. However, a gravel surface that is upgraded to a more impervious surface (gravel to BST, ACP, or PCCP) is defined as a new impervious surface.

**net-new impervious surface** The total area of new impervious surface being added to the TDA minus the total area of existing impervious surface being removed from the TDA. In order to use this concept, the existing impervious surface removal area must fully revert to a natural condition as specified in Section 4-3.6.1. The concept of net-new impervious surface applies only to Minimum Requirement 6 (Flow Control) and is applied at the threshold discharge area level. (See the definition for *effective impervious surface* and Figure 3.3, Step 8.)

**NOAA Fisheries** National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

**Noneffective impervious surfaces** Those new, applicable replaced, or existing impervious surfaces that are being managed by existing natural dispersion areas meeting the natural dispersion BMP criteria in Section 5-4.2.2.

**Noneffective pollution-generating impervious surface (PGIS)** Those new, applicable replaced, or existing PGIS surfaces that are being managed by existing natural dispersion areas meeting the natural dispersion BMP criteria in Section 5-4.2.2.

**Non-fish-bearing stream** According to WAC 222-16-030: type Ns waters are non-fish-habitat streams. Until the fish habitat water type maps are available, an interim water-typing system applies (see WAC 222-16-031). Type 5 waters are non-fish-habitat streams. (See fish-bearing stream definition for more details.)

**nonmitigated area** The area not included as part of the stormwater treatment.

**Non-pollution-generating surface (NPGS)** A surface that, based on its use, is an insignificant or low source of pollutants in stormwater runoff. For example, roofs that are subject only to atmospheric deposition or have normal heating, ventilation, and air conditioning vents; paved bicycle pathways and pedestrian sidewalks that are separated from roads used by motor vehicles; fenced fire lanes; infrequently used maintenance access roads; and in-slope areas of roads. Sidewalks that are regularly treated with salt or other deicing chemicals are considered pollution-generating impervious surfaces.

**Non-road-related project** A project involving structures, including rest areas, maintenance facilities, and ferry terminal buildings.

**no-vegetation zone (NVZ)** A shallow gravel trench located directly adjacent to the highway pavement.

**off-line facilities** Runoff treatment facilities to which stormwater runoff is restricted to some maximum flow rate or volume by a flow-splitter.

**off-site** Any area lying upstream of the project site that drains onto the site and any area lying downstream of the site to which the site drains.

**oil control** The treatment of stormwater runoff with BMPs to remove oil, grease, and total petroleum hydrocarbons (TPH).

**oil/water separator** A vault, usually underground, designed to provide a quiescent environment to separate oil from water.

**on-line facilities** Runoff treatment facilities that receive all the stormwater runoff from a drainage area. Flows above the runoff treatment design flow rate or volume are passed through at a lower-percentage removal efficiency.

**on-site** The entire property that includes the proposed development.

**operational BMP** A type of source control BMP that includes schedules of activities, prohibition of practices, and other managerial actions to prevent or reduce pollutants entering stormwater. Operational BMPs include formation of a pollution prevention team; good housekeeping; preventive maintenance procedures; spill prevention and cleanup; employee training; inspections of pollutant sources and BMPs; recordkeeping; process changes; raw material and product changes; and recycling of wastes.

**ordinary high water mark (OHWM)** The line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation; the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area. The ordinary high water mark is found by examining the bed and banks of a stream and ascertaining where the presence and action of waters are so common and usual, and so long maintained in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation. In any area where the ordinary high water mark cannot be found, the line of mean high water is substituted. In any area where neither can be found, the channel bank is substituted. In braided channels and alluvial fans, the ordinary high water mark or substitute must be measured to include the entire stream feature.

**organic matter** Decomposed animal or vegetable matter, measured by ASTM D 2974. Organic matter is an important reservoir of carbon and a dynamic component of soil and the carbon cycle. It improves soil and plant efficiency by improving soil physical properties including drainage, aeration, and other structural characteristics. It contains the nutrients, microbes, and higher-form soil food web organisms necessary for plant growth. The maturity of organic matter is a measure of its beneficial properties. Raw organic matter can release water-soluble nutrients (similar to chemical fertilizer). Beneficial organic matter has undergone a humification process either naturally in the environment or through a composting process.

**orifice** An opening with closed perimeter, usually sharp-edged, and of regular form in a plate, wall, or partition through which water may flow; generally used for the purpose of measurement or control of water.

**outlet** The point of water disposal from a stream, river, lake, tidewater, or artificial drain.

**outlet channel** A waterway constructed or altered primarily to carry water from manufactured structures, such as terraces, tile lines, and diversions.

**outlet protection** A protective barrier of rock, erosion control blankets, vegetation, or sod constructed at a conveyance outlet.

**outwash soils** Soils formed from highly permeable sands and gravels.

**overflow** A pipeline or conduit device with an outlet pipe that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regular device has allowed the portion of the flow that can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

**PAM** A large class of polymers (polyacrylamides), some of which have applications in highway construction. PAM products are used as soil stabilizers to prevent erosion, flocculants to remove sediments from stormwater, drilling lubricants, and soil moisture retention enhancers.

**particle size** The effective diameter of a particle as measured by sedimentation, sieving, or micrometric methods.

**peak discharge, peak flow** The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

**percolation** The movement of water through soil.

**percolation rate** The rate, often expressed in minutes per inch, at which clear water maintained at a relatively constant depth seeps out of a standardized test hole that has been previously saturated—often used synonymously with *infiltration rate* (short-term infiltration rate).

**permeable pavement** A permeable surface that readily transmits fluids into the underlying base material. The pavement may be permeable concrete, permeable asphalt, or manufactured systems such as interlocking brick or a combination of sand and brick lattice.

**permeable soils** Soil materials having a sufficiently rapid infiltration rate so as to greatly reduce or eliminate surface and stormwater runoff; generally classified as Soil Conservation Service hydrologic soil types A and B.

**pervious pavement** See *permeable pavement*.

**pH** A measure of the alkalinity or acidity of a substance that is determined by measuring the concentration of hydrogen ions in the substance. A pH of 7.0 indicates neutral water. A 6.5 reading is slightly acidic.

**pipe slope drain** A pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized water course, a sediment-trapping device, or a stabilized outfall.

**point of compliance** The location at which compliance with a discharge performance standard or a receiving water quality standard is measured.

**point source** A general classification of the origin of an air or water pollutant, usually characterized as smokestacks or outfalls.

**pollution-generating impervious surface (PGIS)** An impervious surface that is considered a significant source of pollutants in stormwater runoff, including surfaces that receive direct rainfall (or run-on or blow-in of rainfall) and are subject to vehicular use; industrial activities; or storage of erodible or leachable materials, wastes, or chemicals. Erodible or leachable materials, wastes, or chemicals are substances that, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage container leakage. Metal roofs are also considered pollution-generating impervious surfaces unless they are coated with an inert, nonleachable material (such as a baked-on enamel coating). A surface, whether paved or not, is considered subject to vehicular use if it is regularly used by motor vehicles. The following are considered regularly used surfaces: roads, unvegetated road shoulders, bicycle lanes within the travel lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways. The following are not considered regularly used surfaces: paved bicycle pathways separated from roads for motor vehicles, fenced fire lanes, and infrequently used maintenance access roads.

**pollution-generating pervious surface (PGPS)** Any nonimpervious surface subject to the ongoing use of pesticides and fertilizers or loss of soil, such as lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields. Grass highway shoulders and medians are not subject to such intensive landscape maintenance practices and are not considered pollution-generating pervious surfaces. It is WSDOT policy to create self-sustaining, native plant communities that require no fertilizer and little to no weed control after they are established. During the plant establishment period, usually the first three years after planting, WSDOT revegetation and mitigation projects are intensely managed to aid plant establishment. However, throughout the life of the project, WSDOT practices integrated vegetation management (IVM), which recognizes herbicides as tools in maintaining planting are as (one of many tools available). Questions regarding whether a specific area may be considered a pollution-generating pervious surface should be directed to the local maintenance area superintendent or the region landscape architect.

**porous pavement** See *permeable pavement*.

**postproject** Description of project site conditions after development.

**predeveloped condition** The modeled site conditions prior to development to which postdevelopment runoff flow rates are matched. (See Minimum Requirement 6 in Chapter 3.)

**preproject** Description of project site conditions prior to development.

**presumptive approach** (versus *demonstrative approach*) See Section 1-1.3.

**pretreatment** The removal of material such as solids, grit, grease, and scum from flows to improve treatability prior to biological or physical treatment processes; may include screening, grit removal, settling, oil/water separation, or application of a basic treatment BMP prior to infiltration.

**project** Any proposed action to alter or develop a site; the proposed action of a permit application or an approval, which requires drainage review.

**project limits** For road projects, the beginning project station to the end project station and from right of way line to right of way line. For nonroad projects, the legal boundaries of land parcels that are subject to project development (also called the project area perimeter).

**project site** The portion of a site to undergo development or redevelopment. For road projects, it is the area between the beginning and ending mileposts within WSDOT right of way. It is defined in the formal project definition agreed upon by the region and Headquarters as to the work to be done, the estimated cost, and the project schedule. For nonroad projects, refer to the definitions for *project limits*.

**Puget Sound basin** Puget Sound south of Admiralty Inlet (including Hood Canal and Saratoga Passage); the waters north to the Canadian border, including portions of the Strait of Georgia; the Strait of Juan de Fuca south of the Canadian border; and all the lands draining into these waters, as mapped in water resource inventory areas (WRIAs) 1 through 19, set forth in WAC 173-500-040.

**rational method** A means of computing storm drainage flow rates (Q) by using the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity, and A is the area. (This method is no longer used in the Washington State Department of Ecology technical manual.)

**reach** A length of channel with uniform characteristics.

**receiving waters** Bodies of water or surface water systems to which surface runoff is discharged via a point source of stormwater or via sheet flow.

**recharge** The addition of water to the zone of saturation (that is, an aquifer).

**redevelopment** On a site that is already substantially developed (has 35% or more of existing impervious surface coverage): the creation or addition of impervious surfaces; the expansion of a building footprint or addition or replacement of a structure; structural development, including construction, installation, or expansion of a building or other structure; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities.

**regional detention facility** A stormwater quantity control structure designed to correct surface water runoff problems within a drainage basin or subbasin, such as regional flooding or erosion problems; a detention facility sited to detain stormwater runoff from a number of new developments or areas within a catchment.

**release rate** The computed peak discharge rate in volume per unit time of surface and stormwater runoff from a site.

**replaced impervious surface** Those roadway areas that are excavated to a depth at or below the top of the subgrade (pavement repair work excluded) and replaced in kind. The subgrade is taken to be the crushed surfacing directly below the pavement layer (ACP, PCCP, BST). If the removal and replacement of existing pavement does not go below the pavement layer, as with typical PCCP grinding, ACP planing, or "paver" projects, the new surfacing is not considered "replaced impervious surface." Certain situations that do not include excavation of the existing roadway are also considered replaced impervious surface. (See Section 3-3.6.3 for a discussion of these situations.)

**replaced PGIS** Those PGIS areas that are removed and replaced in kind by the project, or for roadway areas that are excavated to a depth at or below the top of the subgrade (pavement repair work excluded) and replaced in kind. The subgrade is taken to be the crushed surfacing directly below the pavement layer (ACP, PCCP, BST). If the removal and replacement of existing pavement does not go below the pavement layer, as with typical PCCP grinding, ACP planing, or "paver" projects, the new surfacing is not considered "replaced PGIS." Certain situations that do not include excavation of the existing roadway are also considered replaced PGIS. (See Section 3-3.5.3 for a discussion of these situations.)

**restoration** In an area that no longer meets wetland criteria, actions performed to reestablish wetland functional characteristics and processes that have been lost through alterations, land uses, or catastrophic events.

**retention** The process of collecting and holding surface and stormwater runoff with no surface outflow.

**retention/detention facility (R/D)** A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, or infiltration; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

**retrofit** The renovation of an existing structure or facility to meet changed conditions or to improve performance.

**return frequency (recurrence interval)** A statistical representation of the average time between storm events of a given intensity or size (for example, a stormwater flow that occurs every two years on average).

**reversion of existing impervious surfaces** Removing an existing impervious surface and restoring that area to a pervious state using the methods shown in Section 4-3.6.1. The flow control benefits for reversion of an existing impervious surface will depend on the level of reversion (Step 1 or Step 2). At this time, the reversion of an existing impervious surface only applies to meeting flow control thresholds. It does not apply to runoff treatment thresholds.

**right of way (ROW)** Public land devoted to the passage of people and goods. State highway rights of way include state limited access highways inside or outside cities or towns, but not city or town streets forming part of state highway routes that are not limited access highways. The term does not include state property under WSDOT jurisdiction that is outside the right of way lines of a state highway (RCW 90.03.520).

**rill** A small, intermittent watercourse with steep sides, usually only a few inches deep; often caused by an increase in surface water flow where soil is cleared of vegetation.

**riparian** Pertaining to the banks of streams, wetlands, lakes, or tidewater.

**riprap** A facing layer or protective mound of rocks placed to prevent erosion or sloughing of a structure or embankment due to flow of surface and stormwater runoff.

**riser** A vertical pipe extending from the bottom of a pond that is used to control the discharge rate from a stormwater facility for a specified design storm.

**runoff** Rainwater or snowmelt that directly leaves an area as a surface drainage.

**runoff treatment** Pollutant removal to a specified level via engineered or natural stormwater management systems.

**runoff treatment BMP** A BMP specifically designed for pollutant removal.

**salmonid** A member of the fish family Salmonidae, including Chinook, coho, chum, sockeye and pink salmon; cutthroat, brook, brown, rainbow, and steelhead trout; and Dolly Varden, kokanee, and char species.

**sand filter** A constructed depression or basin with a layer of sand that treats stormwater as it percolates through the sand and is discharged via a central collector pipe.

**Sanitary Control Areas (SCAs)** Well protection buffers.

**Santa Barbara Urban Hydrograph method (SBUH)** A single-event hydrologic analysis technique for estimating runoff based on the curve number method. The curve numbers are published by the Natural Resources Conservation Service (NRCS) in *Urban Hydrology for Small Watersheds*, 55 TR, June 1976. Updated curve numbers are provided in Appendix 4-B.

**scour** Erosion of channel banks due to excessive velocity of the flow of surface and stormwater runoff.

**SCS** Soil Conservation Service (now the Natural Resources Conservation Service), U.S. Department of Agriculture.

**SCS method** A single-event hydrologic analysis technique for estimating runoff based on the curve number method. The curve numbers are published by the Natural Resources Conservation Service (NRCS) in *Urban Hydrology for Small Watersheds,* 55 TR, June 1976. With the change in name from Soil Conservation Service (SCS) to Natural Resources Conservation Service, the method may be referred to as the NRCS method.

**seasonal stream** An ephemeral stream.

**sediment** Fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits and is transported by, suspended in, or deposited by water.

**semiarid** Description of a geographical area characterized by light rainfall and having about 10 to 20 inches of annual precipitation.

**sensitive area** Any area designated by a federal, state, or local government as having unique or important environmental characteristics that may require additional protective measures (also see *critical areas*). These areas include but are not limited to:

- "Critical habitat" as defined in Section 3 of the federal Endangered Species Act of 1973.
- Designated "critical water resources" as defined in 33 CFR Part 330, Nationwide Permit Program.
- Water bodies designated as "impaired" under the provision of Section 303d of the federal Clean Water Act enacted by Public Law 92-500.
- Sole-source aquifers as defined under the federal Safe Drinking Water Act, Public Law 93-523.
- Wellhead protection zones as defined under WAC 246-290, Public Water Supplies.
- Areas identified in local critical area ordinances or in an approved basin plan.

**sheet flow** Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

**short-circuiting** The passage of runoff through a stormwater treatment facility in less than the design treatment time.

**shotcrete** Concrete that is placed by means of a spray nozzle, pneumatically applied.

**silt fence** A temporary sediment barrier consisting of a geotextile fabric stretched across and attached to supporting posts, which are entrenched. Adding rigid wire fence backing can strengthen silt fence.

**site** The area within the legal boundaries of a parcel (or parcels) of land that is subject to the development project. For road projects, the site is defined by the length of the project and the right of way boundaries.

**slope** Degree of deviation of a surface from the horizontal, measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise); for example, 2H**:**1V. A 2H**:**1V slope is a 50% slope. Expressed in degrees, the slope is the angle from the horizontal plane, so that a 90° slope is vertical (maximum), and a 45° slope is 1H**:**1V (a 100% slope).

**soil** The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (See also *topsoil*.)

**soil amendments** Materials that improve soil fertility for establishing vegetation or permeability for infiltrating runoff.

**soil drainage** As a natural condition of the soil, the frequency and duration of periods when the soil is free of saturation. In well-drained soils, the water is removed readily, but not rapidly; in poorly drained soils, the root zone is waterlogged for long periods unless artificially drained, and the roots of ordinary crop plants cannot get enough oxygen; and in excessively drained soils, the water is removed so completely that most crop plants suffer from lack of water. Strictly speaking, excessively drained soils are a result of excessive runoff due to steep slopes or low available water-holding capacity due to small amounts of silt and clay in the soil material. The following classes are used to express soil drainage:

- Well drained – Excess water drains away rapidly; no mottling occurs within 36 inches of the surface.
- Moderately well drained – Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness; mottling occurs between 18 and 36 inches.
- Somewhat poorly drained – Water is removed from the soil slowly enough to keep it wet for significant periods but not all the time; mottling occurs between 8 and 18 inches.
- Poorly drained – Water is removed so slowly that the soil is wet for a large part of the time; mottling occurs between 0 and 8 inches.
- Very poorly drained – Water is removed so slowly that the water table remains at or near the surface for a greater part of the time. There may also be periods of surface ponding. The soil has a black-to-gray surface layer with mottles up to the surface.

**soil permeability** The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil.

**soil stabilization** The use of measures such as rock lining, vegetation, or other engineering structures to prevent the movement of soil when loads are applied to the soil.

**sole-source aquifer** An aquifer or aquifer system that supplies 50% or more of the drinking water for a given service area and for which there are no reasonably available alternative sources should the aquifer become contaminated, and the possibility of contamination exists. The U.S. Environmental Protection Agency designates sole-source aquifers, and Section 1424(e) of the Safe Drinking Water Act is the statutory authority for the Sole-Source Aquifer Protection Program.

**source control** A structure or operation intended to prevent pollutants from coming into contact with stormwater, either through physical separation of areas or through careful management of activities that are sources of pollutants.

- *Structural source control BMPs* are physical, structural, or mechanical devices or facilities intended to prevent pollutants from entering stormwater.
- *Operational BMPs* are nonstructural practices that prevent or reduce pollutants entering stormwater.

**spill control device** A tee section or down-turned elbow designed to retain a limited volume of a pollutant that floats on water, such as oil or antifreeze. Spill control devices are passive and must be cleaned out in order to remove the spilled pollutant.

**spill prevention, control, and countermeasures (SPCC) plan** A plan prepared by a construction contractor, as required in Standard Specification 1-07.15(1), to prevent sediment and other pollutants associated with construction activity from affecting soil, air, and water quality.

**spillway** A passage, such as a paved apron or channel carrying surplus water over or around a dam or similar obstruction, or an open or closed channel used to convey excess water from a reservoir. A spillway may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

**stabilized construction entrance** A construction site entrance that is reinforced or finished with media such as riprap, gravel, or hog fuel to minimize the tracking of sediment onto adjacent streets.

**staging area (construction)** A site used temporarily during construction for materials or equipment storage, assembly, or other temporary construction activities.

**stairstep grading** A technique of grading slopes to minimize erosion, in which continuous slopes are replaced with a series of terraces.

***Standard Plans*** WSDOT *Standard Plans for Road, Bridge, and Municipal Construction*. Standardized design drawings for commonly used structures that can be referenced in contracts. The Headquarters Design Office maintains the *Standard Plans*.

***Standard Specifications*** WSDOT *Standard Specifications for Road, Bridge, and Municipal Construction*. Construction requirements for commonly used structures that can be referenced in contracts. The Headquarters Construction Office maintains the *Standard Specifications*.

**State Environmental Policy Act (SEPA)** The Washington State law (RCW 43.21C) intended to minimize environmental damage; modeled after the National Environmental Policy Act (NEPA). SEPA requires that state agencies and local governments consider environmental factors when making decisions on development proposals over a certain size, comprehensive plans and zoning requirements, and other programmatic proposals. As part of this process, environmental documents are prepared and opportunities for public comment are provided.

**steep slope** A slope of 40% gradient or steeper within a vertical elevation change of at least 10 feet.

**stoloniferous** Description of a type of plant having a long shoot that grows from the central rosette and droops to the ground, where it roots to form a new plant.

**storm frequency** The time interval between major storms of predetermined intensity and volumes of runoff that storm sewers and other structures are designed to handle hydraulically without surcharging and backflooding (for example, a 2-year, 10-year, or 100-year storm).

**storm sewer system** A sewer that carries stormwater and surface water, street wash, and other washwaters or drainage, but excludes sewage and industrial wastes (also called a storm drain).

**stormwater** That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes, and other features of a stormwater drainage system into a defined surface water body or a constructed infiltration facility.

**stormwater facility** A constructed component of a stormwater drainage system, designed or constructed to perform a particular function or multiple functions. Stormwater facilities include but are not limited to pipes, swales, ditches, culverts, street gutters, detention ponds, retention ponds, constructed wetlands, infiltration devices, catch basins, oil/water separators, and biofiltration swales.

***Stormwater Management Manual for Eastern Washington* (SMMEW)**
A technical manual prepared by the Washington State Department of Ecology containing BMPs intended to prevent, control, and treat pollution in stormwater and to reduce other stormwater-related impacts on waters of the state. The stormwater manual provides guidance on measures necessary in eastern Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

***Stormwater Management Manual for Western Washington* (SMMWW)**
A technical manual prepared by the Washington State Department of Ecology containing BMPs intended to prevent, control, and treat pollution in stormwater and to reduce other stormwater-related impacts on waters of the state. The stormwater manual provides guidance on measures necessary in western Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

**stormwater outfall** Any location where concentrated stormwater runoff leaves WSDOT right of way. Outfalls may discharge to surface waters or groundwater.

**stream** An area where surface waters flow sufficiently to produce a defined channel or bed. A defined channel or bed is an area that demonstrates clear evidence of the passage of water, indicated by hydraulically sorted sediments or the removal of vegetative litter or loosely rooted vegetation by the action of moving water. The channel or bed need not contain water year-round. This definition does not include irrigation ditches, canals, stormwater runoff devices, or other entirely artificial watercourses unless they are used to convey streams naturally occurring prior to construction. Topographic features that resemble streams but have no defined channels (swales) are considered streams when hydrologic and hydraulic analyses performed pursuant to a development proposal predict formation of a defined channel after development.

**streambanks** The usual boundaries, not the flood boundaries, of a stream channel. Right and left banks are named facing downstream.

**structural BMPs** Physical, structural, or mechanical devices or facilities intended to prevent pollutants from entering stormwater.

**subgrade** A layer of stone or soil used as the underlying base for a BMP.

**substrate** The natural soil base underlying a BMP measure.

**swale** A natural depression or shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than 1 foot, used to temporarily store, route, or filter runoff.

**tackifier** A plant-based or synthetic polymer used to help hydroseed mixes stick together and adhere to the soil. Some tackifiers directly stabilize soil.

**take** Defined under the federal Endangered Species Act as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct," including modification to a species habitat. The habitat could be a riparian area, spawning bed, or a rearing area. Changing the hydraulic characteristics of a stream system may result in a habitat alteration and could be considered a *take*. Release of physical, chemical, or biological pollutants into a stream system may result in a *take*.

**Technology Assessment Protocol – Ecology (TAPE)** A Washington State Department of Ecology process for reviewing and approving new stormwater treatment technologies.

**temporary erosion and sedimentation control (TESC) plan** A plan that includes all physical and procedural BMPs for preventing erosion and turbid discharges throughout a project and during construction.

**terrace** An embankment or combination of an embankment and channel across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

**threatened species** Any species (other than pest insects) likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

**threshold discharge area (TDA)** An on-site area draining to a single natural discharge location or multiple natural discharge locations that combine within ¼ mile downstream (as determined by the shortest flow path).

**tight-line** A continuous length of aboveground pipe that conveys water from one point to another (typically down a steep slope) with no inlets or collection points in between.

**till** A layer of poorly sorted soil deposited by glacial action that generally has very low infiltration rates.

**time of concentration** The time necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.

**tire wash** A facility for washing mud off vehicles to prevent track-out of sediment.

**topsoil** Surface soil presumed to be fertile and used to cover planting areas. Topsoil must meet ASTM D 5268 Standard Specification, and water permeability must be 0.6 inches per hour or greater. Organic matter must have no more than 10% of nutrients in mineralized water-soluble forms. Topsoil must not have phytotoxic characteristics.

**total maximum daily load (TMDL) – Water Cleanup Plan** A calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards and an allocation of that amount to the pollutant's sources. A TMDL (also known as a Water Cleanup Plan) is the sum of allowable loads of a single pollutant from all contributing point sources and nonpoint sources. The calculation must include a margin of safety to ensure the water body can be used for the purposes the state has designated. The calculation must also account for seasonal variation in water quality. Water quality standards are set by states, territories, and tribes. They identify the uses for each water body; for example, drinking water supply, contact recreation (such as swimming), and aquatic support (such as fishing) and the scientific criteria to support each use. The federal Clean Water Act, Section 303, establishes the water quality standards and TMDL programs.

**total petroleum hydrocarbons (TPH)** TPH-Gx: the qualitative and quantitative method (extended) for volatile (gasoline) petroleum products in water; and TPH-Dx: the qualitative and quantitative method (extended) for semivolatile (diesel) petroleum products in water.

**total suspended solids (TSS)** That portion of the solids carried by stormwater that can be captured on a standard glass filter.

**toxic** Poisonous, carcinogenic, or otherwise directly harmful to life.

**track walking** A technique for roughening soils on slopes to reduce erosion, involving systematically covering soils with cleat marks that run perpendicular to the slope, for detaining and infiltrating runoff.

**trash rack** A structural device used to prevent debris from entering a spillway or other hydraulic structure.

**travel time** The estimated time for surface water to flow between two points of interest.

**treatment liner** A layer of soil designed to slow the rate of infiltration and provide sufficient pollutant removal to protect groundwater quality.

**treatment train** A combination of two or more treatment facilities connected in series.

**triangular silt dike** A geotextile-encased foam check dam.

**trip end** The expected number of vehicles using a parking area, represented by the projected trip end counts for the parking area associated with a proposed land use. Trip end counts are estimated using either *Trip Generation* (published by the Institute of Transportation Engineers) or a traffic study prepared by a professional engineer or transportation specialist with expertise in traffic volume estimation. Trip end counts must be made for the design life of the project. For project sites with seasonal or varied use, the highest period of expected traffic impacts is evaluated.

**turbidity** Dispersion or scattering of light in a liquid, caused by suspended solids and other factors; commonly used as a measure of suspended solids in a liquid. Turbidity is a state-regulated parameter. Turbidity can be measured in the field with a hand-held meter and is recorded in nephelometric turbidity units (NTU).

**underdrain** Plastic pipes with holes drilled through the top, installed on the bottom of an infiltration facility, that are used to collect and remove excess runoff.

**underground injection control (UIC) well** A bored, drilled, or driven shaft whose depth is greater than the largest surface dimension; a dug hole whose depth is greater than the largest surface dimension; an improved sinkhole; a subsurface fluid distribution system that includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground. Examples of UIC wells or subsurface infiltration systems are drywells, drainfields, and french drains that include pipes and other similar devices that discharge to ground. Underground Injection Control is a federal regulatory program established to protect underground sources of drinking water from UIC well discharges.

**unstable slope** A sloping area of land that at any time exhibits mass movement of earth.

**upgrade** The replacement of paved areas with a better surface or in a way that enhances the traffic capacity of the road.

**urban growth area (UGA)** Those areas designated by a county according to RCW 36.70A.110.

**urbanized area** An area designated and identified by the U.S. Bureau of Census according to the following criteria: a densely settled area that has a minimum residential population of 50,000 people and a minimum average density of 1,000 people per square mile.

**Vactor truck** A vacuum truck used to remove the waste material found in the bottom of a catch basin.

**vault** See *dry vault or tank* and *wet vault or tank.*

**vegetated filter strip** A facility designed to provide runoff treatment of conventional pollutants (but not nutrients) through the process of biofiltration.

**vertical curve** The up and down component of a roadway curve.

**water bar** A small ditch cut perpendicular to the flow of water in roads or hillsides. A cross-sectional view reveals a ditch with the excavated material placed on the downslope side.

**water body** Surface waters including rivers, streams, lakes, marine waters, estuaries, and wetlands.

**Water Cleanup Plan** See *total maximum daily load.*

**water quality** A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

**water quality standards** The minimum requirements for water purity for uses like drinking water supply, contact recreation (such as swimming), and aquatic support (such as fishing). The Washington State Department of Ecology sets water quality standards for Washington State. Surface water and groundwater standards are established in WAC 173-201A and WAC 173-200, respectively.

**water quality treatment** See *runoff treatment*.

**water resource inventory area (WRIA)** A geographic area within which water drains into a particular river, stream, or receiving water body, identified and numbered by the state of Washington (defined in WAC 173-500).

**watershed** A geographic region within which water drains into a particular river, stream, or body of water. Watersheds can be as large as those identified and numbered by the state of Washington as water resource inventory areas (WRIAs), defined in WAC 173-500.

**waters of the state** All surface waters and watercourses within the jurisdiction of the state of Washington, including lakes, rivers, ponds, streams, inland waters, undergroundwaters, saltwaters, and wetlands.

**water table** The upper surface or top of the saturated portion of the soil or bedrock layer, indicating the uppermost extent of groundwater.

**wattle** Temporary erosion and sediment control barriers consisting of any plant material that is wrapped in biodegradable fiber, tubular plastic, or similar encasing material. Wattles are typically 8 to 10 inches in diameter and 25 to 30 feet in length.

**weir** A device for measuring or regulating the flow of water.

**wetland functions** See *functions/wetland*.

**wetlands** Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. They do not include artificial wetlands intentionally created from nonwetland sites, including but not limited to irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities; or wetlands unintentionally created after July 1, 1990, as a result of construction of a road, street, or highway. Wetlands may include artificial wetlands intentionally created from nonwetland areas to mitigate adverse impacts resulting from the conversion of wetlands. (Water bodies not included in this definition of wetlands, as well as those mentioned in the definition, are still waters of the state.)

**wet pond** A facility that provides water quality treatment for stormwater by using a permanent pool of water to remove conventional pollutants from runoff through sedimentation, biological uptake, and plant filtration. Wet ponds are designed to (1) optimize water quality by providing retention time in order to settle out particles of fine sediment to which pollutants such as heavy metals absorb and (2) to allow biological activity to occur that metabolizes nutrients and organic pollutants.

**wet vault *or* tank** Underground storage facility that treats stormwater for water quality through the use of a permanent pool of water that acts as a settling basin. It is designed (1) to optimize water quality by providing retention time in order to settle out particles of fine sediment that absorb pollutants such as heavy metals and (2) to allow biological activity to occur that metabolizes nutrients and organic pollutants.