City of Gig Harbor
Stormwater Management and Site Development Manual

Volume III
Hydrologic Analysis and Flow Control BMPs

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Modified for:
City of Gig Harbor Public Works Department
Ordinance No. 1511
Effective Date: May 3, 2023

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Chapter 1 - Introduction

1.1 Purpose of This Volume

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

- BMPs addressing the volume and timing of stormwater flows
- BMPs addressing prevention of pollution from potential sources
- BMPs addressing treatment of runoff to remove sediment and other pollutants.

This volume of the stormwater manual focuses mainly on the first category. It presents techniques for hydrologic analysis, and BMPs related to management of the amount and timing of stormwater flows from developed sites. The purpose of this volume is to provide guidance on the estimation and control of stormwater runoff quantity.

BMPs for preventing pollution of stormwater runoff and for treating contaminated runoff are presented in Volumes IV and V, respectively.

This chapter details the City of Gig Harbor's policies regarding the quantity control of runoff from developed or artificially altered sites. The scope of this chapter includes:

- Design criteria and specifications for the construction of runoff quantity control facilities
- Approved methods for estimating peak flow rates, volume of runoff, required input data, and required storage volumes based on site conditions
- Approved materials for use in private and public drainage facilities.

The intent of this chapter is to prescribe approved methods and requirements for runoff control to prevent impacts to downstream properties or natural resources to the maximum extent practical. The city recognizes that it is not always possible to fully prevent any impacts downstream; in these extreme cases, the project applicant may be required to provide offsite mitigation as determined by the city.

These regulations and criteria are based on fundamental principles of drainage, hydraulics, hydrology, environmental considerations and publications, manuals, and texts accepted by the professional engineering community. The engineer is responsible for being knowledgeable and proficient with the necessary design methodologies identified within this manual. A partial listing of publications which may be used as reference documents follows:

- The current Washington State Department of Ecology (Ecology) Stormwater Management Manual for Western Washington
- Any Ecology-approved stormwater management manual
- The Low Impact Development Technical Guidance Manual for Puget Sound (Washington State University Extension and the Puget Sound Partnership)
- "Applied Handbook of Hydrology," by Chow
- "Handbook of Hydraulics," by E.G. Brater and H.W. King
- The following references published by the Washington State Department of Transportation (WSDOT):
    - Current "Hydraulics Manual"
    - Current "Standard Specifications for Road, Bridge, and Municipal Construction"
    - Current "Standard Plans"
- "Soil Survey of Pierce County Area, Washington," published by the Soil Conservation Service, U.S. Department of Agriculture (USDA)
- "City of Gig Harbor Public Works Standards, Ordinance No.832," or the latest amendment
- Other information sources acceptable to the city and based on general use by the professional engineering community.

The most current edition of all publications shall be used.

1.2 Content and Organization of This Volume

Volume III of the stormwater manual contains four chapters:

- **Chapter 1** serves as an introduction.
- **Chapter 2** discusses hydrologic design standards and methods of hydrologic analysis, including the use of hydrograph methods for designing BMPs, an overview of various computerized modeling methods, and analysis of closed depressions.
- **Chapter 3** describes flow control BMPs and provides design specifications for infiltration, detention, and retention facilities. This volume's focus is on flow control. Additional water quality design considerations are addressed in Volume V.

- **Chapter 4** describes natural and constructed conveyance systems and acceptable analysis methods. It also includes sections on hydraulic structures which link the conveyance system to the runoff treatment and flow control facilities.

This volume includes four appendices. Appendix III-A details infiltration testing procedures. Additionally, the USDA soil textural triangle has been included to support determining alternative infiltration rates. Appendix III-B discusses Santa Barbara Urban Hydrograph (SBUH)/Natural Resources Conservation Service (NRCS) computer models and includes number of charts and tables useful in designing conveyance systems with non-continuous hydrologic models. This includes: design storm rainfall totals, isopluvial maps for western Washington, common Gig Harbor soil types and hydrologic groupings, NRCS curve numbers, roughness coefficients. Appendix III-C includes several nomographs that may be useful for culvert sizing. Appendix III-D summarizes the infeasibility criteria that can be used to justify not using various onsite stormwater management BMPs for consideration in the List #1 or List #2 option of Minimum Requirement #5. This information is also presented under the description of each BMP, but is summarized in Appendix III-D as a quick reference point.

1.3 How to Use This Volume

Volume I should be consulted to determine minimum requirements for flow management (e.g., Minimum Requirements #4, #5, and #7 in Volume I, Chapter 2). After the minimum requirements have been determined, this volume should be consulted to design flow management facilities. These facilities can then be included in any required stormwater plan submittals (see Volume I, Chapter 3). This volume also includes information on the design of stormwater conveyance systems (Chapter 4).

Chapter 2 - Hydrologic Analysis and Design Standards

The broad definition of hydrology is "the science which studies the source, properties, distribution, and laws of water as it moves through its closed cycle on the earth (the hydrologic cycle)." As applied in this manual, however, the term "hydrologic analysis" addresses and quantifies only a small portion of this cycle. That portion is the relatively short-term movement of water over the land resulting directly from precipitation and called surface water or stormwater runoff. Localized and long-term groundwater movement must also be of concern, but generally only as this relates to the movement of water on or near the surface, such as stream baseflow or infiltration systems.

The purpose of this chapter is to define the minimum computational standards required, to outline how these may be applied, and to reference where more complete details may be found, should they be needed. This chapter also provides details on the hydrologic design process; that is, what are the steps required in conducting a hydrologic analysis, including flow routing.

Due to the inseparable interdependent nature of stormwater runoff quantity and quality, it is important that the design professional keep foremost the concept of water quality when designing for water quantity and vice versa. Water quantity and quality goals can often be accomplished in one facility. For instance, bioretention areas can be designed to provide both quantity and quality control. Many onsite stormwater management BMPs can also provide both quantity and quality control. Acceptable water quality design practices and methods are detailed in Volume V.

Site planning and layout play an important role in the amount of stormwater runoff generated by a project site. It is important to keep stormwater issues in mind when laying out the project. Reductions in impervious areas result in smaller treatment and quantity control facilities, thereby reducing the costs of managing the stormwater. Low impact development (LID) directly addresses this idea and can benefit the designer by limiting the runoff and creating more appealing sites. Most of the common LID BMPs (also referred to as onsite stormwater management BMPs in this manual) are presented in this volume. Additional information on general LID site design and the City's specific requirements for Comprehensive LID Site Design (Title 17 GHMC) are provided in Volume VI.

Some of the things that must be considered during site planning and layout include: minimizing creating hard and impervious surfaces, clustering buildings and preserving larger areas of open space, minimizing directly connected hard and impervious areas (try to separate impervious surfaces with areas of turf, or other vegetation), incorporation of low maintenance landscaping that doesn't need frequent applications of fertilizers, herbicides and pesticides and minimizing the impact area and soil compaction during construction.

2.1 Minimum Computational Standards

The minimum computational standards depend on the type of information required and the size of the drainage area to be analyzed, as follows:

- For the purpose of designing runoff treatment BMPs, a calibrated continuous simulation hydrologic model based on the U.S. Environmental Protection Agency's (U.S. EPA) Hydrological Simulation Program-Fortran (HSPF) program, or an approved equivalent model (e.g., using the latest version of the Western Washington Hydrology Model [WWHM]), must be used to calculate runoff and determine the water quality design flow rates and volumes. Design standard and sizing of water quality BMPs can be found in Volume V.

- For conveyance system design the designer may use an approved continuous simulation runoff model or a single event hydrologic model to determine the peak flow rate. The peak flow rate from a continuous runoff model will vary depending on the time step used in the model. Therefore, the length of the time step must be sufficiently short relative to the time of concentration of the watershed to provide for reasonable conveyance system design flows. For most situations in the City of Gig Harbor, a 15-minute (maximum) time step will be sufficient for conveyance system design. If the project is in a predominantly urbanized watershed with a time of concentration less than about 15 minutes (roughly 10 acres in size), the conveyance design must either use a 5-minute time step (if available), or use an event-based model for conveyance sizing. Conveyance design is discussed in detail in Chapter 4.

- For the purpose of designing flow control BMPs, a calibrated continuous simulation runoff model, based on the U.S. EPA's HSPF, must be used. Flow control BMP criteria are discussed in detail in Chapter 3. The circumstances under which different methodologies apply are summarized in Table 2.1 below.

Table 2.1. Summary of the Application Design Methodologies.

Method	BMP/Conveyance Designs in Western Washington		
	Treatment	**Flow Control**	**Conveyance**
Continuous Runoff Models: (WWHM or approved alternatives. See below.)	Method applies to all BMPs	Method applies throughout Western Washington	Method applies throughout Western Washington
Soil Conservation Service Unit Hydrograph (SCSUH)/ Santa Barbara Unit Hydrograph (SBUH)	Not Applicable	Not Applicable	Acceptable
Rational Method	Not Applicable	Not Applicable	Acceptable for Certain Conveyance Design Only (see below)

- If a basin plan is being prepared, then a hydrologic analysis shall be performed using a continuous simulation runoff model such as the U.S. EPA's HSPF model, the U.S. EPA's Stormwater Management Model (SWMM), or an equivalent model as approved by the City of Gig Harbor.
- Ecology has developed the HSPF-based WWHM. By default, WWHM uses rainfall/runoff relationships developed for specific basins in the Puget Sound region to all parts of western Washington. **Pierce County has developed a 158 year precipitation time series specific to the county that must be used when modeling with WWHM in the City of Gig Harbor.** These data are included in WWHM2012.
- Use of other continuous simulation runoff models must be approved by Ecology and receive prior concurrence from the City of Gig Harbor before being used for facility design.

Where large master-planned developments are proposed, the city may require a basin-specific calibration of HSPF rather than use of the default parameters in the above-referenced models. Basin-specific calibrations may be required for projects that will occupy more than 320 acres.

2.1.1 Discussion of Hydrologic Analysis Methods Used for Designing BMPs

This section provides a discussion of the methodologies to be used for calculating stormwater runoff from a project site. It includes a discussion of estimating stormwater runoff with single event models, such as the Santa Barbara Unit Hydrograph (SBUH), versus continuous simulation models.

Single Event and Continuous Simulation Runoff Model

A continuous simulation runoff model has considerable advantages over the single event-based methods such as the SCSUH, SBUH, or the rational method. HSPF is a continuous simulation model that is capable of simulating a wider range of hydrologic responses than the single event models such as the SBUH method. Single event models cannot take into account storm events that may occur just before or just after the single event (the design storm) that is under consideration. In addition, the runoff files generated by the HSPF models are the result of a considerable effort to introduce local parameters and actual rainfall data into the model and therefore produce better estimations of runoff than the SCSUH, SBUH, or rational methods which tend to overestimate peak runoff.

A major weakness of the single event model is that it is used to model a 24-hour storm event, which is too short to model longer-term storms in western Washington. The use of a longer-term (e.g., 3- or 7-day storm) is perhaps better suited for western Washington.

Related to the last concern is the fact that single event approaches, such as SBUH, assume that flow control ponds are empty at the start of the design event. Continuous runoff models are able to simulate a continuous long-term record of runoff and soil moisture conditions. They simulate situations where ponds are not empty when another rain event begins.

Finally, single event models do not allow for estimation and analyses of flow durations nor water level fluctuations. Flow durations are necessary for discharges to streams. Estimates of water level fluctuations are necessary for discharges to wetlands and for tracking influent water elevations and bypass quantities to properly size treatment facilities.

Guidance for Flow Control Standards

Flow control standards are used to determine whether or not a proposed stormwater facility will provide a sufficient level of mitigation for the additional runoff from land development.

There are three flow-related standards stated in Volume I of this manual: Minimum Requirement #5: Onsite Stormwater Management; Minimum Requirement #7: Flow Control; and Minimum Requirement #8: Wetlands Protection.

Minimum Requirement #5 allows the user to demonstrate compliance with the LID Performance Standard of matching developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 8 percent of the 2-year peak flow to 50 percent of the 2-year peak flow. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 8 percent and 50 percent of the 2-year predevelopment peak flow values, then the LID performance standard has not been met.

Minimum Requirement #7 specifies that stormwater discharges to streams shall match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50 percent of the 2-year recurrence interval peak flow up to the full 50-year peak flow.

- The continuous runoff models compute the predevelopment 2- through 100-year recurrence interval flow values and compute the postdevelopment runoff 2-year through 100-year recurrence interval flow values from the outlet of the proposed stormwater facility
- The model uses pond discharge data to compare the predevelopment and postdevelopment durations and determines if the flow control standards have been met
- There are three criteria by which flow duration values are compared:
    1. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 50 percent and 100 percent of the 2-year recurrence interval predevelopment peak flow values (100 percent threshold) then the flow duration requirement has not been met

2. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 100 percent of the 2-year and 100 percent of the 50-year recurrence interval predevelopment peak flow values more than 10 percent of the time (110 percent threshold) then the flow duration requirement has not been met

3. If more than 50 percent of the flow duration levels exceed the 100 percent threshold then the flow duration requirement has not been met.

Minimum Requirement #8 includes measures to protect the hydroperiod of the wetland. Flow components feeding the wetland under both pre- and post-development scenarios are assumed to be the sum of the surface, interflow, and groundwater flows from the project site. Ecology has added the capability to model flows to wetlands and analyze the daily and monthly flow deviations (per these requirements) to WWHM2012.

As of July 1, 2019, the algorithms needed to perform the analysis associated with the hydroperiod protection guidelines described in I-B.4 Wetland Hydroperiod Protection are not available in WWHM. However, WWHM can be used to provide model simulation of flows to wetlands under both predevelopment condition and postdevelopment condition. The analysis and comparisons of those flows (under predevelopment and postdevelopment conditions) must be conducted outside WWHM; for example, by using a spreadsheet.

Single Event Storms – Hydrograph

Hydrograph analysis utilizes the standard plot of runoff flow versus time for a given single event design storm, thereby allowing the key characteristics of runoff such as peak, volume, and phasing to be considered in the design of drainage facilities. All storm event hydrograph methods require input of parameters that describe physical drainage basin characteristics. These parameters provide the basis from which the runoff hydrograph is developed. Because the only application for single event methods in this volume is to size conveyance systems, only a limited discussion of design storms, curve numbers and calculating peak runoffs are presented in Appendix III-B. If single event methods are used to size temporary and permanent conveyances, the reader should reference other texts and software for assistance. Conveyance systems can be designed using unit hydrograph analysis methods for estimating storm runoff rates. All storage facilities shall be designed to meet the Minimum Requirement #7 for frequency and duration control using a continuous runoff model. If the engineer decides to use a single event runoff model for conveyance design the preferred method is the SBUH method; or the SCSUH method as a second choice. The rational method may be used for conveyance sizing on sites of 25 acres or less, and having a time of concentration of less than 100 minutes. See also Chapter 4.

2.2 Western Washington Hydrology Model

This section summarizes the assumptions made in creating the WWHM and discusses limitations of the model. Note that the WWHM is being updated regularly and much of the following information is for background and overview only. However, since the first version of WWHM was developed and released to public in 2001, the WWHM program has gone through several upgrades incorporating new features and capabilities including LID modeling capability. For example, WWHM2012 now includes modeling elements for stormwater LID BMPs. WWHM users should periodically check Ecology's WWHM web site for the latest releases of WWHM, user manuals, and any supplemental instructions.

More information on the WWHM can be found on Ecology's web site.

2.2.1 Limitations to the WWHM

The WWHM has been created for the specific purpose of sizing stormwater control facilities for new developments and redevelopments in western Washington. The WWHM can be used for a range of conditions and developments; however, certain limitations are inherent in this software. In addition, note that the model is frequently updated and some of the following limitations may change with subsequent updates.

WWHM uses the U.S. EPA HSPF software program to do all of the rainfall-runoff and routing computations. Therefore, HSPF limitations are included in the WWHM. For example, backwater or tailwater control situations are not explicitly modeled by HSPF. This is also true in the WWHM.

Earlier versions of WWHM, WWHM1, and WWHM2 had limited routing capabilities. The routing capabilities of WWHM3 and WWHM2012 have improved and the user can input multiple stormwater control facilities and runoff is routed through them. If the proposed development site involves routing through a natural lake or wetland in addition to multiple stormwater control facilities, WWHM2012 can be used to do the routing computations and additional analysis.

2.2.2 Assumptions Made in Creating the WWHM

Precipitation Data

- By default, the WWHM uses long-term (over 50 years) precipitation data to simulate the potential impacts of land use development in western Washington. A minimum period of 20 years is required to simulate enough peak flow events to produce accurate flow frequency results.
- **As noted previously, Pierce County has developed an extended precipitation time series specific to the county that must be used when modeling with WWHM in the City of Gig Harbor.** Note that WWHM2012 includes this county-specific information within the model.
- WWHM2012 incorporates and uses 15-minute precipitation data. This data is used in WWHM2012 computations to generate runoff hydrographs. The computations include generating design flows and volumes for sizing water quality treatment facilities. The 15-minute water quality design flows are used

for the design of water quality treatment facilities that are expected to have a hydraulic residence time of less than one hour.

Pan Evaporation Data

- WWHM uses pan evaporation coefficients to compute the actual evapotranspiration potential for a site, based on the potential evapotranspiration and available moisture supply. Actual evapotranspiration potential accounts for the precipitation that returns to the atmosphere without becoming runoff.
- The pan evaporation coefficients have been placed in the WWHM database and linked to each county's map. They will be transparent to the general user. The advanced user will have the ability to change the coefficient for a specific site (subject to City approval). These changes will be recorded in the WWHM output.

Soil Data

- WWHM uses three predominant soil types to represent the soils of western Washington – till, outwash, and saturated.
- The user determines actual local soil conditions for the specific development planned and inputs that data into the WWHM. The user inputs the number of acres of outwash (A/B), till (C/D), and saturated (wetland) soils for the site conditions.
- Additional soils will be included in the WWHM if appropriate HSPF parameter values are found to represent other major soil groups.

Vegetation Data

- WWHM will represent the vegetation of western Washington with three predominate vegetation categories: forest, pasture, and lawn (also known as grass).
- The predevelopment land conditions are generally assumed as forest (the default condition), however, the user has the option of specifying pasture if there is documented evidence that pasture vegetation was native to the predevelopment site. In highly urbanized basins (see Minimum Requirement #7 in Volume I, Chapter 2), it is possible to use the existing land cover as the predeveloped land condition.

Development Land Use Data

- Development land use data are used to represent the type of development planned for the site and are used to determine the appropriate size of the required stormwater mitigation facility.

- Earlier version of WWHM included a standard residential development which made specific assumptions about the amount of impervious area per lot and its division between driveways and rooftops. Streets and sidewalk areas are input separately. Ecology has selected a standard impervious area of 4,200 square feet per residential lot, with 1,000 square feet of that as driveway, walkways, and patio area, and the remainder as rooftop area. The more recent versions of WWHM (e.g., WWHM3 or WWHM2012) no longer have the Standard residential development category. Users can use the above land use assumptions for a modeling runoff from Standard residential development or, where better land use information is available, use that information to model and estimate runoff from the residential development.

- WWHM distinguishes between effective impervious area and non-effective impervious area in calculating total impervious area.

- Credits are given for infiltration and dispersion of roof runoff and for use of permeable pavement for driveway areas. Unlike earlier version of WWHM, newer versions (e.g., WWHM2012) now includes LID modeling features, calculate credits directly in the model, and comes with a user manual that provides modeling instructions for LID BMPs. Explicit elements representing bioretention, green roofs, permeable pavement, and compost amended vegetated filter strips can be modeled in WWHM to determine the flow control credits obtained. WWHM is actively being updated to include options for obtaining credits for the use of permeable pavements on streets, sidewalks, and parking. Designers should also look to the LID credit guidance associated with each BMP for determining modeling credits for all LID BMPs.

- Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the development. ***Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances.***

- WWHM can model bypassing a portion of the runoff from the development area around a stormwater detention facility and/or having offsite inflow enter the development area.

Application of WWHM in Redevelopments Projects

Redevelopment requirements may allow, for some portions of the redevelopment project area, the predeveloped condition to be modeled as the existing condition rather than forested or pasture condition. For instance, where the replaced impervious areas do not have to be served by updated flow control facilities because area or cost thresholds in Volume I, Section 2.3 are not exceeded.

Pervious and Impervious Land Categories (PERLND and IMPLND Parameter Values)

- In WWHM (and HSPF) pervious land categories are represented by PERLNDs; impervious land categories by IMPLNDs.
- WWHM includes multiple default PERLND and IMPLND parameters that describe various hydrologic factors that influence runoff. Some of these parameters can be modified as site conditions require. All changes from the default WWHM settings will be flagged in the output and will require written justification by the engineer.
- These values are based on regional parameter values developed by the U.S. Geological Survey (USGS) for watersheds in western Washington (Dinicola, 1990) plus additional HSPF modeling work conducted by AQUA TERRA Consultants.
- Surface runoff and interflow are computed based on the PERLND and IMPLND parameter values. Groundwater flow can also be computed and added to the total runoff from a development if there is a reason to believe that groundwater would be surfacing (such where there is a cut in a slope). However, the default condition in WWHM assumes that no groundwater flow from small catchments reaches the surface to become runoff.

2.3 Closed Depression Analysis

The analysis of closed depressions requires careful assessment of the existing hydrologic performance in order to evaluate the impacts a proposed project will have. Discharge criteria are described in Volume I, Chapter 2. The applicable requirements (see Minimum Requirements #5 and #7) and the city's critical areas ordinance and rules (if applicable) must be thoroughly reviewed prior to proceeding with the analysis.

Closed depressions generally facilitate infiltration of runoff. If a closed depression is classified as a wetland or the discharge path flows through a wetland, then the Minimum Requirement #8 for wetlands applies. If there is an outflow from this wetland to a surface water (such as a creek), then the flow from this wetland must also meet the Minimum Requirement #7 for flow control. A calibrated continuous simulation runoff model must be used for closed depression analysis and design of mitigation facilities. If a closed depression is not classified as a wetland, model the ponding area at the bottom of the closed depression as an infiltration pond using the latest version of WWHM or an Ecology approved continuous runoff model.

2.4 Flow Control Criteria

Refer to Volume I, Chapter 2 for thresholds, exemptions, and specific criteria for runoff quantity control. Minimum Requirement #7 contains the primary flow control criteria, including the city's four categories of project requirements. However, project proponents must assess the potential impact of all 10 Minimum Requirements on project flow control designs, with particular attention to Minimum Requirements #5, #6, and #8.

2.5 Infiltration Facilities for Flow Control

Unless otherwise specified within a specific subsection, the information outlined in Section 2.5 applies to infiltration basins and trenches. Information and procedures specific to other infiltration facilities (e.g., bioretention areas, permeable pavement surfaces, rain gardens, and downspout infiltration systems) are included in those BMP sections in Chapter 3.

2.5.1 Purpose

The purpose of this section is to describe the steps required to evaluate the suitability of a site for infiltration facilities, establish a design infiltration rate, and design facilities for infiltration.

Infiltration is the percolation of surface water into the ground. While other flow control facilities, such as detention ponds, reduce peak flow rates associated with developed areas, infiltration facilities also reduce surface water runoff volumes. When properly sited and designed, infiltration facilities can help to decrease runoff, recharge groundwater, and protect downstream receiving waters.

Infiltration for water quality treatment is permitted within the City of Gig Harbor. However, the requirements for infiltration for water quality treatment are substantially different from those for flow control and are outlined in Volume V, Chapter 6. To be used for runoff treatment, soils must include sufficient organic content and sorption capacity to remove pollutants. Examples of suitable soils are silty and sandy loams. Coarser soils, such as gravelly sands, can provide flow control but are not suitable for providing runoff treatment. The use of coarser soils to provide flow control for runoff from pollution generating surfaces must be preceded by treatment to protect groundwater quality. Thus, there will be instances when soils are suitable for treatment but not flow control, and vice versa. As a result, it is not recommended that large infiltration facilities be designed as combined flow control and water quality treatment facilities. The space requirements and maintenance needs generally make these facilities undesirable in the City of Gig Harbor. However, smaller onsite stormwater management BMPs (e.g., rain gardens/bioretention) can work well as combined flow control and treatment BMPs. The following guidelines are applicable for stormwater runoff quantity and flow control only.

Also note that although infiltration is one of the preferred methods for disposing of excess stormwater, infiltration is regulated by Ecology and the Underground Injection Control (UIC) Program (WAC 173-218). Additional information, requirements, site suitability criteria, prohibitive activities and conditions on UIC and how it applies to infiltration and stormwater management is included in Section 2.6, Volume I, Appendix I-C – Underground Injection Control (UIC) Program Guidelines and Ecology’s web page for the UIC program.

This section also highlights design criteria that are applicable to infiltration facilities serving a treatment function.

2.5.2 Procedures

The following procedures must be followed when considering and designing an infiltration basin or trench. Each step is outlined in more detail in the subsequent sections. All pertinent information must be reported in the soils report portion of the Drainage Control Plan (see Volume I, Section 3.3).

Step 1 – Conduct general site reconnaissance, and review survey and other information to identify existing drinking water wells or aquifers, existing and proposed buildings, steep slopes, and septic systems in the vicinity of the proposed facility.

Step 2 – Evaluate minimum requirements for infiltration facilities to determine whether infiltration is feasible for the site. For additional information on site suitability criteria, prohibitive activities and conditions see Volume I, Appendix I-C.

Step 3 – Determine whether the simple or detailed method of analysis is required. Consultation with the City of Gig Harbor is required at this stage to obtain approval of the proposed method of analysis (simple or detailed).

Step 4 – Complete simple analysis.

Step 5 – Complete detailed analysis, if necessary.

Step 1: General Site Characterization

The first step in designing an infiltration facility is to select a location, and assess the site suitability. The information to be reviewed as part of this initial site characterization will vary from site to site, but may include:

- Topography within 500 feet of the proposed facility
- Anticipated site use (street/highway, residential, commercial, high-use site)
- Location of water supply wells within 500 feet of proposed facility
- Location of groundwater protection areas and/or 1-, 5-, and 10-year time of travel zones for municipal well protection areas
- Location of steep slope, erosion hazard, or landslide hazard areas
- Location of septic systems in the vicinity of the proposed facility
- A description of local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.

This information, along with additional geotechnical information necessary to design the facility, shall be summarized in the soils report prepared under Step 4.

Step 2: Minimum Requirements for Infiltration Facilities

*Infiltration is not permissible unless all of the following criteria are met. Note: not all sites that meet the following criteria will be suitable for infiltration – these are **minimum** requirements only.*

- The base of all infiltration basins or trench systems (without a perforation pipe) shall be a minimum of 3 feet above seasonal high groundwater levels, bedrock (or hardpan), or other low permeability layer. Infiltration basins may not be constructed within a floodplain area.
- The base of a trench system, that is considered a Class V UIC well shall be a minimum of 5 feet above the seasonal high groundwater levels, bedrock (or hardpan), or other low permeability layer , unless a demonstrative approach confirms that a separation of 3 feet will meet the non-endangerment standard. See Volume I, Appendix I-C for requirements to meet the non-endangerment standard.
- Refer to Setbacks in Section 2.5.3 for setbacks that apply to all infiltration ponds/basins and trenches. Refer to Section 3.6 and 3.7 for additional setbacks listed for these BMPs. Refer to other sections in Chapter 3 for setbacks that apply to other infiltration BMPs (i.e., bioretention areas, permeable pavement surfaces, rain gardens, and downspout infiltration systems.
- Infiltration facilities up gradient of drinking water supplies and within the 1-, 5-, and 10-year time of travel zones must comply with Chapter 18.08 Critical Areas GHMC, as well as any applicable Washington Department of Health requirements.
- If the depth of the infiltration facility being considered is greater than the largest surface dimension, it is considered an injection well and is subject to the requirements of the UIC Program, Chapter 173-218 WAC **and must be registered with Ecology.** See also Section 2.6 and Volume I, Appendix I-C – Underground Injection Control (UIC) Program Guidelines.
- The maximum depth of an infiltration facility is 20 feet below the surrounding finished (developed) ground elevation, in order to provide for long-term maintenance access to the facility.

Step 3: Determine Method of Analysis

The City of Gig Harbor encourages consideration of infiltration facilities for sites where conditions are appropriate. However, some sites may not be appropriate for infiltration due to soil characteristics, groundwater levels, steep slopes, or other constraints. All proposed infiltration basins and trenches are required, at a minimum, to perform the simple analyses specified below. For those sites that present a risk of infiltration system failure, a more detailed method of analysis is required in addition to the simple analysis.

The sections below outline the criteria to be considered when determining whether a project is subject to the simplified or the detailed method of analysis. The chosen method of analysis must be approved by the City of Gig Harbor. Moreover, the city may require that the detailed method of analysis be conducted based on the results of the simple method. (See Section 3.4, Bioretention Cells, Swales, and Planter Boxes, and Section 3.8, Rain Gardens, for methods specific to bioretention and rain gardens. See Section 3.5, Permeable Pavement, for methods specific to permeable pavement.)

Simple Method

Projects considering using the simplified method generally will have the following characteristics:

- For individual small facilities serving short plats or commercial developments less than one acre of contributing area
- High infiltration capacity soils (NRCS [SCS] soil types A or B)
- Other infiltration facilities performing successfully at nearby locations
- No septic systems, drinking water wells, steep slopes, or other sensitive features within 500 feet
- Low risk of flooding and property damage in the event of clogging or other failure of the infiltration system.

Detailed Method

Where there is not clear evidence that a site is well-suited to infiltration, a more detailed method of analysis will be required. The detailed method of analysis, described below, includes more intensive field testing and soils investigation and analyses than the simplified method. Site conditions that will likely require use of the detailed method may include:

- Low infiltration capacity soils (NRCS [SCS] soil types C or D)
- History of unsuccessful infiltration facility performance, or no history of successful infiltration performance at nearby locations
- A large contributing drainage area
- High groundwater levels
- High risk of flooding in the event of clogging or other failure.

Step 4: Simple Analysis for all Proposed Infiltration Projects

The following analyses are required for all proposed infiltration basins and trenches.

Conduct Soils Testing

- Test hole or test pit explorations shall be conducted during mid to late in the wet season (December 1 through April 30) to provide accurate groundwater saturation and groundwater information.

  Collect representative samples from each soil type and/or unit to a depth below the base of the infiltration facility of 2.5 times the maximum design ponded water depth, but not less than 6 feet.

- If proposing to estimate the infiltration rate using the soil grain size analysis method, obtain samples adequate for the purposes of that gradation/classification testing.

  For infiltration basins, there shall be one test pit or test hole per 5,000 square feet of basin infiltrating surface with a minimum of two per basin, regardless of basin size. For infiltration trenches, there shall be one test pit or test hole per 200 feet of trench length with a minimum of two required per trench, regardless of length.

- Prepare detailed logs for each test pit or test hole and a map showing the location of the test pits or test holes. Logs must include the depth, soil descriptions, depth to water, evidence of seasonal high groundwater elevation, existing ground surface elevation, proposed basin bottom elevation, and presence of stratification that may impact the infiltration design.

  If using the soil Grain Size Analysis Method for estimating infiltration rates, include laboratory testing as necessary to establish the soil gradation characteristics and other properties to complete the infiltration facility design. At a minimum, conduct one grain size analysis per soil stratum in each test hole to a depth of 6 feet below the proposed base of the infiltration facility. When assessing the 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.

- Determine Design Infiltration Rate:

  There are three acceptable methods for estimating initial infiltration rates. Each is described in detail in Appendix III-A.

Prepare Soils Report

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

- Figure showing the following:
    - Topography within 500 feet of the proposed facility
    - Locations of any water supply wells within 500 feet of the proposed facility
    - Location of groundwater protection areas, aquifer recharge areas, or 1-, 5-, and 10-year times of travel zones for wellhead protection areas
    - Locations of test pits or test holes.
- Results of soils tests including but not limited to: detailed soil logs, visual grain size analysis, grain-size distribution (required if using the grain size analysis method to estimate infiltration rates), percent clay content (include type of clay, if known), color/ mottling, variations and nature of stratification
- Description of local site geology, including soil or rock units likely to be encountered at soil sampling depths and the seasonal high groundwater elevation
- Detailed documentation of the design infiltration rate determination, as specified above
- State whether location is suitable for infiltration and recommend a design infiltration rate. Note that the maximum allowable design infiltration rate is 30 inches per hour.

Estimate Volume of Stormwater

Use the latest version of the Western Washington Hydrology Model (WWHM), or other approved continuous runoff model to generate an influent file that will be used to size the infiltration facility. The facility must infiltrate either all of the flow volume as specified by the influent file, or a sufficient amount of the flow volume such that any overflow/bypass meets the flow duration standard in Minimum Requirement #7. In addition, the overflow/bypass must meet the LID performance standard if it is the option chosen to meet Minimum Requirement #5, or if it is required of the project.

Step 5: Detailed Analysis – Additional Requirements

In addition to the simple method requirements outlined above, projects subject to the detailed analysis method shall include infiltration receptor characterization.

Infiltration Receptor Characterization

Monitor Groundwater Levels

- A minimum of three groundwater monitoring wells shall be installed per infiltration facility that will establish a three-dimensional relationship for the groundwater table, unless the highest groundwater level is known to be at least 50 feet below the proposed base of the infiltration facility.
- Seasonal groundwater levels must be monitored at the site during at least one wet season (December 1 through April 30).
- Normalize the single wet season observation to historic groundwater records in the region.

Characterize Infiltration Receptors in Soils Report

Address the following:

- Depth to groundwater and to bedrock/impermeable layers.
- Seasonal variation of groundwater table based on well water levels and observed mottling of soils.
- Existing groundwater flow direction and gradient.
- Volumetric water holding capacity of the infiltration receptor soils. The volumetric water holding capacity is the storage volume in the soil layer directly below the infiltration facility and above the seasonal high groundwater mark, bedrock, hardpan, or other low permeability layer.
- Horizontal hydraulic conductivity of the saturated zone to assess the aquifer’s ability to laterally transport the infiltrated water.
- Approximation of the lateral extent of infiltration receptor.
- Impact of the infiltration rate and proposed added volume from the project site on local groundwater mounding, flow direction, and water table determined by hydrogeologic methods.
- The City may require a groundwater mounding analysis on projects where an infiltration facility has a drainage area exceeding one acre and has less than 6 feet depth to seasonal high groundwater (as measured from the bottom of the infiltration basin or trench) or other low permeability stratum. Groundwater mounding analysis methods are subject to city approval, and may include an

analytical groundwater model (such as MODERET) to investigate the effects of the local hydrologic conditions on facility performance.

- State whether location is suitable for infiltration and recommend a design infiltration rate. Note that the maximum allowable design infiltration rate is 30 inches per hour.

Construct the Facility and Conduct Performance Testing:

To demonstrate that the facility performs as designed, the constructed facility must be tested and monitored per the Verification of Performance requirements in Section 2.5.3, and documented as part of the Engineer's Inspection Report Form (obtainable from City of Gig Harbor Public Works Department' web site).

2.5.3 General Criteria for Infiltration Basins and Trenches

This section covers design, construction, and maintenance criteria that apply to infiltration basins and trenches. Similar information for other infiltration BMPs (i.e., bioretention areas, permeable pavement surfaces, rain gardens, and downspout infiltration systems) is included under the detailed BMP descriptions in Chapter 3.

Design Criteria – Sizing Facilities

The size of infiltration basins and trenches can be determined by routing the influent runoff file generated by the continuous runoff model through it. In general, an infiltration facility would have two discharge modes. The primary mode of discharge from an infiltration facility is infiltration into the ground. However, when the infiltration capacity of the facility is reached, additional runoff to the facility will cause the facility to overflow. Overflows from an infiltration basin or trench must comply with the Minimum Requirement #7 for flow control in Volume I. Infiltration facilities used for runoff treatment must not overflow more than 9 percent of the influent runoff file. All infiltration basins **are required to include a crest gauge** that will record maximum basin water surface elevation after a storm event. The designer may submit alternative crest recording device for city approval. See Attachments Section A, Detail 25.0 for crest gauge details. In addition, project submittals **must** include a table that identifies the design stage/storage/discharge expected for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval flows.

In order to determine compliance with the flow control requirements, the latest version of WWHM, or an approved Ecology appropriately calibrated continuous simulation runoff model based on HSPF, must be used. When using WWHM for simulating flow through an infiltrating facility, the facility is represented by using a pond element and entering the predetermined infiltration rates. Below are the procedures for sizing a basin to completely infiltrate 100 percent of runoff.

For 100 percent Infiltration

- Input dimensions of your infiltration basin.

- Input infiltration rate and safety (rate reduction) factor. See Appendix III-A for methods for determining infiltration rates.
- Input a riser height and diameter (any flow through the riser indicates that you have less than 100 percent infiltration and must increase your infiltration basin dimensions).
- Run only HSPF for developed mitigated scenario (if that is where you put the infiltration basin).
- Go back to your infiltration basin and look at the percentage infiltrated at the bottom right. If less than 100 percent infiltrated, increase basin dimension until you get 100 percent.

Pretreatment

A facility to remove a portion of the influent suspended solids must precede infiltration basins and trenches. Use either an option under the basic treatment facility menu (see Volume V, Chapter 2), or a pretreatment option from Volume V, Chapter 5. The lower the influent suspended solids loading to the infiltration facility, the longer the infiltration facility can infiltrate the desired amount of water or more, and the longer interval between maintenance activity.

Reduction in infiltration capability can have significant maintenance or replacement costs in infiltration basins and trenches, therefore selection of a reliable treatment device with high solids removal capability is preferred. In facilities that allow easier access for maintenance and less costly maintenance activity (e.g., infiltration basins with gentle side slopes), there is a trade-off between using a treatment device with a higher solids removal capability and a device with a lower capability. Generally, treatment options on the basic treatment menu are more capable at solids removal than pretreatment devices listed in Volume V, Chapter 5. Though basic treatment options may be higher in initial cost and space demands, the infiltration facility should have lower maintenance costs. If designed as a pretreatment facility and a water quality treatment facility (in compliance with Minimum Requirement #6), the pretreatment facility must be designed to treat runoff from the water quality design storm event, but must also safely convey or bypass the developed 100-year recurrence interval peak flow. Note that pretreatment is not required for roof runoff.

100-year Overflow Conveyance

An overflow route must be identified for stormwater flows that overtop the infiltration basin/trench when infiltration capacity is exceeded or the facility becomes plugged and fails. The overflow route must be able to convey the 100-year recurrence interval developed peak flow to the downstream conveyance system or other acceptable discharge point without posing a health or safety risk or causing property damage.

Spill Control Device

All infiltration basins and trenches must have a spill control device upstream of the facility to capture oil or other floatable contaminants before they enter the infiltration facility. If a T-section is used for spill control, the top of the spill control riser must be set above the facility's 100-year overflow elevation to prevent oils from entering the infiltration facility.

Access Road

Access roads are needed to all drainage structures, and at least one access point per cell, and they may be designed and constructed as specified for detention ponds in Section 3.12.1.

Signage

See the signage requirements under Section 3.12.1 for infiltration basin sign requirements.

Setbacks

All infiltration basins/trenches shall maintain minimum setback distances as follows. All setbacks shall be horizontal unless otherwise specified or modified with written approval by the TPCHD for wells and septic:

- 1 foot — positive vertical clearance from any open water maximum surface elevation to structures within 25 feet.
- 5 feet — from septic tank, holding tank, containment vessel, pump chamber, and distribution box.
- 10 feet — from open water maximum surface elevation or edge of infiltration facility to property lines and onsite structures.
- 10 feet — from open water maximum surface elevation or edge of infiltration facility to building sewer.
- 50 feet — from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on the slope. The soils report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.
- 300 feet — from an erosion hazard, or landslide hazard area (as defined by Chapter 18.08 GHMC) unless the slope stability impacts of such systems have been analyzed and mitigation proposed by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.

- Infiltration basins and trenches with a maximum design flow less than 0.5cfs must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas. Infiltration basins and trenches with a maximum design flow of 0.5cfs or greater must be at least 100 feet from of the drainfield primary and reserve areas.
- Infiltration basins and trenches shall be set back at least 100 feet from drinking water wells and springs used for public drinking water supplies.

Projects within Groundwater Protection Areas

The applicant must check the critical aquifer recharge area map, sole source aquifer designations, and wellhead protection areas mapped by the Washington State Department of Health to determine if the project lies within a groundwater protection area. A site is not suitable if the infiltration facility will cause a violation of groundwater quality standards. At a minimum, projects located within groundwater protection areas may be required to meet one of the soil requirements for infiltration for water quality treatment outlined in Volume V, Chapter 6.

Infiltration Near Water Supply Wells

In no case should infiltration basins or trenches be placed closer than 100 feet from drinking water wells and springs used for drinking water supplies. Where water supply wells exist nearby, it is the responsibility of the applicant’s engineer to locate such wells, meet any applicable protection standards, and assess possible impacts of the proposed infiltration facility on groundwater quality. If negative impacts on an individual or community water supply are possible, additional runoff treatment must be included in the facility design, or relocation of the facility should be considered.

All infiltration basins or trenches located within the 1-year capture zone of any well must be preceded by a water quality treatment facility. Infiltration basins or trenches upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Washington State Wellhead Protection Program Guidance Document, DOH, 6/2010. Infiltration systems that qualify as Underground Injection Control Wells must comply with Chapter 173-218 WAC and follow the Washington Department of Ecology’s “Guidance for UIC Wells that Manage Stormwater,” Publication No. 05-10-067 and Volume I, Appendix I-C - Underground Injection Control (UIC) Program Guidelines.

The soils report must be updated to demonstrate and document that the above criteria are met and to address potential impacts to water supply wells or springs.

Infiltration Near Steep Slopes or Landslide Hazard Areas

Along with the setback restrictions listed above for the design of infiltration basins and trenches located near a slope greater than 20 percent; a geotechnical assessment must be performed to demonstrate and document that the above criteria and Chapter 18.08

GHMC requirements are met and to address potential impacts to steep slopes, erosion hazard, or landslide hazard areas.

Construction Criteria

During construction, it is critical that the subgrade soils be protected from clogging and compaction to maintain the soil properties identified during infiltration testing (e.g., infiltration capacity) and ensure facility performance. Most of the construction requirements for small scale infiltration facilities included in Volume II, Section 3.3 apply to all infiltration facilities. Any additional BMP specific construction requirements are included in the infiltration BMP "Construction Criteria" sections of Chapter 3.

Operations and Maintenance Criteria

Adequate access for operation and maintenance (O&M) must be included in the design of infiltration basins and trenches. Provisions must be made for regular and perpetual maintenance of the infiltration basin/trench, including replacement and/or reconstruction of the any media that are relied upon for treatment purposes. A City-approved Maintenance and Source Control Manual shall ensure maintaining the desired infiltration rate.

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

Verification of Performance

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

In addition, before release of the financial guarantee the completed facility must be monitored through a minimum of one storm season, October to April, to demonstrate that the facility performs as designed. The monitoring must occur after permanent erosion control and site stabilization measures have been installed. If tests indicate that the facility will not function as designed (as per the Maintenance and Source Control Manual developed for the project), this information must be brought to the immediate attention of the city along with reasons and potential remedies.

2.6 Underground Injection Control

The following information on UIC is excerpted from the 2006 Ecology document titled "Guidance for UIC Wells that Manage Stormwater" (Ecology 2006). This document is available online at Ecology's web site.

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

UIC systems include drywells, pipe or french drains, drainfields, and other similar devices that are used to discharge stormwater directly into the ground. Infiltration trenches with perforated pipe used to disperse and inject flows (as opposed to collect and route to surface drainage, as in an underdrain) are considered to be UIC wells. This type of infiltration trench must be registered with Ecology (60 days prior to construction).

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

- Buried pipe and/or tile networks that serve to collect water and discharge that water to a conveyance system or to surface water
- Surface infiltration basins and flow dispersion stormwater infiltration facilities, unless they contain additional infiltration structures at the bottom of the basin/system such as perforated pipe, or additional bored, drilled, or dug shafts meant to inject water further into the subsurface greater than 20 feet deeper than the bottom of the pond (or deeper than the largest surface dimension per above)
- Infiltration trenches designed without perforated pipe or a similar mechanism
- A system receiving roof runoff from a single family home (or duplex).

The two basic requirements of the UIC Program are:

- Register UIC wells with Ecology (60 days prior to construction) unless the wells are located on tribal land (Those wells should be registered with the Environmental Protection Agency.)
- Make sure that current and future underground sources of groundwater are not endangered by pollutants in the discharge (non-endangerment standard).

UIC wells must either be rule-authorized or covered by a state waste discharge permit to operate. If a UIC well is rule-authorized, a permit is not required. Rule authorization can be rescinded if a UIC well no longer meets the non-endangerment standard. Ecology can also require corrective action or closure of a UIC well that is not in compliance. Additional information on UIC systems can be found online at Ecology's web site and Volume I, Appendix I-C.

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

Chapter 3 - Flow Control Design

3.1 Soil Preservation and Amendment (Ecology BMP T5.13)

3.1.1 Description

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

Additional guidance for this BMP can be found in *Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13* (Stenn et al.2016), which is available at: <www.buildingsoil.org>.

Naturally occurring (undisturbed) soil, soil organisms, and vegetation provide the following important stormwater management functions:

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

These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal soil and sod. Not only are these important stormwater management functions lost, but such landscapes themselves can become pollution-generating pervious surfaces due to compaction; increased use of pesticides, fertilizers, and other landscaping and household/industrial chemicals; the concentration of pet wastes; and pollutants that accompany roadside litter.

Soil preservation and amendment requirements help to regain greater stormwater functions in the post development landscape, provide increased treatment of pollutants and sediments that result from development and habitation, and minimize the need for some landscaping chemicals (thus reducing pollution through prevention).

3.1.2 Applications and Limitations

- When used in combination with other onsite stormwater management BMPs, soil preservation and amendment can help achieve compliance with the Performance Standard option of Minimum Requirement #5.

  On sites that are underlain by cemented till layers, which are nearly impermeable, the upper soil horizon (native topsoil) processes the majority of stormwater on the site. Ensure that the existing depth of the upper soil horizon is either left in place or removed and replaced (according to the requirements herein) during the grading process.

- On sites which are underlain by outwash soils, the existing topsoil is not usually as deep (as with till soils), but must still be preserved or replaced.
- Portions of the site comprised of till soils with slopes greater than 33 percent need not implement this BMP.

3.1.3 Modeling and Sizing

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

In addition, flow control credit is given in runoff modeling when soil preservation and amendment BMP requirements are met and used as part of a dispersion design under the conditions described in:

- Full Dispersion (Section 3.2.2 and Volume VI, Section 2.3)
- Sheet Flow Dispersion (Section 3.2.3)
- Concentrated Flow Dispersion (Section 3.2.4)
- Downspout Dispersion (Section 3.9.4).

3.1.4 Soil Preservation and Amendment Design Criteria

This section describes the implementation options and design requirements for soil preservation and amendment. Typical cross-sections of compost-amended soil in planting bed and turf applications are shown in Figure 3.1. Design criteria are provided in this section for the following elements:

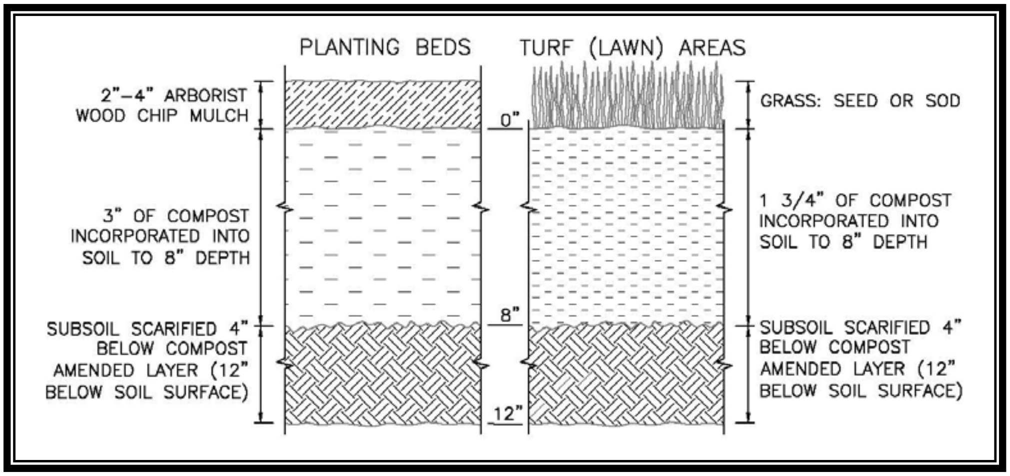
- Implementation options
- Soil retention
- Soil amendment
- Soil stockpiling
- Soil importing
- Soil Preservation and Amendment Plan.

Implementation Options

The soil quality design requirements can be met by using one of the four options listed below. Additional details for each option are provided in the subsequent subsections:

1. Retain and Protect Undisturbed Soil:

- Leave undisturbed vegetation and soil, and protect from compaction by fencing and keeping materials storage and equipment off these areas during construction.
- For all areas where soil or vegetation are disturbed, use option 2, 3, or 4.



Source: City of Seattle (reproduced with permission)

Figure 3.1. Cross-section of Soil Amendment.

2. Amend Soil:

- Soil amendments shall be applied to all areas which are being set aside as non-buildable areas (open space or natural resource protection areas) and are in need of rehabilitation because of past land use disturbances such as clearing and intrusion of invasive species. The purpose is to enhance and accelerate the rehabilitation of the soil structure. The application will be non-destructive to the existing vegetation that is retained by taking care to taper depths of soil amendment near the surface roots.
- Amend existing site topsoil or subsoil either at default "pre-approved" rates, or at custom calculated rates to meet the soil quality guidelines based on engineering tests of the soil and amendment. (Refer to the Building Soil manual [Stenn et al. 2016] or web site <www.buildingsoil.org>, for custom calculation methods.)

3. Stockpile Soil:

- Stockpile existing topsoil during grading and replace it prior to planting. Amend stockpiled topsoil if needed to meet the organic matter or depth requirements either at the default "pre-approved" rate or at a custom calculated rate (refer to the *Building Soil* manual [Stenn et al.2016] or web site <www.buildingsoil.org>, for custom calculation method). Scarify subsoil and mulch planting beds, as described under the Soil Amendment heading below.

4. **Import Soil:**

   - Import topsoil mix of sufficient organic content and depth to meet the requirements. Imported soils should not contain excessive clay or silt fines (more than 5 percent passing the US #200 sieve) because that could restrict stormwater infiltration. Use imported topsoil that meets default "pre-approved" rates.

   - Scarify subsoil and mulch planting beds, as described under the Soil Amendment heading below.

Note: more than one method may be used on different portions of the same site.

Soil Retention

In buildable areas where minimal excavation foundation systems may be applied, existing topsoils shall be left in place to the greatest extent feasible and shaped or feathered only with tracked grading equipment not exceeding 650 pounds per square foot machine loads. Where some re-grading is required, re-compaction of placed materials, which may include topsoils free of vegetated matter, shall be limited to the minimum densities required by the foundation system engineering.

Soil Amendment

If soil retention and protection is not feasible, disturbed soil must be amended. Soil organic matter is often missing from disturbed soils. Replenish organic matter by amending with compost. It is important that the materials used to meet the soil preservation and amendment BMP are appropriate and beneficial to the plant cover to be established. Likewise, it is important that imported topsoils improve soil conditions and do not have an excessive percent of clay or silt fines.

Amend existing site topsoil or subsoil either at default "pre-approved" soil amendment rates or at custom calculated rates to meet the soil quality guidelines based on engineering tests of the soil and amendment. Both options are described in further detail below.

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

- A topsoil layer meeting these requirements:

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

- Root zones where tree roots limit the depth of incorporation of amendments are exempted from this requirement. Fence and protect these root zones from stripping of soil, grading, or compaction to the maximum extent practical.
- Scarify (loosen) subsoils below the topsoil layer at least 4 inches for a finished minimum depth of 12 inches of uncompacted soil. Incorporate some of the upper material to avoid stratified layers, where feasible.
- For turf installations: water or roll to compact to 85 percent of maximum dry density, rake to level, and remove surface woody debris and rocks larger than 1 inch diameter (*Building Soil* manual [Stenn et al.2016] or web site <www.buildingsoil.org>).
- After planting: mulch planting beds with 2 to 4 inches of organic material such as arborist wood chips, bark, shredded leaves, compost, etc. Do not use fine bark because it can seal the soil surface.
- Use compost and other materials that meet the following organic content requirements:
  - The organic content for "pre-approved" amendment rates can only be met using compost meeting the compost specification for bioretention (see Section 3.4), with the exception that the compost may have up to 35 percent biosolids or manure. The compost must have an organic matter content of 40 percent to 65 percent, and a carbon to nitrogen ratio below 25:1. The carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.
  - Calculated amendment rates may be met through use of composted materials as defined above, or other organic materials amended to meet the carbon to nitrogen ratio requirements, and not exceeding the

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

contaminant limits identified in Table 220-B, Testing Parameters, in WAC 173-350-220.

Assure that the resulting soil is conducive to the type of vegetation to be established.

Soil Stockpiling

In any areas requiring grading, remove and stockpile the duff layer and topsoil on site in a designated, controlled area, which is not adjacent to public resources and critical areas. Reapply to other portions of the site where feasible.

- In buildable areas of the site, where conventional grading is required, the areas requiring cuts shall have the upper native topsoil removed and stockpiled for replacement to areas of the development utilized for stormwater and/or vegetation management (yards, bioretention areas, interflow pathways, vegetated channels, or degraded natural resource protection areas).
- The depth of upper native topsoil required to be stockpiled and replaced shall be the entire depth of the native topsoil horizon up to a maximum of 3 feet.
- Over-excavation of cut sections may be necessary if the cut is in a location that will be utilized for stormwater management. Cut to a depth that will allow replacement of stockpiled native topsoil to the entire depth that was on the site post-development up to a maximum of 3 feet.
- Cut sections where native topsoil replacement is required shall require ripping of any cemented till layers to a depth of 6 inches. Subsequently the replacement of stockpiled topsoil shall be thoroughly mixed into the ripped till to provide a gradual transition between the cemented till layer and the topsoil.
- Stockpiled topsoil shall be replaced in lifts no greater than 1 foot deep and compacted by rolling to a density that matches existing conditions.

Importing Soil

The default pre-approved rates for imported topsoils are:

- For planting beds: use a mix by volume of 35 percent compost with 65 percent mineral soil to achieve the requirement of a minimum 8 percent (target 10 percent) organic matter by loss-on-ignition test
- For turf areas: use a mix by volume of 20 percent compost with 80 percent mineral soil to achieve the requirement of a minimum 4 percent (target 5 percent) organic matter by loss-on-ignition test.

Soil Preservation and Amendment Plan

A Soil Preservation and Amendment Plan must be included in the project submittal, i.e., the Construction SWPPP, and Drainage Control Plan or Abbreviated Plan. The Soil Preservation and Amendment Plan must include the following:

- A site map showing areas to be fenced and left undisturbed during construction, and areas that will be amended at the turf or planting bed rates
- Calculations of the amounts of compost, compost amended topsoil, and mulch to be used on the site.

General guidance on these procedures can be found in the *Building Soil* manual (Stenn et al. 2016), available at <www.buildingsoil.org>.

3.1.5 Construction Criteria

Most of the construction requirements for small scale infiltration and dispersion facilities included in Volume II, Section 3.3 also apply to soil preservation and amendment areas. Minimum construction requirements for disturbed areas include the following:

- Install soil to meet soil preservation and amendment BMP requirements toward the end of construction, and once established, protect from compaction and erosion
- Plant soil with appropriate vegetation and mulch planting beds installation.

3.1.6 Operations and Maintenance Criteria

The most important maintenance issue is to replenish the soil organic matter by leaving leaf litter and grass clippings onsite (or by adding compost and mulch regularly). This BMP is designed to reduce the need for irrigation, fertilizers, herbicides, and pesticides.

3.2 Dispersion Facilities

3.2.1 General Dispersion Facility Design Criteria

General Site Considerations

The following are key considerations in determining the feasibility of dispersion BMPs for a particular site:

- **Dispersion flow path area**: Dispersion BMPs generally require large areas of vegetated ground cover to meet flow path requirements and are not feasible in many urban settings, and some rural settings
- **Erosion or flooding potential**: Dispersion is not allowed in settings where the dispersed flows might cause erosion or flooding problems, either onsite or on adjacent properties

- **Site topography**: Dispersion flow paths are prohibited in and near certain sloped areas (refer to detailed flow path requirements below).

General Design Criteria

Flow path design requirements that are common to all dispersion BMPs are listed below. Additional requirements that are specific to the individual dispersion types are provided in each BMP section.

- Natural resource protection areas and critical area buffers may count towards flow path lengths. This does not include steep slopes. However, the natural resource protection area must be permanently protected from modification through a covenant or easement, or a tract dedicated by the proposed project.

- Dispersion facilities shall be placed no closer than 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high, and a vegetated flow path must be maintained between the outlet of the facility and the slope. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on the slope. The geotechnical assessment may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope. For sites unable to meet the above setbacks, a geotechnical assessment recommending dispersion on a slope may be allowed. Approval will be at the discretion of the City of Gig Harbor.

- The dispersion discharge point for the facility is not permitted within 300 feet of an erosion hazard, or landslide hazard area (as defined by Chapter 18.08 GHMC) unless the slope stability impacts of such systems have been analyzed and mitigated by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.

- For sites with onsite or adjacent septic systems, the discharge point must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas. In addition, the entire flow path must be oriented so as to not intersect with the primary or reserve areas. These requirements may be modified by the Tacoma-Pierce County Health Department if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that a shorter setback is feasible.

- The vegetated flow path must consist of either undisturbed native landscape, or well-established lawn, landscape, groundcover over soil that meets the soil preservation and amendment BMP requirements outlined in Section 3.1. The groundcover must be dense to help disperse and infiltrate flows and prevent erosion.

- The dispersion flow path is not permitted over contaminated sites or abandoned landfills.

3.2.2 Full Dispersion (Ecology BMP T5.30)

This BMP allows projects to disperse runoff from impervious surfaces and cleared areas of development sites into areas preserved as forest or native vegetation. See Volume VI, Section 2.3 for design requirements and other information on Full Dispersion. Projects that meet the requirements for Full Dispersion will have fully met the requirements of Volume I, Minimum Requirements #5, #6, and #7.

3.2.3 Sheet Flow Dispersion (Ecology BMP T5.12)

Description

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

Applications and Limitations

- Use for flat or moderately sloping (less than 15 percent slope) surfaces such as driveways, sport courts, patios, roofs without gutters, lawns, pastures; or any situation where concentration of flows can be avoided.
- Where the contributing surface is flat to moderately sloped, and cross-sloped at a minimum of 2 percent (to convey runoff across the contributing surface), a transition zone shall be used to route runoff to a vegetated buffer.
- Where the contributing surface is of variable slope, berms and dispersion trenches shall be used to route runoff to the vegetated buffer.
- Modeling credits for sheet flow dispersion (see Modeling and Sizing below) can be applied to help meet the flow control standards of Minimum Requirement #7 as well as to achieve compliance with the Performance Standard option of Minimum Requirement #5.

Modeling and Sizing

Where sheet flow dispersion is used to disperse runoff into an undisturbed native landscape area or an area that meets the requirements of Section 3.1, the impervious area may be modeled as grass/lawn area.

Sheet Flow Dispersion Design Criteria

Refer to Section 3.2.1 for general dispersion design criteria. This section provides additional design criteria specific to sheet flow dispersion:

- See Figure 3.2 for required setbacks and flow path lengths. Figure 3.2 is applicable for non-driveway surfaces.
- Transition Zones

  - A 2-foot-wide transition zone to discourage channeling must be provided between the edge of the contributing surface (or building eaves) and the downslope vegetation. This transition zone may consist of subgrade material (crushed rock), modular pavement, drain rock, or other material approved by the City of Gig Harbor.
  - Provide a 10-foot wide vegetated buffer for up to 20 feet of width of contributing surface. Provide an additional 10 feet of width for each additional 20 feet of contributing area width or fraction thereof. (For example, if a driveway is 30 feet wide and 60 feet long, provide a 15-foot wide by 60-foot long vegetated buffer, with a 2-foot by 60-foot transition zone).

- Berms
  - Berms must be diagonal to surface flow to intercept and convey runoff to dispersion trenches.
  - Dispersion trenches must be designed in accordance with Section 3.9.4.
  - Provide a 25-foot vegetated flow path between the discharge point of the dispersion trench and any property line, structure, steep slope (greater than 20 percent), stream, lake, wetland, or other impervious surface.

Construction Criteria

Protect the dispersion flow path from sedimentation and compaction during construction. If the flow path area is disturbed during construction, restore the area to meet the soil amendment BMP requirements in Section 3.1 and establish a dense cover of lawn, landscape, or groundcover. See Volume II, Section 3.3 for additional dispersion facility construction requirements.

Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

3.2.4 Concentrated Flow Dispersion (Ecology BMP T5.11)

Description

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits. See Figures 3.2 and 3.3.

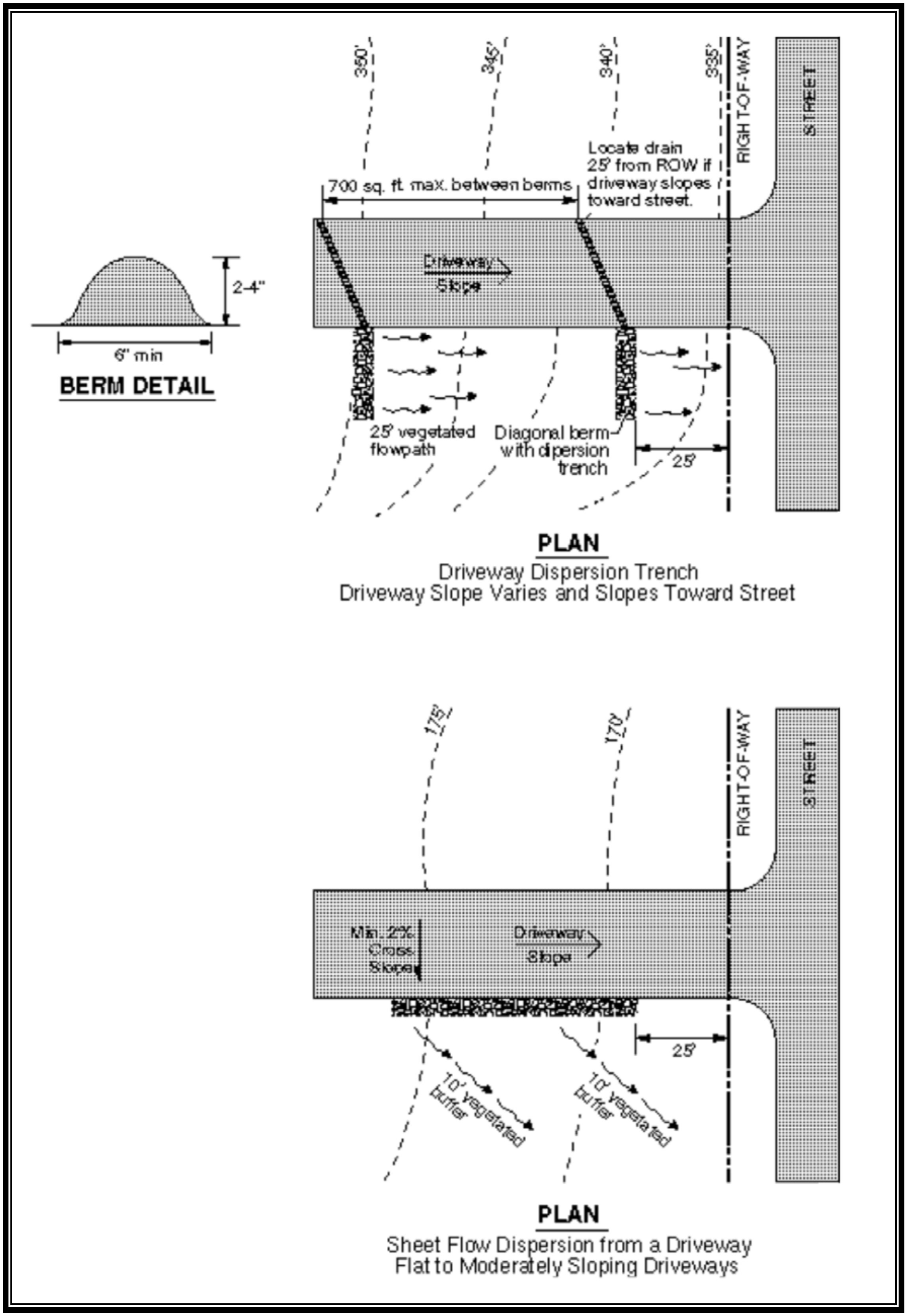


Figure 3.2. Sheet Flow Dispersion for Driveways.

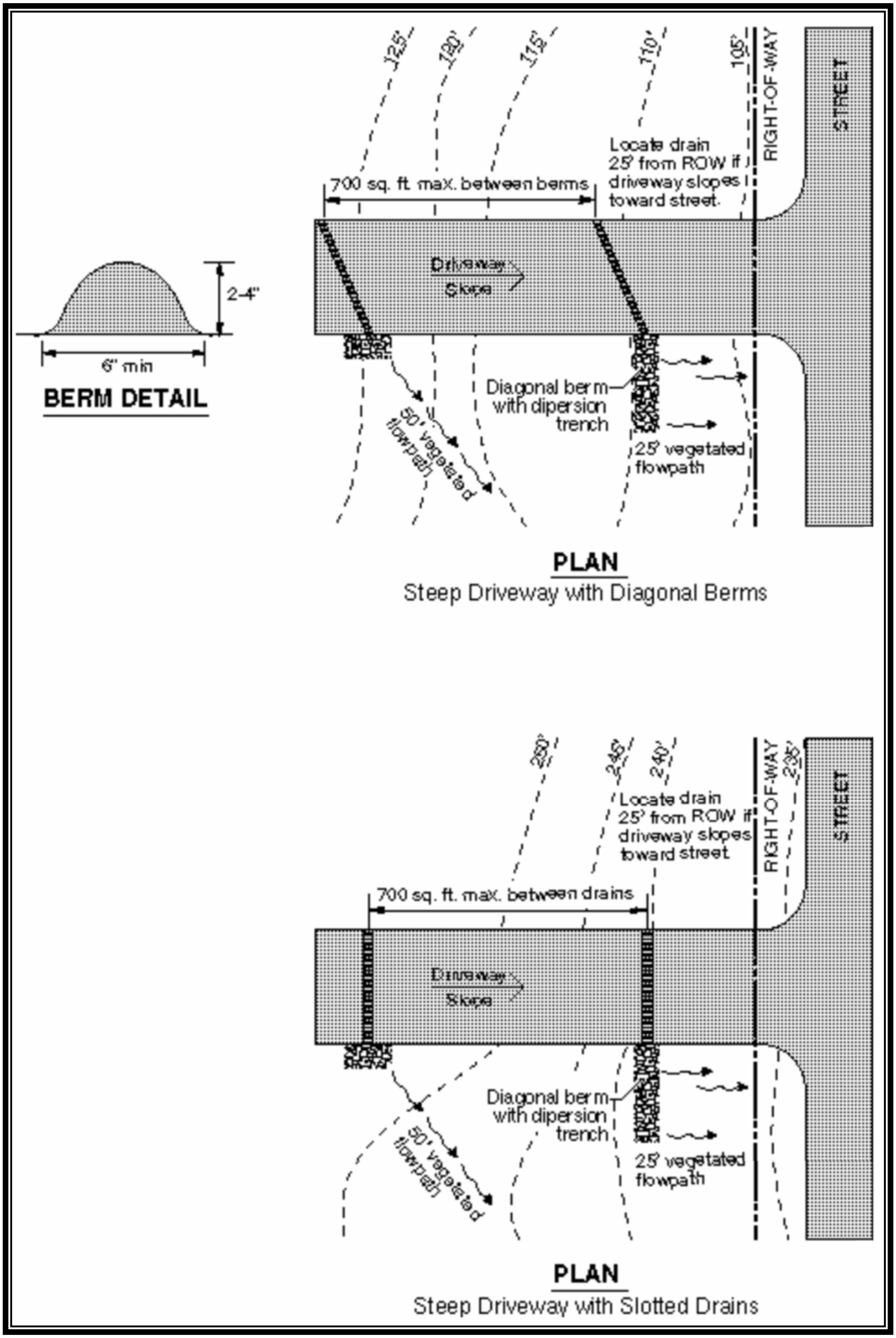


Figure 3.3. Typical Concentrated Flow Dispersion for Steep Driveways.

Applications and Limitations

- Concentrated flow dispersion can be used in any situation where concentrated flow can be dispersed through vegetation.
- Modeling credits for concentrated flow dispersion (see below) can be applied to help meet the flow control standards of Minimum Requirement #7, as well as to help achieve compliance with the Performance Standard option of Minimum Requirement #5.
- Dispersion for driveways will generally only be effective for single-family residences on large lots and in rural short plats. Lots proposed by short plats in urban areas will generally be too small to provide effective dispersion of driveway runoff.
- Figure 3.3 shows two possible ways of spreading flows from steep driveways.

Modeling and Sizing

Where concentrated flow dispersion is used to disperse runoff into an undisturbed native landscape area or an area that meets the requirements of Section 3.1, the impervious area may be modeled as a lateral flow impervious area. Do this in WWHM on the Mitigated Scenario screen by connecting the lateral flow impervious area element (representing the area that is dispersed) to the lawn/landscape lateral flow soil basin element (representing the area that will be used for dispersion). The design must adhere to the flow path lengths and dispersion trench/rock pad options described below as a prerequisite to using the lateral flow elements. In situations where multiple instances of concentrated flow dispersion will occur, the City allows the following options:

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

Concentrated Flow Dispersion Design Criteria

Refer to Section 3.2.1 for general dispersion design criteria. This section provides additional design criteria specific to concentrated flow dispersion:

- Maintain a vegetated flow path of at least 50 feet (if using rock pads), or 25 feet (if using dispersion trenches) between the discharge point and any property line, structure, steep slope (greater than 20 percent), stream, lake, wetland, or other impervious surface. The flowpath length is measured perpendicular to site contours.

- A slotted drain, diagonal berm, or similar measure must be provided to direct flow to the rock pad or dispersion trench.
- A maximum of 700 square feet of impervious area may drain to each concentrated flow dispersion device.
- Provide a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) or dispersion trench (per Section 3.9.4) at each discharge point.
- No erosion or flooding of downstream properties may result.
- Each dispersion device must have a separate flow path. For the purpose of maintaining adequate separation of flows discharged from adjacent dispersion devices, vegetated flow paths must be at least 20 feet apart at the upslope end and must not overlap with other flow paths at any point along the minimum required flow path lengths.

Construction Criteria

Protect the dispersion flow path from sedimentation and compaction during construction. If the flow path area is disturbed during construction, restore the area to meet the soil preservation and amendment BMP requirements in Section 3.1 and establish a dense cover of lawn, landscape, or groundcover. See Volume II, Section 3.3 for additional dispersion facility construction requirements.

Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements.

3.3 Tree Planting and Tree Retention (for Flow Control Credit, Ecology BMP T5.16)

This flow control application is currently not adopted by the City of Gig Harbor.

3.4 Bioretention Cells, Swales, and Planter Boxes (Ecology BMPs T5.14 and T7.30)

3.4.1 Description

Bioretention areas are shallow stormwater systems with a designed soil mix and plants adapted to the local climate and soil moisture conditions. Bioretention areas are designed to mimic a forested condition by controlling stormwater through detention, infiltration, and evapotranspiration. Bioretention areas also provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation.

Bioretention areas function by storing stormwater as surface ponding before it filters through the underlying amended soil. Stormwater that exceeds the surface storage capacity overflows to an adjacent drainage system. Treated water is infiltrated into the underlying soil.

The terms bioretention and rain garden are sometimes used interchangeably. Bioretention areas and rain gardens are applications of the same LID concept and can be highly effective for reducing surface runoff and removing pollutants. However, in the City of Gig Harbor (in accordance with the Department of Ecology's distinction), the term bioretention is used to describe an engineered facility that includes designed soil mixes and perhaps underdrains and control structures. The term, rain garden, is used to describe a shallow landscaped depression on small project sites that only trigger Minimum Requirements #1-#5. Rain gardens have less restrictive design criteria for the soil mix and do not include underdrains or other control structures. See Section 3.8 for more information on rain garden design.

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

- **Bioretention cells**: Shallow depressions with a designed planting soil mix and a variety of plant material, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells may or may not have an underdrain and are not designed as a conveyance system.

- **Bioretention swales**: Incorporate the same design features as bioretention cells; however, bioretention swales are designed as part of a system that can convey stormwater when maximum ponding depth is exceeded. Bioretention swales have relatively gentle side slopes and ponding depths that are typically 6 to 12 inches.

- **Bioretention planters and planter boxes**: Designed soil mix and a variety of plant material including trees, shrubs, grasses, and/or other herbaceous plants within a vertical walled container usually constructed from formed concrete, but could include other materials. Planter boxes are completely impervious and include a bottom (must include an underdrain). Planters have an open bottom and allow infiltration to the subgrade. These designs are often used in ultra-urban settings.

Note: Ecology has approved use of certain patented treatment systems that use specific, high rate media for treatment. Such systems are not considered onsite stormwater management BMPs and are not options for meeting the requirements of Minimum Requirement #5. The Ecology approval (General Use Level Designations only) is meant to be used to meet Minimum Requirement #6, where appropriate.

Figure 3.6 provides an example illustration of a bioretention area. See Attachments Section A, Details 29.0, 30.0, and 32.0 for bioretention details.

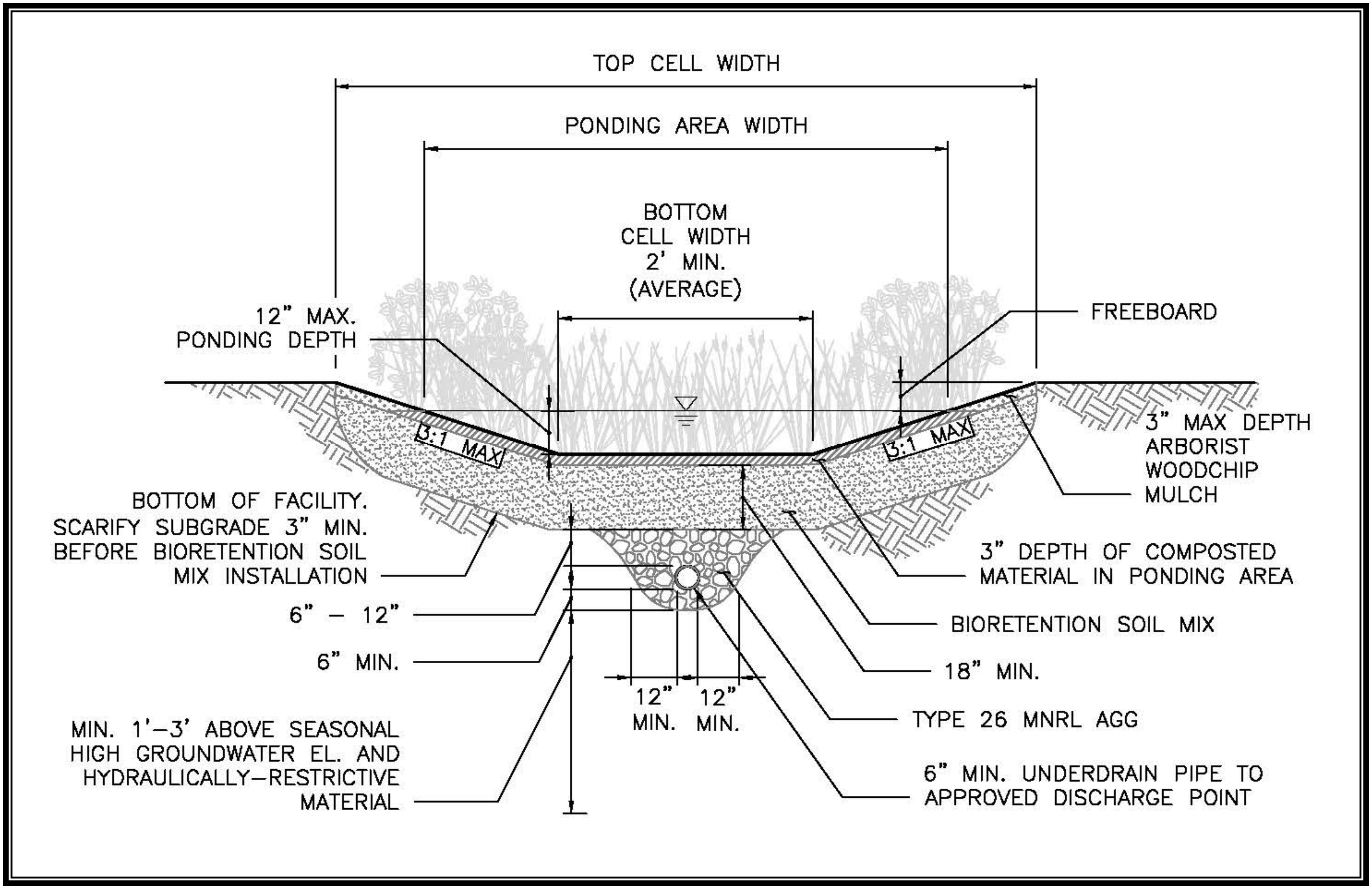
3.4.2 Applications and Limitations

Bioretention provides effective removal of many stormwater pollutants by passing stormwater through a soil profile that meets specified characteristics. Bioretention areas that infiltrate stormwater into the ground can also serve a significant flow reduction function.

- Bioretention areas are an onsite stormwater management BMP option for 1) projects that only have to comply with Minimum Requirements #1 through #5, and 2) projects that trigger Minimum Requirements #1 through #10
- Bioretention can achieve the Performance Standard option or can be applied from List #1 or List #2 option of Minimum Requirement #5.

Bioretention areas may meet the Minimum Requirement #6 requirements for basic and enhanced treatment (see Volumes I and V) when the bioretention soil meets the requirements outlined in Section 3.4.6.

- Bioretention can be designed to fully meet the flow control duration standard of Minimum Requirement #7. Because they typically do not have an orifice restricting overflow or underflow discharge rates, they typically don't fully meet Minimum Requirement #7. However, their performance contributes to meeting the standard, and that can result in much smaller flow control facilities at the bottom of the project site.
- Because bioretention areas use an imported soil mix that has a moderate design infiltration rate, they are best applied for small drainage areas, and near the source of the stormwater. Cells may be scattered throughout a subdivision; a swale may run alongside the access road; or a series of planter boxes may serve the road.
- Bioretention areas are particularly effective where the underlying soil has a high infiltration rate. Where the native soils have low infiltration rates, underdrain systems can be installed and the facility used to filter pollutants and detain flows that exceed infiltration capacity of the surrounding soil. However, designs utilizing underdrains provide less flow control benefits.
- Bioretention areas are applicable to new development, redevelopment and retrofit projects. Typical applications with or without underdrains include:



Source: City of Seattle (reproduced with permission)

Figure 3.6. Bioretention Area (shown with optional underdrain)

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

3.4.3 Infeasibility Criteria

The following criteria describe conditions that make bioretention not required for consideration in the List #1 or List #2 option of Minimum Requirement #5. In addition, other bioretention design criteria and site limitations that make bioretention areas infeasible (e.g., setback requirements) may also be used to demonstrate infeasibility, subject to approval by the City. See also Appendix III-D for a summary of infeasibility criteria for all BMPs. If a project proponent wishes to use a bioretention BMP though not required to because of these feasibility criteria, they may propose a functional design to the city.

Note: Criteria with setback distances are as measured from the bottom edge of the bioretention soil mix.

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

- Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or downgradient flooding
- In accordance with Chapter 18 GHMC limitations may exist and reports may be required when bioretention area is within 300 feet of a landslide hazard area or within 200 feet of an erosion hazard area
- Where the only area available for siting would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, pre-existing structures, or pre-existing road or parking lot surfaces

- Where the only area available for siting does not allow for a safe overflow pathway to a stormwater drainage system
- Where there is a lack of usable space for bioretention areas at re-development sites, or where there is insufficient space within the existing public right-of-way on public road projects
- Where infiltrating water would threaten existing below grade basements
- Where infiltrating water would threaten shoreline structures such as bulkheads.

The following criteria can be cited as reasons for infeasibility without further justification (though some require professional services to make the observation):

- Within setbacks provided in Section 3.4.6.
- Where they are not compatible with a surrounding drainage system as determined by the city (e.g., project drains to an existing stormwater collection system whose elevation or location precludes connection to a properly functioning bioretention area).
- Where land for bioretention is within an erosion hazard, or landslide hazard area (as defined by Chapter 18.08 GHMC).
- Where the site cannot be reasonably designed to locate bioretention areas on slopes less than 8 percent.
- For properties with known soil or groundwater contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
    - Within 100 feet of an area known to have deep soil contamination
    - Where groundwater modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the groundwater
    - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the bioretention area
    - Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW.
- Within 100 feet of a closed or active landfill.
- For sites with onsite or adjacent septic systems, the discharge point must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas. This requirement may be modified by the Tacoma-Pierce County Health Department if site topography clearly prohibits flows from intersecting

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

- Within 10 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is 1,100 gallons or less. (As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10 percent or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.

- Within 100 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is greater than 1,100 gallons.

- Where the field testing indicates potential bioretention area sites have a measured (a.k.a., initial) native soil saturated hydraulic conductivity less than 0.30 inches per hour. A small-scale or large-scale PIT in accordance with Appendix III-A shall be used to demonstrate infeasibility of bioretention areas. If the measured native soil infiltration rate is less than 0.30 in/hour, this option is not required to be evaluated as an option in List #1 or List #2 of Minimum Requirement #5. In these slow draining soils, a bioretention area with an underdrain may be used to treat pollution-generating surfaces to help meet Minimum Requirement #6, Runoff Treatment. If the underdrain is elevated within a base course of gravel, it will also provide some modest flow reduction benefit that will help achieve Minimum Requirement #7.

Other Site Suitability Factors:

- **Utility conflicts**: Consult the City of Gig Harbor requirements for horizontal and vertical separation required for publicly-owned utilities, such as sewer. Consult the appropriate franchise utility owners for separation requirements from their utilities, which may include communications, water, power, and gas. When separation requirements cannot be met, designs should include appropriate mitigation measures, such as impermeable liners over the utility, sleeving utilities, fixing known leaky joints or cracked conduits, and/or adding an underdrain to the bioretention.

- **Transportation safety**: The design configuration and selected plant types should provide adequate sight distances, clear zones, and appropriate setbacks for roadway applications in accordance with the City's requirements.

- **Ponding depth and surface water draw-down**: Flow control needs, as well as location in the development, and mosquito breeding cycles will determine draw-down timing. For example, front yards and entrances to residential or commercial developments may require rapid surface dewatering for aesthetics.

- **Impacts of surrounding activities**: Human activity influences the location of the facility in the development. For example, locate bioretention areas away from traveled areas on individual lots to prevent soil compaction and damage to vegetation or provide elevated or bermed pathways in areas where foot traffic is inevitable and provide barriers, such as wheel stops, to restrict vehicle access in roadside applications.

- **Visual buffering**: Bioretention areas can be used to buffer structures from roads, enhance privacy among residences, and for an aesthetic site feature.
- **Site growing characteristics and plant selection**: Appropriate plants should be selected for sun exposure, soil moisture, and adjacent plant communities. Native species or hardy cultivars are recommended and can flourish in the properly designed and placed bioretention soil mix with no nutrient or pesticide inputs and 2 to 3 years irrigation for establishment. Invasive species control may be necessary.

3.4.4 Modeling and Sizing

Bioretention areas receiving runoff from roads or a combination of roads and other impervious/pervious surfaces will be larger than rain gardens. For bioretention areas designed to meet Minimum Requirement #5, the bioretention area shall have a horizontally projected surface area below the overflow which is at least 5 percent of the total surface area draining to it. If lawn/landscape area will also be draining to the bioretention area, the horizontally projected surface area below the overflow shall be increased by 2 percent of the lawn/landscape area. For bioretention areas designed to meet Minimum Requirement #6 or #7, the bioretention area must be sized using an approved continuous simulation model.

When using continuous modeling to size bioretention areas, the assumptions listed in Table 3.3 shall be applied. It is recommended that bioretention cells be modeled as a layer of soil (with specified infiltration rate) with infiltration to underlying soil, ponding, and overflow. The bioretention soil is designed in accordance with the treatment soil requirements outlined in the design criteria below. To meet Minimum Requirement #6, at least 91 percent of the influent runoff file produced using a continuous simulation model must be infiltrated. Applicable water quality design storm volume drawdown requirements must also be met (see Volume V, Section 6.3).

If 91 percent of the influent runoff file cannot be infiltrated, the percent infiltrated may be subtracted from the 91 percent volume that must be treated, and downstream treatment facilities may be significantly smaller as a result.

The tributary areas, cell bottom area, and ponding depth should be iteratively sized until the duration curves and/or peak values meet the applicable flow control requirements (see Volume I).

At the time of publication of this volume, the latest version of WWHM includes a bioretention module that can be used to size the cell with or without an underdrain as a function of tributary area, land use type, native soil infiltration rate, side slopes, etc. It is anticipated that other modeling programs will develop similar modules to represent bioretention cells in the future.

Infiltration rates of the native soil (i.e., the undisturbed soil below the imported and/or amended facility soil) and bioretention soil mix infiltration rate must be used when sizing and modeling bioretention areas. The native infiltration rate shall be determined using the methods outlined above. The method for determining infiltration rate of bioretention soil mix is described in Section 3.4.6.

Table 3.3. Continuous Modeling Assumptions for Bioretention Cells.

Variable	Assumption
Precipitation Series	City of Gig Harbor
Computational Time Step	15 minutes
Inflows to Facility	Surface flow and interflow from drainage area routed to facility
Precipitation and Evaporation Applied to Facility	Yes. If model does not apply precipitation and evaporation to facility, include the facility area in the basin area (note that this will underestimate the evaporation of ponded water).
Default Bioretention Soil Mix Measured Infiltration Rate	The infiltration rate is 12.0 inch per hour before applying the correction factor.
Bioretention Soil Porosity	30 percent
Bioretention Soil Depth	Minimum of 18 inches
Native Soil Infiltration Rate	Measured infiltration rate, including applicable safety factors (see Volume III, Appendix III-A)
Infiltration Across Wetted Surface Area	Only if side slopes are 3:1 or flatter
Underdrain (optional)	If an underdrain is placed at bottom extent of the bioretention soil layer, all water that filters through the bioretention soil must be routed through the underdrain (i.e., no losses to infiltration). If there is no liner or impermeable layer and the underdrain is elevated above the bottom extent of the bioretention soil or aggregate layer, water stored in the bioretention soil or aggregate below the underdrain invert may be allowed to infiltrate.
Overflow	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over riser edge or riser notch. Note that the total facility depth (including freeboard) must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge.

3.4.5 Field and Design Procedures

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

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

If the bioretention area includes a liner and does not infiltrate into the underlying soils, they are not considered infiltration facilities and are not subject the infiltration procedures or the setbacks provided in this section. Adhere to setbacks and site constraints for detention vaults included in Section 3.12.3 for these facilities.

Determining Design Infiltration Rate

Determining the infiltration rate of the site soils is necessary to determine feasibility of designs that intend to infiltrate stormwater on site. Infiltration rates are also necessary to estimate bioretention performance using the latest version of the Western Washington Hydrology Model (WWHM).

Determining Initial Soil Infiltration Rate

Initial (measured) infiltration rates are determined through soil infiltration tests. Infiltration tests should be run at the anticipated elevation of the top of the native soil beneath the bioretention area. Test hole or test pit explorations shall be conducted during mid to late in the wet season (December 1 through April 30) to provide accurate groundwater saturation and groundwater information. The soil log shall extend a minimum of 4 feet below feet below the bottom of the subgrade (which is the lowest point of excavation where soil is to be amended). The following provides recommended test procedures for analysis of the soils underlying bioretention areas.

- Projects subject to Minimum Requirement #1 through #5:
  - One small-scale PIT, or other methods outlined in Appendix III-A, shall be performed at each potential bioretention site. Tests at more than one site could reveal the advantages of one location over another.
  - Note that to demonstrate infeasibility of bioretention areas for Minimum Requirement #5, a small-scale PIT or large-scale PIT in accordance with Appendix III-A must be used (i.e., measured infiltration rate of less than 0.3 inches per hour).
  - Confirm that the site has the required 1- or 3-foot minimum clearance to the seasonal high groundwater or other impermeable layer (refer to Setbacks and Site Constraints below).
- Projects subject to Minimum Requirements #1 through #10:
  - For small bioretention cells (bioretention areas receiving water from one or two individual lots or < 0.25 acre of pavement or other impervious surface), a small-scale PIT, or other methods outlined in Appendix III-A, shall be performed at each potential bioretention site. Tests at more than one site could reveal the advantages of one location over another.

- For large bioretention cells (bioretention areas receiving water from several lots or 0.25 acre or more of pavement or other impervious surface), a small-scale PIT, or other methods outlined in Appendix III-A shall be performed every 5,000 square feet. The more test pits/borings used, and the more evidence of consistency in the soils, the less of a safety factor may be used. If soil characteristics across the site are consistent, a geotechnical professional may recommend a reduction in the number of tests.
  - If using the PIT method, multiple small-scale or one large-scale PIT can be used. If using the small-scale test, measurements should be taken at several locations within the area of interest.
- For bioretention swales or long, narrow bioretention areas (i.e., one following the road right-of-way), small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A shall be performed every 200 lineal feet and within each length of road with varying subsurface characteristics, i.e., groundwater elevation, soils type, infiltration rates. However, if the site subsurface characterization, including soil borings across the development site, indicate consistent soil characteristics and depths to seasonal high groundwater conditions, the number of test locations may be reduced to a frequency recommended by a geotechnical professional.
- Note that to demonstrate infeasibility of bioretention areas for Minimum Requirement #5, only the small-scale or large-scale PIT methods may be used (i.e., measured infiltration rate of less than 0.3 inches per hour).
- Confirm that the site has the required 1- or 3-foot minimum clearance to the seasonal high groundwater or other impermeable layer (refer to Setbacks and Site Constraints below).
- If a single bioretention area serves a drainage area exceeding one acre, infiltration receptor analysis and performance testing may be necessary. See Section 2.5.2, Step 5 for specific requirements for infiltration receptor characterization.

Assignment of Appropriate Safety Factor

- If deemed necessary by a qualified professional engineer, a safety factor may be applied to the measured Ksat of the subgrade soils to estimate its design (long-term) infiltration rate. Depending on the size of the facility, the variability of the underlying soils, and the number of infiltration tests performed, a safety factor may be advisable. (Note: This is a separate design issue from the assignment of a safety factor to the overlying, designed bioretention soil mix. See the "Bioretention Soil Mix" subsection below).
- The overlying bioretention soil mix provides excellent protection for the underlying native soil from sedimentation. Accordingly, a safety factor for the

native soil (i.e., $F_{plugging}$ used in Appendix III-A) does not have to take into consideration the extent of influent control and clogging over time.

Prepare Soils Report

For projects subject to Minimum Requirements #1 through #5, a soils report must be prepared by a professional soil scientist certified by the Soil Science Society of America (or an equivalent national program), a locally licensed onsite sewage designer, or by other suitably trained persons working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington. Refer to Volume I, Section 3.2.8 for Abbreviated Plan Soils Report requirements.

For projects subject to Minimum Requirements #1 through #10, a soils report must be prepared that is stamped by a professional engineer with geotechnical expertise, a licensed geologist, a hydrogeologist, or an engineering geologist registered in the State of Washington that summarizes site characteristics and demonstrates that sufficient permeable soil for infiltration exists at the proposed facility location. At a minimum, the report must contain the following:

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

the upper soil structure, including the pathway the discharged stormwater will take.

Estimate Volume of Stormwater

Use the latest version of the Western Washington Hydrology Model (WWHM), or other approved continuous runoff model to generate an influent file that will be used to size the bioretention area. The facility must infiltrate either all of the flow volume as specified by the influent file, or a sufficient amount of the flow volume such that any overflow/bypass meets the flow duration standard in Minimum Requirement #7. In addition, the overflow/bypass must meet the LID performance standard if it is the option chosen to meet Minimum Requirement #5, or if it is required of the project.

3.4.6 Bioretention Design Criteria

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

- Setbacks and site constraints
- Flow entrance / presettling
- Ponding area
- Bottom area and side slopes
- Overflow
- Bioretention soil mix
- Underdrain (if included)
- Check dams and weirs
- Planting
- Mulch layer
- Hydraulic restriction layer.

Setbacks and Site Constraints

For setbacks and site constraints for non-infiltrating bioretention (lined bioretention cells or planter boxes), refer to the setbacks for detention vaults in Section 3.12.3. See Infeasibility Criteria in Section 3.4.3 for setbacks and site constraints used to evaluate the bioretention option of List #1 and List #2 (Minimum Requirement #5). (See also Appendix III-D for a summary of infeasibility criteria for all BMPs.) The following minimum setbacks and site constraints apply to all infiltrating bioretention areas (bioretention without a liner or planter box).

- All bioretention areas shall be a minimum of 1 foot positive vertical clearance from any open water maximum surface elevation to structures within 25 feet.
- All bioretention areas shall be a minimum of 10 feet away from any structure or property line. This setback may be reduced by the City for facilities within or adjacent to the right-of-way.
- All bioretention areas shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on the slope. The soils report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.
- All bioretention areas shall be a minimum of 5 feet from septic tanks and distribution boxes.
- For sites with onsite or adjacent septic systems, the edge of the design water surface must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas. This requirement may be modified by the Tacoma-Pierce County Health Department if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.
- All bioretention areas shall be a minimum of 3 feet from the lowest elevation of the bioretention soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the facility meets or exceeds any of the following thresholds:
    - 5,000 square feet of pollution-generating impervious surface (PGIS)
    - 10,000 square feet of impervious area
    - 0.75 acres of lawn and landscape.
- For bioretention systems with a contributing area less than the above thresholds, a minimum of 1 foot of clearance from seasonal high groundwater or other impermeable layer is acceptable.
- Bioretention is prohibited within 300 feet of an erosion hazard, or landslide hazard area (as defined by Chapter 18.08 GHMC) unless the slope stability impacts of such systems have been analyzed and mitigation proposed by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.
- In no case shall bioretention areas be placed closer than 100 feet from drinking water wells and springs used for drinking water supplies.

- Where water supply wells exist nearby, it is the responsibility of the applicant's engineer to locate such wells, meet any applicable protection standards, and assess possible impacts of the proposed infiltration facility on groundwater quality. If negative impacts on an individual or community water supply are possible, additional runoff treatment must be included in the facility design, or relocation of the facility should be considered.
- Bioretention areas upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Washington State Wellhead Protection Program Guidance Document, DOH, 6/2010. Infiltration systems that qualify as Underground Injection Control Wells must comply with Chapter 173-218 WAC and follow the Washington Department of Ecology's "Guidance for UIC Wells that Manage Stormwater," Publication No. 05-10-067. For additional requirements refer to Volume I, Appendix I-C – Underground Injection Control (UIC) Program Guidelines.
- The soils report must be updated to demonstrate and document that the above criteria are met and to address potential impacts to water supply wells or springs.

- Bioretention constructed with imported composted materials should not be used within one-quarter mile of phosphorus-sensitive waterbodies if the underlying native soil does not meet the soil suitability criteria for treatment in Volume V, Chapter 6. Preliminary monitoring indicates that new bioretention areas can add phosphorus to stormwater. Therefore, they shall also not be used with an underdrain when the underdrain water would be routed to a phosphorus-sensitive receiving water.
- In the event that the downstream pathway of infiltration, interflow, and/or the infiltration capacity is insufficient to handle the contributing area flows (e.g., a facility enclosed in a loop roadway system or a landscape island within a parking lot), an underdrain system can be incorporated into the bioretention area. The underdrain system can then be conveyed to a nearby vegetated channel, another stormwater facility, or dispersed into a natural protection area. See the underdrain section below for additional information.

Flow Entrance/Presettling

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

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

- If concentrated flows are entering the facility, engineered flow dissipation (e.g., rock pad or flow dispersion weir) must be incorporated
- A minimum 2-inch grade change between the edge of a contributing impervious surface and the vegetated flow entrance, or 5 percent slope from the outer curb face extending to a minimum of 12 inches beyond the back of curb, is required.

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

1. Dispersed, low velocity flow across a grass or landscape area – this is the preferred method of delivering flows to the facility and can provide initial settling of particulates. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.
2. Dispersed flow across pavement or gravel and past wheel stops for parking areas.
3. Drainage curb cuts for, driveway, or parking lot areas – curb cuts shall include rock or other erosion protection material in the channel entrance to dissipate energy. See also Attachments Section A Detail 26.1. Drainage curb cuts along roadsides shall include a metal cap on top of the curb per Attachments Section A, Detail 26.3 to prevent vehicle launching.
    - Parking lots that incorporate bioretention into landscaped areas should use concrete curb blocks as wheel stops to protect the bioretention area from traffic intrusion while also allowing the parking lot runoff to flow somewhat unobstructed to the bioretention area.
    - The minimum 12-inch drainage curb cut results in a 12-inch opening measured at the curb flow line and will require a 3-foot cut in an existing curb. An 18-inch curb cut is recommended for most applications. Avoid the use of angular rock or quarry spalls and instead use round (river) rock if needed. Removing sediment from angular rock is difficult. Curb cut flow entrances must have either a minimum of 5 percent slope from the outer curb face extending to a minimum of 12 inches beyond the back of curb, or provide a minimum of a 2-inch vertical drop from the back of curb to the vegetated surface of the facility. Provide an area for settling and periodic removal of sediment and coarse material before flow dissipates to the remainder of the cell.
    - Curb cuts used for bioretention areas in high-use parking lots or roadways require increased level of maintenance due to high coarse particulates and trash accumulation in the flow entrance and associated bypass of flows. The following are methods recommended for areas where heavy trash and coarse particulates are anticipated:
        - Curb cut width: 18 inches.

- At a minimum the flow entrance should drop 2 to 3 inches from gutter line into the bioretention area and provide an area for settling and periodic removal of debris.

- Anticipate relatively more frequent inspection and maintenance for areas with large impervious areas, high traffic loads and larger debris loads.

- Catch basins or forebays may be necessary at the flow entrance to adequately capture debris and sediment load from large contributing areas and high-use areas. Piped flow entrance in this setting can easily clog and catch basins with regular maintenance are necessary to capture coarse and fine debris and sediment.

4. Pipe flow entrance – piped entrances shall include rock or other erosion protection material in the facility entrance to dissipate energy and/or provide flow dispersion.

   - *Catch basin:* In some locations where road sanding or higher than usual sediment inputs are anticipated, catch basins can be used to settle sediment and release water to the bioretention area through a grate for filtering coarse material.

   - *Trench drains:* can be used to cross sidewalks or driveways where a deeper pipe conveyance creates elevation problems. Trench drains tend to clog and may require additional maintenance.

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

Ponding Area

Bioretention ponding area may be an earthen depression (for bioretention cells and swales), or a planter box (for bioretention planters or planter boxes). The ponding area provides surface storage for storm flows, particulate settling, and the first stages of pollutant treatment within the facility. Ponding depth and draw-down rate requirements are to provide surface storage, adequate infiltration capability, and soil moisture conditions that allow for a range of appropriate plant species. Soils must be allowed to dry out periodically in order to 1) restore hydraulic capacity of system, 2) maintain infiltration rates, 3) maintain adequate soil oxygen levels for healthy soil biota and vegetation, 4) provide proper soil conditions for biodegradation and retention of pollutants, and 5) prevent conditions supportive of mosquito breeding.

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

- The ponding depth shall be a maximum of 12 inches

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

For projects subject to Minimum Requirement #5 and choosing to use List #1 or List #2 of that requirement, the bioretention area shall have a horizontally projected surface area below the overflow which is at least 5 percent of the total impervious surface area draining to it. If lawn/landscape area will also be draining to the bioretention area, the horizontally projected surface area below the overflow shall be increased by 2 percent of the lawn/landscape area.

The minimum freeboard measured from the invert of the overflow pipe or earthen channel to facility overtopping elevation shall be 2 inches for drainage areas less than 1,000 square feet and 6 inches for drainage areas 1,000 square feet or greater.

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

Bottom Area and Side Slopes

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

- The maximum planted side slope shall be 3H:1V. If steeper side slopes are necessary rockeries, concrete walls, or soil wraps may be effective design options.
- The bottom width shall be no less than 2 feet.

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

Overflow

An overflow route must be identified for stormwater flows that overtop the bioretention area when infiltration capacity is exceeded or the facility becomes plugged and fails. The overflow route must be able to convey the 100-year recurrence interval developed peak flow to the downstream conveyance system or other acceptable discharge point without posing a health or safety risk or causing property damage.

Overflow designs shall be tailored to site conditions. Options include, but are not limited to: an emergency overflow spillway per Attachments Section A, Detail 7.0 (minimum length of 3 feet), a vertical drain pipe installed at the designed maximum ponding elevation

(12 inches) and connected to a downstream BMP or an approved discharge point, a curb cut at the down-gradient end of the bioretention area to direct overflows back to the street, drainage curb cuts along roadsides shall include a metal cap on top of the curb per Attachments Section A, Detail 26.3 to prevent vehicle launching. See also Attachments Section A Detail 26.2.

Bioretention Soil Mix

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

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

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

- Minimum depth of treatment soil must be 18 inches
- Projects can either use a default bioretention soil mix or can create a custom bioretention soil mix.
  - Projects which use the default bioretention soil mix do not have to test bioretention soil mix infiltration rate. They may assume the rates specified in the next subsection.
  - Projects which create a custom bioretention soil mix rather than using the default requirements must demonstrate compliance with the specific design criteria and must test the bioretention soil mix infiltration rate as described in the “Custom Bioretention Soil Mix” section below.

Default Bioretention Soil Mix

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

- **Mineral Aggregate**:
    - Percent Fines: A range of 2 to 4 percent passing the US #200 sieve is ideal and fines should not be above 5 percent for a proper functioning specification according to ASTM D422.
- **Mineral Aggregate Gradation**:
    - Mineral Aggregate shall be free of wood, waste, coating, or any other deleterious material. The aggregate portion of the Bioretention Soil Mix (BSM) should be well-graded. According to ASTM D 2487-98 (Classification of Soils for Engineering Purposes (Unified Soil Classification System)), well-graded sand should have the following gradation coefficients:
        - Coefficient of Uniformity (Cu = D60/D10) equal to or greater than 4, and
        - Coefficient of Curve (Cc = (D30)2/D60 x D10) greater than or equal to 1 and less than or equal to 3.

Aggregate shall be analyzed by an accredited lab using the US sieve numbers and gradation noted in Table 3.4.

Table 3.4. Aggregate for Bioretention Soil.

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

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

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

- **Compost to aggregate ratio**: 60-65 percent mineral aggregate, 35–40 percent compost.
- **Organic matter content**: 5–8 percent by weight.
- **Cation Exchange Capacity (CEC)** must be > 5 milliequivalents/100 g dry soil. Note: Soil mixes meeting the above specifications do not have to be tested for CEC. They will readily meet the minimum CEC.

Composted Material

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

- Material must meet the definition of “composted material” in WAC 173-350-100 and complies with testing parameters and other standards in WAC 173-350-220.
- Material must be produced at a composting facility that is permitted by a jurisdictional health authority. Permitted compost facilities in Washington are included on a list available on Ecology’s web site.
- The compost product must originate a minimum of 65 percent by volume from recycled plant waste comprised of “yard debris,” “crop residues,” and “bulking agents” as those terms are defined in WAC 173-350-100. A maximum of 35 percent by volume of “postconsumer food waste” as defined in WAC 173-350-100, but not including biosolids, may be substituted for recycled plant waste.
- Moisture content must be such that there is no visible free water or dust produced when handling the material.
- The material shall be tested in accordance with the U.S. Composting Council “Test Method for the Examination of Compost and Composting” (TMECC), as established in the Composting Council’s “Seal of Testing Assurance” (STA) program. Most Washington compost facilities now use these tests.
- Composted material shall meet the size gradations established in the U.S. Composting Council’s Seal of Testing Assurance (STA) program, as follows: Fine Compost shall meet the following gradation by dry weight:

	Min.	**Max.**
Percent passing 2"	100	
Percent passing 1"	99	100
Percent passing 0.625"	90	100
Percent passing 0.25"	75	100

- The pH shall be between 6.0 and 8.5 (TMECC 04.11-A). “Physical contaminants” (as defined in WAC 173-350-100) content shall be less than 1 percent by weight (TMECC 03.08-A) total, not to exceed 0.25 percent film plastic by dry weight.
- Minimum organic matter content shall be 40 percent by dry weight basis as determined by TMECC 05.07A, “Loss-On-Ignition Organic Matter Method.”

- Soluble salt contents shall be less than 4.0 dS/mm (mmhos/cm) tested in accordance with TMECC 04.10-A, “1:5 Slurry Method, Mass Basis.”
- Maturity indicators from a cucumber bioassay shall be greater than 80 percent for both emergence and vigor, in accordance with TMECC 05.05-A, “Germination and Vigor.”
- The material must be stable (low oxygen use and CO2 generation) and mature (capable of supporting plant growth). This is critical to plant success in a bioretention soil mixes. Stability shall be 7 mg CO_2-C/g OM/day or below in accordance with TMECC 05.08-B, “Carbon Dioxide Evolution Rate.”
- Fine Compost shall have a carbon to nitrogen ratio of less than 25:1 as determined using TMECC 05.02A “Carbon to Nitrogen Ratio” which uses TMECC 04.01 “Organic Carbon” and TMECC 04.02D “Total Nitrogen by Oxidation.” The Engineer may specify a C:N ratio up to 35:1 for projects where the plants selected are entirely Puget Sound lowland native species and up to 40:1 for coarse compost to be used as a surface mulch (not in a soil mix).

Compost not conforming to the above requirements or taken from a source other than those tested and accepted shall be immediately removed from the project and replaced.

Acceptable compost product sources include:

- Cedar Grove Composting, Washington
- Other approved equal.

If using the bioretention soil mix recommended herein, a default infiltration rate of 12 inches per hour shall be used. Refer to Determining Design Bioretention Soil Mix Infiltration Rate below.

Custom Bioretention Soil Mixes

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

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

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

Determining Design Bioretention Soil Mix Infiltration Rate

- A long-term infiltration rate correction factor of 4 shall be used for the bioretention soil if the area tributary to the facility meets or exceeds any of the below thresholds (for bioretention areas with a contributing area less than the below thresholds, a long-term infiltration rate correction factor of 2 for the bioretention soil mix is acceptable):
  - 10,000 square feet of impervious area
  - 5,000 square feet of PGIS
  - 0.75 acres of lawn and landscape.

Underdrain (Optional)

Where the underlying native soils have an estimated initial infiltration rate between 0.3 and 0.6 inches per hour, bioretention areas without an underdrain, or with an elevated underdrain directed to a surface outlet, may be used to satisfy List #2 of Minimum Requirement #5. Underdrained bioretention areas that drain to a retention/detention facility must meet the following criteria if they are used to satisfy List #2 of Minimum Requirement #5.

- The invert of the underdrain must be elevated 6 inches above the bottom of the aggregate bedding layer. A larger distance between the underdrain and bottom of the bedding layer is desirable.
- The distance between the bottom of the bioretention soil mix and the crown of the underdrain pipe must be not less than 6 or more than 12 inches.
- The aggregate bedding layer must run the full length and the full width of the bottom of the bioretention area.
- The facility must not be underlain by a low permeability liner that prevents infiltration into the native soil.

Underdrain systems should be installed only if the bioretention area is located where infiltration is not permitted and a liner is used, or where subgrade soils have infiltration rates that do not meet the maximum pool drawdown time. In these cases, underdrain systems can be installed and the facility can be used to filter pollutants and detain flows. However, designs utilizing underdrains provide less infiltration and flow control benefits.

The volume above an underdrain pipe in a bioretention area provides pollutant filtering and some flow attenuation; however, only the void volume of the aggregate below the underdrain invert and above the bottom of the bioretention area (subgrade) can be used in the latest version of WWHM for dead storage volume that provides flow control benefit. Assume a 40 percent void volume for the filter material aggregate specified below.

Elevating the underdrain to create a temporary saturated zone beneath the drain is advised to promote denitrification (conversion of nitrate to nitrogen gas) and prolong moist soil conditions for plant survival during dry periods.

The minimum requirements associated with the underdrain design include:

- Slotted, thick-walled plastic pipe must be used:
    - Minimum pipe diameter: 4 inches (pipe diameter will depend on hydraulic capacity required, 4 to 8 inches is common).
    - Slotted subsurface drain PVC per ASTM D1785 SCH 40.
    - Slots should be cut perpendicular to the long axis of the pipe and be 0.04 to 0.069 inches by 1 inch long and be spaced 0.25 inches apart (spaced longitudinally). Slots should be arranged in four rows spaced on 45-degree centers and cover one-half of the circumference of the pipe. See Filter Materials section for aggregate gradation appropriate for this slot size.
- Underdrain pipe slope must be no less than 0.5 percent
- Pipe must be placed in filter material and have a minimum cover depth of 4 inches
- Filter material shall meet the requirements of WSDOT Standard Specifications 9-03.12(4) (gravel backfill for drains)
- A 6-inch non-perforated cleanout must be connected to the underdrain every 300 feet minimum.
    - The underdrain can be connected to a downstream BMP such as another bioretention/rain garden area as part of a connected system, or to an approved discharge point. A geotextile fabric (specifications in Volume V, Appendix V-A) must be used between the soil layer and underdrain.

Check Dams and Weirs

- For sloped bioretention areas, check dams are necessary to provide ponding, reduce flow velocities and reduce the potential for erosion. Typical check dam materials include concrete, wood, rock, compacted dense soil covered with vegetation, and vegetated hedge rows. Design depends on flow control goals, local regulations for structures within road right-of-ways and aesthetics. Optimum spacing is determined by performance (modeling) and cost considerations. See the *Low Impact Development Technical Guidance Manual for Puget Sound* for typical designs.

Planting

The design intent for bioretention plantings is to replicate, to the extent possible, the hydrologic function of a mature forest including succession plants and groundcover. Plant roots aid in the physical and chemical bonding of soil particles that is necessary to form stable aggregates, improve soil structure, and increase infiltration capacity.

The minimum requirements associated with the vegetation design include the following:

- The design plans must specify that vegetation coverage of selected plants will achieve 90 percent coverage within 2 years or additional plantings will be provided until this coverage requirement is met
- For facilities receiving runoff from 5,000 square feet or more impervious surface, plant spacing and plant size must be designed to achieve specified coverage by a certified landscape architect
- The plants must be sited according to sun, soil, wind, and moisture requirements
- At a minimum, provisions must be made for supplemental irrigation during the first two growing seasons following installation.

Refer to the LID Technical Guidance Manual for Puget Sound for guidance on plant selection and recommendations for increasing survival rates.

Mulch Layer

Bioretention areas should be designed with a mulch layer or a dense groundcover. Properly selected mulch material also reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to soil. Mulch should be:

- Compost in the bottom of the facilities (compost is less likely to float than wood chip mulch and is a better source for organic materials).
- Wood chip mulch composed of shredded or chipped hardwood or softwood on cell slopes above ponding elevation and rim area. Arborist mulch is mostly woody trimmings from trees and shrubs and is a good source of mulch material.

Wood chip operations are a good source for mulch material that has more control of size distribution and consistency. Do not use shredded construction wood debris or any shredded wood to which preservatives have been added.

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

Mulch shall not include weed seeds, soil, roots and other material that are not from the above ground components of a tree, grass clippings (decomposing grass clippings are a source of nitrogen and are not recommended for mulch in bioretention areas), pure bark (bark is essentially sterile and inhibits plant establishment).

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

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

Hydraulic Restriction Layer

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

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

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

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

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

Signage

The City of Gig Harbor requires that bioretention installations used to meet Minimum #6 and/or #7 include informational signage upon completion of the installation to help identify the vegetated area as a stormwater BMP and to inform maintenance crews and the general public about protecting the facility's function. Signage is recommended for bioretention installations used to meet Minimum Requirement #5 but is not required.

3.4.7 Bioretention Construction Criteria

See Volume II, Section 3.3 for infiltration facility construction requirements. Minimum requirements associated with bioretention area construction include the following:

- Bioretention areas that infiltrate into the underlying soil (i.e., do not include a liner) rely on water movement through the surface soils as infiltration and interflow to underlying soils. Therefore, it is important to always consider the pathway of interflow and assure that the pathway is maintained in an unobstructed and uncompacted state. This is true during the construction phase as well as postconstruction.
- During construction, it is critical to prevent clogging and over-compaction of the subgrade and bioretention soils. Specific construction criteria for bioretention areas are provided below.
- Place bioretention soil per the requirements of bioretention soil mix requirements specified in this section.

Verification of Performance

The project engineer or designee shall inspect bioretention areas before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place. Prior to placement of the Bioretention Soil Mix, the project engineer shall verify that the finished subgrade is scarified and meets the designed infiltration rate. Before release of the financial guarantee, the project engineer shall perform a minimum of two performance tests after construction to determine that the facility will operate as designed. The type of test will depend on specific facility and site constraints, and therefore shall be determined by the project engineer on a case-by-case basis and must be approved by the City prior to testing. The City must be notified of the scheduled infiltration testing at least two working days in advance of the test. See Appendix III-A for testing requirements. If the tests indicate the facility will not function as designed, this information must be brought to the immediate attention of the city along with any reasons as to why not and how it can be remedied.

3.4.8 Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements.

3.5 Permeable Paving (Ecology BMP T5.15)

3.5.1 Description

Stormwater runoff from vehicular pavement can contain significant levels of solids, heavy metals, and hydrocarbon pollutants. Both pedestrian and vehicular pavements also contribute to increased peak flow durations and associated physical habitat degradation of streams and wetlands. Permeable pavement is designed to accommodate pedestrian, bicycle, and auto traffic while allowing infiltration and storage of stormwater.

Permeable pavement includes porous asphalt; pervious concrete; permeable pavers, aggregate pavers, and grid systems permeable paver systems.

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

- **Sidewalk infiltration galleries** are equivalent to pervious Portland Cement concrete sidewalk or permeable concrete pavers.

3.5.2 Applications and Limitations

- Permeable pavement is an onsite stormwater management BMP option for 1) projects that only have to comply with Minimum Requirements #1 through #5, and 2) projects that trigger Minimum Requirements #1 through #10.
- Permeable pavement can also achieve compliance with the Performance Standard option or can be applied from List #1 or List #2 option of Minimum Requirement #5.
- Permeable pavement can meet water quality treatment requirements of Minimum Requirement #6 when the underlying soil meets the treatment soil requirements outlined in Volume V, Section 6.3, or a water quality treatment course is included.
- Permeable pavement can meet the flow control duration standard of Minimum Requirement #7. The flow control performance is typically a function of the infiltration rate of the underlying subgrade soil and the depth of the aggregate storage reservoir that stores stormwater until it is infiltrated.
- Appropriate applications for permeable pavement include parking lots, low volume roads, alleys, access drives, pedestrian and bike trails, and patios. The application of permeable pavement on roads shall be limited to those roadways that receive very low-traffic volumes (i.e., ADT less than or equal to 400).
- For public and private roadway projects, permeable pavement installations must consist of pervious concrete only. This requirement does not apply to shared accesses, driveways, sidewalks, and off-street parking. See Attachments Section A, Detail 27.0 for pervious concrete roadway sections.
- Permeable pavement works well in concert with other onsite stormwater management BMPs such as permeable pavement parking stalls adjacent to bioretention areas, and permeable roadway surfaces bordered by vegetated swales.
- Because permeable pavement can clog with sediment, permeable pavement is not recommended under the following conditions:
    - Excessive sediment contamination is likely on the pavement surface (e.g., construction areas, landscaping material yards)
    - It is infeasible to prevent stormwater runon to the permeable pavement from unstabilized erodible areas without pre-settling

  - Sites where the risk of concentrated pollutant spills are more likely (e.g., gas stations, truck stops, car washes, vehicle maintenance areas, industrial chemical storage sites).

- To reduce the potential of clogging, runoff generated from unstabilized pervious surfaces may not be directed onto a permeable pavement surface. Absolutely no point discharges may be directed onto permeable pavement. If runoff comes from minor or incidental pervious areas (including lawns), those areas must be fully stabilized.

- ADA compliance should be requested from the manufacturer and is a consideration in determining where to use permeable pavement.

3.5.3 Infeasibility Criteria

These are conditions that make permeable pavement not required for consideration in the List #1 or List #2 option of Minimum Requirement #5. If a project proponent wishes to use permeable pavement - though not required to because of these feasibility criteria - they may propose a functional design to the local government. These criteria also apply to impervious pavements that would employ stormwater collection from the surface of impervious pavement with redistribution below the pavement. In addition, other permeable pavement design criteria and site limitations that make permeable pavement infeasible (e.g., setback requirements) may also be used to demonstrate infeasibility, subject to approval by the city. See also Appendix III-D for a summary of infeasibility criteria for all BMPs.

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

- Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or downgradient flooding

- In accordance with Chapter 18.08 GHMC limitations may exist and reports may be required when permeable pavement is within 300 feet of a landslide hazard area or within 200 feet of an erosion hazard area

- Where infiltrating and ponded water below new permeable pavement area would compromise adjacent impervious pavements

- Where infiltrating water below a new permeable pavement area would threaten existing below grade basements

- Where infiltrating water would threaten shoreline structures such as bulkheads

- Down slope of steep, erosion prone areas that are likely to deliver sediment

- Where fill soils are used that can become unstable when saturated

- Excessively steep slopes where water within the aggregate base layer or at the subgrade surface cannot be controlled by check dams and may cause erosion and structural failure, or where surface runoff velocities may preclude adequate infiltration at the pavement surface
- Where permeable pavements cannot provide sufficient strength to support heavy loads at industrial facilities such as ports
- Where installation of permeable pavement would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, or pre-existing road subgrades.

The following criteria can be cited as reasons for infeasibility without further justification (though some require professional services to make the observation):

- Within setbacks provided in Section 3.5.6.
- For properties with known soil or groundwater contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
  - Within 100 feet of an area known to have deep soil contamination
  - Where groundwater modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the groundwater
  - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area
  - Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW.
- Within 100 feet of a closed or active landfill.
- Within 10 feet of any underground storage tank and connecting underground pipes, regardless of tank size. As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10 percent or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.
- At multi-level parking garages, and over culverts and bridges.
- Where the site design cannot avoid putting pavement in areas likely to have long-term excessive sediment deposition after construction (e.g., construction and landscaping material yards).
- Where the site cannot reasonably be designed to have a porous asphalt surface at less than 5 percent slope, or a pervious concrete surface at less than 10

percent slope, or a permeable interlocking concrete pavement surface (where appropriate) at less than 12 percent slope. Grid systems upper slope limit can range from 6 to 12 percent; check with manufacturer and local supplier.

- Where the subgrade soils below a pollution-generating permeable pavement (e.g., road or parking lot) do not meet the soil suitability criteria for providing treatment. See soil suitability criteria for treatment in Volume V, Chapter 6. Note: In these instances, the city may approve installation of a 6-inch sand filter layer meeting city specifications for treatment as a condition of construction.

- Where underlying soils are unsuitable for supporting traffic loads when saturated. Soils meeting a California Bearing Ratio of 5 percent are considered suitable for residential access roads.

- Where appropriate field testing indicates soils have a measured (a.k.a., initial) subgrade soil saturated hydraulic conductivity less than 0.3 inches per hour. A small-scale PIT or large-scale PIT accordance with Appendix III-A shall be used to demonstrate infeasibility of permeable pavement areas. (Note: In these instances, unless other infeasibility restrictions apply, roads and parking lots may be built with an underdrain, preferably elevated within the base course, if flow control benefits are desired.)

- Roads that receive more than very low traffic volumes, and areas having more than very low truck traffic. Roads with a projected average daily traffic volume of 400 vehicles or less are very low volume roads (currently adopted AASHTO manual)(U.S. Dept. of Transportation, 2013). Areas with very low truck traffic volumes are roads and other areas not subject to through truck traffic but may receive up to weekly use by utility trucks (e.g., garbage, recycling), daily school bus use, and multiple daily use by pick-up trucks, mail/parcel delivery trucks, and maintenance vehicles. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces associated with the collector or arterial.

- Where replacing existing impervious surfaces unless the existing surface is a non-pollution generating surface over an outwash soil with a saturated hydraulic conductivity of 4 inches per hour or greater.

- At sites defined as “high-use sites.” For more information on high-use sites, refer to the Glossary in Volume I; and Volume V, Section 2.1, Step 3.

- In areas with “industrial activity” as defined in the Glossary (located in Volume I).

- Where the risk of concentrated pollutant spills is more likely, e.g., gas stations, truck stops, and industrial chemical storage sites.

- Where routine, heavy applications of sand occur in frequent snow zones to maintain traction during weeks of snow and ice accumulation.

3.5.4 Modeling and Sizing

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

For permeable pavements designed to meet Minimum Requirements #5, #6, #7 or #8, the permeable pavement must be sized using an approved continuous simulation model.

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

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

- For grades less than 2 percent, no adjustment to the below ground volumes are necessary.
- For grades greater than 2 percent without internal dams within the base materials, the below ground storage volume must be adjusted as follows:
  - Permeable pavement surfaces that are below the surrounding grade and that are on a slope can be modeled as permeable pavement with an infiltration rate and a nominal depth.
  - The dimensions of the permeable pavement are: the length (parallel to and beneath the road) of the base materials that are below grade; the width of the below grade base materials; and an Effective Total Depth of 1 inch. If the continuous runoff model requires the permeable pavement to have an overflow riser to model overflows that occur should the available storage get exceeded, enter 0.04 ft (1/2 inch) for the "Riser Height" and a large Riser Diameter (say 1000 inches) to ensure that there is no head build up.
  - If a drainage pipe is embedded and elevated in the below grade base materials, the pipe should only have perforations on the lower half (below the spring line) or near the invert. Pipe volume and trench volume above the pipe invert cannot be assumed as available storage space. If a drainage pipe is placed at the bottom of the base material, the pavement is modeled as an impervious surface without any gravel trench.
- For roads on a slope with internal dams within the base materials that are below grade, the below ground storage volume must be adjusted as follows:
  - Each stretch of permeable pavement (cell) that is separated by barriers can be modeled separately. For each cell, determine the average depth of water within the cell at which the barrier at the lower end will be overtopped.
  - Specify the dimensions of each cell of the below-grade base materials using the permeable pavement dimension fields for: the "Pavement Length" (length of

the cell parallel to the road); the "Pavement Bottom Width"(width of the bottom of the base material); and the Effective Total Depth. In WWHM2012, the field entitled "Effective Volume Factor" is used by the program to calculate the effective storage volume within the below-grade base materials for roads on a slope. The Effective Volume Factor is the ratio of the average maximum water depth behind a check dam (typically at the middle of the pavement length) to the below-grade base materials depth.

- Each cell should have its own tributary drainage area within the permeable pavement element that includes the road above it, any project site areas whose runoff drains onto and through the road (lateral flow soil or impervious basin), and any offsite areas. Represent each drainage area with a permeable pavement icon and a lateral flow basin icon (if runon occurs).

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

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

3.5.5 Field and Design Procedures

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

Refer to Appendix III-A for detailed descriptions of methods for infiltration rate testing procedures; however, note that the subgrade safety factors in Appendix III-A may not apply to permeable pavement. Perform infiltration testing in the soil profile at the estimated bottom elevation of base materials for the permeable pavement. If no base materials (e.g., a pervious concrete sidewalk), perform the testing at the estimated bottom elevation of the pavement. All test hole or test pit explorations outlined below shall be conducted during mid to late in the wet season (December 1 through April 30) to provide accurate groundwater saturation and groundwater information.

Determining Initial Subgrade Infiltration Rates

- **Projects subject to Minimum Requirements #1 - #5**:

- A small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A, shall be performed for every 5,000 square feet of permeable pavement, but not less than one test per site.
- Note that to demonstrate infeasibility for Minimum Requirement #5, only the small-scale or large-scale PIT methods may be used (i.e., measured infiltration rate of less than 0.3 inches per hour).
- Confirm that the site has the required 1 foot minimum clearance to the seasonal high groundwater or other impermeable layer (refer to Setbacks and Site Constraints below).

- **Projects subject to Minimum Requirements #1 - #10**:
  - On commercial property: a small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A, shall be performed for every 5,000 square feet of permeable pavement, but not less than one test per site.
  - On residential developments: a small-scale Pilot Infiltration Test (PIT), or other methods outlined in Appendix III-A, shall be performed at every proposed lot, at least every 200 feet of roadway and within each length of road with significant differences in subsurface characteristics. However, if the site subsurface characterization - including soil borings across the development site - indicate consistent soil characteristics and depths to seasonal high groundwater conditions, the number of test locations may be reduced to a frequency recommended by a geotechnical professional.

    Note that to demonstrate infeasibility for Minimum Requirement #5, only the small-scale or large-scale PIT methods may be used (i.e., measured infiltration rate of less than 0.3 inches per hour).
  - Confirm that the site has the required 1 foot minimum clearance to the seasonal high groundwater or other impermeable layer (refer to Setbacks and Site Constraints below).

Assignment of Appropriate Safety/Correction Factors

- If deemed necessary by a qualified professional engineer, a safety factor may be applied to the measured K_{sat} of the subgrade soils to estimate its design (long-term) infiltration rate. Depending on the size of the facility, the variability of the underlying soils, and the number of infiltration tests performed, a safety factor may be advisable.
- A safety factor for the subgrade (i.e., $F_{plugging}$ used in Appendix III-A) does not have to take into consideration the extent of influent control and clogging over time, unless deemed necessary by a professional engineer.
- The quality of pavement aggregate base material may be compromised if the aggregate base is not clean washed material, and has more than 1 percent fines

passing the US #200 sieve. In these cases, a correction factor ($F_{aggregate}$) may be necessary. $F_{aggregate}$ ranges from 0.9 (not clean or washed aggregate, greater than 1 percent fines passing the US #200 sieve) to 1 (aggregate base meets specifications).

Soil Suitability Criteria Confirmation

- Where permeable pavements are used for pollution-generating hard surfaces (primarily roads, shared accesses, driveways, and parking lots), there must be a determination whether the soil suitability criteria of Volume V, Section 6.3 are met. This requirement does not apply to projects that trigger only Minimum Requirement #1 through #5.
- Sites not meeting these criteria are considered infeasible for permeable pavements for pollution-generating hard surfaces, unless a treatment layer is provided.
- The information to make this determination may be obtained from various sources: historic site information, estimated qualities of a general soil type, laboratory analysis of field samples.

Prepare Soils Report

For projects subject to Minimum Requirements #1 through #5, a soils report must be prepared by a professional soil scientist certified by the Soil Science Society of America (or an equivalent national program), a locally licensed onsite sewage designer, or by other suitably trained persons working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington. Refer to Volume I, Section 3.2.8 for Abbreviated Plan Soils Report requirements.

For projects subject to Minimum Requirements #1 through #10, a soils report must be prepared that is stamped by a professional engineer with geotechnical expertise, a licensed geologist, a hydrogeologist, or an engineering geologist registered in the State of Washington that summarizes site characteristics and demonstrates that sufficient permeable soil for infiltration exists at the proposed facility location. At a minimum, the report must contain the following:

- Figure showing the following:
  - Topography within 500 feet of the proposed facility.
  - Locations of any water supply wells within 500 feet of the proposed facility.
  - Location of groundwater protection areas, aquifer recharge areas, or 1-, 5-, and 10-year times of travel zones for wellhead protection areas.
  - Locations of test pits or test holes. A minimum of one soil log or test pit is required at each site.

- Results of soils tests including but not limited to: detailed soil logs, visual grain size analysis, grain-size distribution (required if using the grain size analysis method to estimate infiltration rates), percent clay content (include type of clay, if known), color/ mottling, variations and nature of stratification, description of local site geology, including soil or rock units likely to be encountered at soil sampling depths and the seasonal high groundwater elevation
- Detailed documentation of the design infiltration rate determination, as specified above
- State whether location is suitable for infiltration and recommend a design infiltration rate.

Estimate Volume of Stormwater

Use the latest version of the Western Washington Hydrology Model (WWHM), or other approved continuous runoff model to generate an influent file that will be used to size the permeable pavement facility. The facility must infiltrate either all of the flow volume as specified by the influent file, or a sufficient amount of the flow volume such that any overflow/bypass meets the flow duration standard in Minimum Requirement #7. In addition, the overflow/bypass must meet the LID performance standard if it is the option chosen to meet Minimum Requirement #5, or if it is required of the project.

3.5.6 Paving Surface Design Criteria

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

- Setbacks and site constraints
- Permeable wearing course
- Drainage conveyance
- Leveling course
- Aggregate storage reservoir
- Lateral subsurface impermeable barriers
- Nonwoven geotextile (optional)
- Subgrade
- Water quality treatment layer
- Signage.

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

Setbacks and Site Constraints

See Infeasibility Criteria in Section 3.5.3 for setbacks and site constraints used to evaluate the permeable pavement option of List #1 and List #2 (Minimum Requirement #5). (See also Appendix III-D for a summary of infeasibility criteria for all BMPs.) The following minimum setbacks and site constraints apply to all permeable pavement areas.

- The base of the lowest gravel course or treatment layer shall be a minimum of 1 foot positive vertical clearance structures within 25 feet.
- All permeable pavement surfaces shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on the slope. The geotechnical assessment may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.
- For sites with onsite or adjacent septic systems, the discharge point must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas. This requirement may be modified by the Tacoma-Pierce County Health Department if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.
- Permeable pavement shall not be located where seasonal high groundwater or an underlying impermeable/low permeable layer would create saturated conditions within 1 foot of the bottom of the lowest gravel base course.
- In no case shall permeable pavement surfaces be placed closer than 100 feet from a public water source.
    - Where water supply wells exist nearby, it is the responsibility of the applicant’s engineer to locate such wells, meet any applicable protection standards, and assess possible impacts of the proposed infiltration facility on groundwater quality. If negative impacts on an individual or community water supply are possible, additional runoff treatment must be included in the facility design, or relocation of the facility should be considered.

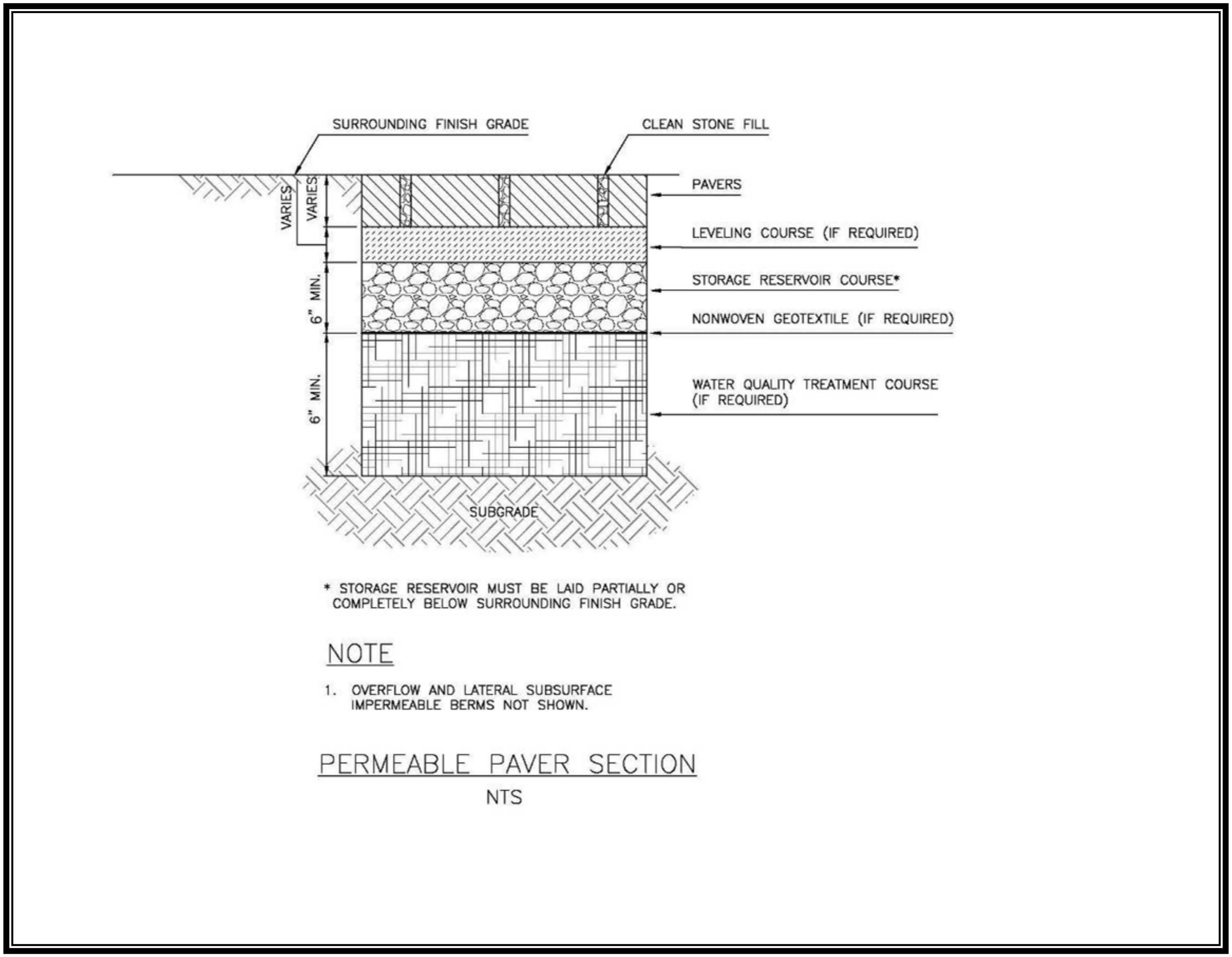


Figure 3.7. Permeable Paver Section

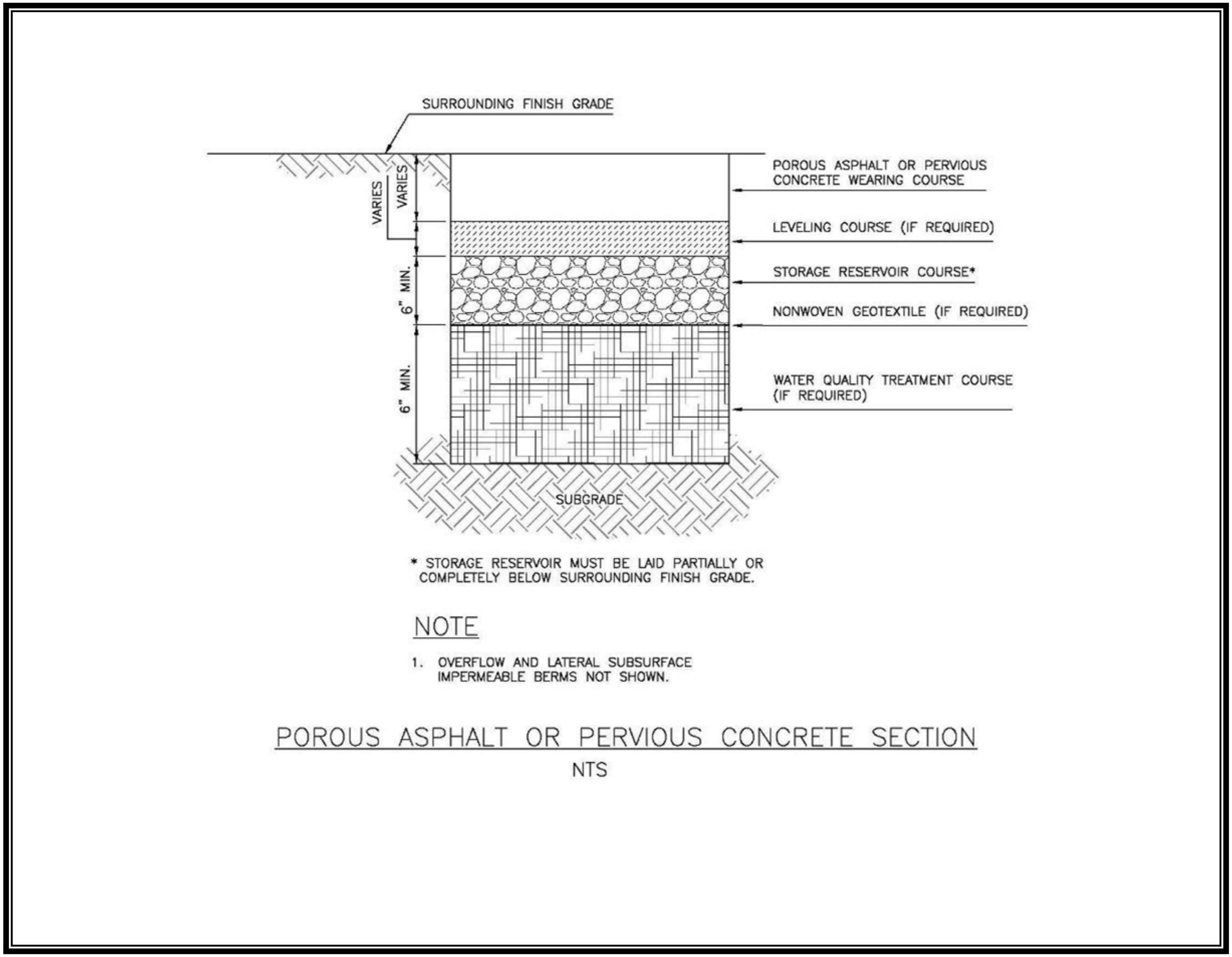


Figure 3.8. Porous Asphalt or Pervious Concrete Section.

  - Permeable pavement surfaces upgradient of drinking water supplies and within 1-, 5-, and 10-year time of travel zones must comply with Washington State Wellhead Protection Program Guidance Document, DOH, 6/2010. Infiltration systems that qualify as Underground Injection Control Wells must comply with Chapter 173-218 WAC and follow the Washington Department of Ecology's "Guidance for UIC Wells that Manage Stormwater," Publication No. 05-10-067.
  - The soils report must be updated to demonstrate and document that the above criteria are met and to address potential impacts to water supply wells or springs.
- Permeable pavement surfaces are prohibited within 300 feet of an erosion hazard, or landslide hazard area (as defined by Chapter 18.08 GHMC) unless the slope stability impacts of such systems have been analyzed and mitigation proposed by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.

Permeable Wearing Course

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

- Recommended maximum wearing course slopes for permeable paving surfaces are 5 percent (porous asphalt), 10 percent (pervious concrete), 12 percent (interlocking pavers), and 12 percent (grid and lattice systems) (check with manufacturer or local supplier).
- Manufacturer's recommendations on design, installation, and maintenance shall be followed for each application.
- For all surface types, a minimum initial infiltration rate of 20 inches per hour is required. To improve the probability of long-term performance, significantly higher initial infiltration rates are desirable. For measuring initial surface infiltration rates for porous asphalt, pervious concrete, or permeable interlocking concrete pavers, ASTM C1701 shall be used. For grid systems, refer to manufacturers testing recommendations.
  - *Porous Asphalt:* Products must have adequate void spaces through which water can infiltrate and must meet performance grade (PG) 70-22. See the LID Technical Guidance Manual for the Puget Sound Basin for additional specifications.
  - *Pervious Concrete:* Products must have adequate void spaces through which water can infiltrate and must meet the most current version of American Concrete Institute (ACI) 522. See the LID Technical Guidance Manual for the Puget Sound Basin for additional specifications.

  - *Grid/lattice systems filled with gravel, sand, or a soil of finer particles with or without grass:* The fill material must be at least a minimum of 2 inches of sand, gravel, or soil. Fill media for grid systems with grass vary per manufacturer from coarse sand to topsoil. Consult manufacturer to confirm that the fill media will provide adequate infiltration capacity and, at that rate, support healthy plant growth.

  - *Permeable Interlocking Concrete Pavement and Aggregate Pavers*: See the LID Technical Guidance Manual for the Puget Sound Basin for specifications and installation procedures published by the Interlocking Concrete Pavement Institute.

- Permeable pavement systems that utilize pavers need to be confined with a rigid edge system to prevent gradual movement of the paving stones.

- Both gravel and soil with vegetation can be used to fill the openings in paver and rigid grid systems and manufacturer recommendations should be followed to apply the appropriate material for each application.

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

Drainage Conveyance

Flow Entrance/Presettling Requirements

- Runon to permeable pavement must be dispersed as sheet flow or delivered subsurface to the storage reservoir. If subsurface delivery is used, primary settling is required (e.g., via catch basin, hooded outlet, sump) followed by distribution to storage reservoir (e.g., via perforated drain pipe).

- Runon from up-gradient adjacent impervious paved surfaces is not recommended, but permissible if the permeable pavement area is twice the area of the impervious area and the length of sheet flow from the impervious paved surface is no greater than half the length across the permeable pavement section.

Overflow Requirements

- In small area applications, the subgrade can be built up with permeable base material and graded to direct runoff through this material to an eventual discharge location, such as bioretention areas. In larger areas, an elevated underdrain system should be installed to collect and convey runoff to bioretention areas or open space. In this manner, stormwater is stored and metered out slowly, similar to the way the existing topsoil on a site captures and slowly releases runoff. (See also the Aggregate Storage Reservoir section below for additional details on underdrains.)

- An overflow route must be identified for stormwater flows that overtop the permeable pavement surface when infiltration capacity is exceeded or the facility becomes plugged and fails. The overflow route must be able to convey the 100-year recurrence interval developed peak flow to the downstream conveyance system or other acceptable discharge point without posing a health or safety risk or causing property damage.
- Overflow must be designed to convey excess flow to an approved point of discharge. Options include:
  - Subsurface slotted drain pipe(s) set at the design ponding elevation to route flow to a conveyance system
  - Lateral flow through the storage reservoir to a daylighted conveyance system.

Leveling Course

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

Leveling course material and thickness shall be included as required per manufacturer recommendations. Leveling course material must be compatible with underlying aggregate storage reservoir material.

Aggregate Storage Reservoir

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

- A 6-inch minimum depth of aggregate storage reservoir is recommended under the permeable wearing course and leveling course (if any) for water storage. The City may allow a reduced depth on a case-by-case basis.
- Aggregate storage reservoir should consist of larger rock at the bottom and smaller rock directly under the top surface (e.g., a gradient from 2 to five-eighths inch).

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

Lateral Subsurface Impermeable Barriers

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

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

Minimum requirements associated with lateral impermeable barriers include the following:

- Lateral impermeable barriers must be installed at regular intervals perpendicular to the subgrade slope to provide the average subsurface ponding depth in the aggregate storage reservoir required to meet the desired performance standard

- The barriers must not extend to the elevation of the surrounding ground

- Each barrier must have an overflow, as described below, or allow overtopping to the next downslope aggregate storage reservoir section without causing flows to express from the pavement surface or out the sides of the base materials that are above grade.

Nonwoven Geotextile (Optional)

Generally, geotextiles and geogrids are applied:

- To prevent fines from migrating to more open-graded material and the associated structural instability.

- For soil types with poor structural stability to prevent downward movement of the aggregate base into the subgrade.

- If a sand layer is utilized, geotextile is required between the aggregate storage reservoir and the sand layer. Geotextile is also required between the native soil and the sand layer.

Geotextiles between the permeable pavement subgrade and aggregate base are not required or necessary for many soil types and, if incorrectly applied, can clog and reduce infiltration capability at the subgrade or other material interface. Therefore, the use of geotextiles is discouraged unless it is deemed necessary. As part of the pavement section design, the designer should review the existing subgrade or subbase characteristics and determine if a nonwoven geotextile is needed for separation of subbase from underlying soils.

Subgrade

- Compact the subgrade to the minimum necessary for structural stability. Two guidelines currently used to specify subgrade compaction are “firm and unyielding” (qualitative), and 90 to 92 percent Standard Proctor (quantitative).
- If the permeable pavement is being designed to provide water quality treatment, underlying soils must meet the requirements for treatment soil provided in Volume V, Chapter 6.

Water Quality Treatment Layer

If the permeable pavement is being designed to provide water quality treatment, underlying soils must meet the requirements for treatment soil provided in Volume V, Chapter 6. If the existing subgrade does not meet these requirements, a 6-inch water quality treatment course may be included between the subbase and the aggregate storage reservoir. The course must be comprised of the sand material specification for sand filters in the Ecology Manual.

Signage

The City of Gig Harbor requires that permeable pavement installations used to meet Minimum Requirement #6 and/or #7 include informational signage upon completion of the installation to help identify the area as a stormwater BMP and to inform maintenance crews and the general public about protecting the facility’s function. Signage is recommended for permeable pavement installations used to meet Minimum Requirement #5 but is not required.

3.5.7 Construction Criteria

Minimum requirements associated with permeable pavement construction include the following:

- Proper installation is one of the key components to ensure the success of permeable pavement. As with any pavement system, permeable pavement requires careful preparation of the subgrade and aggregate storage reservoir to ensure success in terms of strength and permeability. The compressive strength of a permeable paver system relies in large part on the strength of the underlying soils, particularly in the case of modular or plastic units where the pavement itself lacks rigidity. Design and installation of permeable pavement shall be according to manufacturer recommendations.

- Field infiltration and compaction testing of the optional water quality treatment course shall be conducted prior to placement of overlying courses.
- To prevent compaction when installing the aggregate storage reservoir, the following steps (back-dumping) should be followed:
  - The aggregate storage reservoir is dumped onto the subgrade from the edge of the installation and the aggregate is then pushed out onto the subgrade
  - Trucks then dump subsequent loads from on top of the aggregate storage reservoir as the installation progresses.
- The various aggregate storage reservoir materials shall be prevented from intermixing with fines and sediment. All contaminated material must be removed and replaced.
- Field infiltration test of the permeable surface shall be conducted after complete pavement section is installed (see Verification of Performance below).
- If possible, temporary roads should be used during construction and final construction of the aggregate storage reservoir material and permeable surfacing completed after building construction is complete. This construction method is similar to the installation of leveling courses of asphalt in a subdivision prior to building individual lots and installation of the final wearing course upon completion of building construction.

Refer to Volume II, Section 3.3 LID BMP Protection During Construction for construction considerations specific to LID BMPs.

Verification of Performance

The project engineer or designee shall inspect permeable pavement areas before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place. Prior to placing the aggregate storage reservoir, the project engineer shall verify that the finished subgrade is scarified and meets the designed infiltration rate. The project engineer shall verify that the aggregate storage reservoir has been adequately installed and protected (e.g., from compaction and sedimentation) per the design specifications, prior to paving. Prior to accepting the installation of the permeable pavement and also before release of the financial guarantee, the project engineer shall perform a sufficient number of ASTM C1701 tests (a minimum of two) after construction to determine that the facility will operate as designed and to verify that it meets the minimum initial uncorrected infiltration rate of 20 inches per hour (see Wearing Course section). The City must be notified of the scheduled infiltration testing at least two working days in advance of the test. See Appendix III-A for testing requirements. If the tests indicate the facility will not function as designed, this information must be brought to the immediate attention of the city along with any reasons as to why not and how it can be remedied.

3.5.8 Operations and Maintenance Criteria

- See Minimum Requirement #9 in Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.
- Where runon flows onto permeable pavement, these areas shall be identified in the Maintenance and Source Control Manual as requiring more frequent cleaning and inspection to ensure that the overall facility is performing.
- Clogging is the primary mechanism that degrades infiltration rates. However, as discussed above, the surface design can have a significant influence on clogging of void space.
- Studies have indicated that infiltration rates on moderately degraded porous asphalts and pervious concrete can be partially restored by suctioning and sweeping of the surface. Highly degraded porous asphalts and concrete require high pressure washing with suction.
- Maintenance frequencies of suctioning and sweeping shall be specified in the Maintenance and Source Control Manual, or as specified in Volume I, Appendix I-A, whichever is more stringent.
- Permeable pavement systems designed with pavers have advantages of ease of disassembly when repairs or utility work is necessary. However, it is important to note that the paver removal area should be no greater than the area that can be replaced at the end of the day. If an area of pavers is removed, leaving remaining edges unconfined, it is likely that loading in nearby areas will create movement of the remaining pavers thereby unraveling significantly more area than intended.

3.6 Infiltration Trenches (Ecology BMP T7.20)

3.6.1 Description

Infiltration trenches are generally at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the stormwater in a stone trench. Note that an infiltration trench with a perforated pipe is considered an Underground Injection Control (UIC) well and is required to be registered with Ecology, unless the infiltration trench is located at a single-family home (or duplex) and only receives residential roof runoff or is used to control basement flooding (per WAC 173-218-070 (1)(e). See also Section 2.6 and Volume I, Appendix I-C – Underground Injection Control (UIC) Program Guidelines for more information on UIC well registration.

See Attachments Section A, Details 2.0, 3.0, 4.0, and 23.0 for examples of infiltration trench facilities in various configurations and site settings. Included in the details are infiltration trenches with a grass buffer, as well as an example of a parking lot perimeter infiltration trench design. For trenches associated specifically with roof downspout infiltration, see Section 3.9.3.

3.6.2 Applications and Limitations

- Infiltration trenches can be used to meet the flow control standards of Minimum Requirement #7.
- When used in combination with other onsite stormwater management BMPs, they can also help achieve compliance with the Performance Standard option of Minimum Requirement #5.
- Infiltration trenches can be used to meet some of the water quality treatment requirements of Minimum Requirement #6 if the underlying soil meets the requirements provided in Volume V, Section 6.3.

3.6.3 Modeling and Sizing

See Section 2.5.3 for guidance on modeling and sizing of infiltration facilities.

3.6.4 Infiltration Trench Design Criteria

Refer to Section 2.5 for general procedures and design criteria applicable to infiltration trenches. This section provides additional design criteria specific to infiltration trenches:

- Due to accessibility and maintenance limitations, infiltration trenches must be carefully designed and constructed.
- Provide a structure or cleanout at each end of the infiltration trench for accessibility to conduct inspections and maintenance.
- Minimum spacing between distribution pipe centerlines must be 6 feet.
- Maximum spacing between distribution pipe centerlines must be 10 feet.
- Backfill material – The aggregate material for the infiltration trench must consist of a clean aggregate and meet WSDOT Specification 9-03.12(5) that nominally ranges from 0.75-inch to 1.5-inch diameter. A maximum diameter

of 3 inches and a minimum diameter of 1.5 inches may be approved if void space is maintained. Void space for these aggregates must be in the range of 30 to 40 percent.

- Geotextile fabric liner – Completely encase the aggregate fill material in an engineering geotextile material. Geotextile must surround all of the aggregate fill material except for the top 1 foot, which is placed over the geotextile. Carefully select geotextile fabric with acceptable properties to avoid plugging (see Volume V, Appendix V-A).
- A 6-inch minimum layer of sand may be used as a filter media at the bottom of the trench instead of geotextile.
- The bottom sand or geotextile fabric as shown in Attachments Section A, Details 2.0, 3.0, 4.0, and 23.0 is optional.

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

- **Overflow channel** – Because an infiltration trench is generally used for small drainage areas, an emergency spillway is not necessary. However, provide a non-erosive overflow channel leading to a stabilized watercourse.
- **Surface cover** – A stone filled trench can be placed under a porous or impervious surface cover to conserve space.
- **Observation well** – Install an observation well at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. See Attachments Section A, Detail 15.0 for an example observation well detail. It should consist of a perforated PVC pipe which is 4 to 6 inches in diameter and it should be 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 the sediment. The top of the well should be equipped with a secure well cap to discourage vandalism and tampering.

3.6.5 Construction Criteria for Trenches

Most of the construction requirements for small scale infiltration facilities included in Volume II, Section 3.3 apply to all infiltration facilities. Additional specific construction criteria for infiltration trenches are provided below. Criteria for residential roof downspout trenches are located in Section 3.9.

- *Trench preparation* – Excavated materials must be placed away from the trench sides to enhance trench wall stability. Take care to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic (see Erosion and Sediment Control Criteria in Volume II, BMP C123- Plastic Covering).

- *Stone aggregate placement and compaction* – Place the stone aggregate in lifts and compact using plate compactors. In general, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.

- *Potential contamination* – Prevent natural or fill soils from intermixing with the stone aggregate. Remove all contaminated stone aggregate and replace with uncontaminated stone aggregate.

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

- *Voids behind geotextile* – Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Place natural soils in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. This remedial process will avoid soil piping, geotextile clogging, and possible surface subsidence.

- *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. Trench boxes or trapezoidal, rather than rectangular, cross-sections may be needed.

3.6.6 Operations and Maintenance Criteria for Trenches

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

3.7 Infiltration Basins (Ecology BMP T7.10)

3.7.1 Description

Infiltration basins are earthen impoundments used for the collection, temporary storage and infiltration of stormwater runoff. (See schematic in Attachments Section A, Detail 5.0.)

3.7.2 Applications and Limitations

Infiltration basins can be used to meet the flow control standards of Minimum Requirement #7. They can also meet some of the water quality treatment requirements of Minimum Requirement #6 if the underlying soil meets the requirements provided in Volume V, Section 6.3.

3.7.3 Infiltration Basin Design Criteria

Refer to Section 2.5 for general procedures and design criteria applicable to infiltration basins. This section provides additional design criteria specific to infiltration basins:

- Access must be provided for vehicles to easily maintain the forebay (presettling basin) area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.
- The slope of the basin bottom shall not exceed 3 percent in any direction.
- A minimum of 1 foot of freeboard is required when establishing the design ponded water depth. Freeboard is measured from the rim of the infiltration facility to the maximum ponding level or from the rim down to the overflow point if overflow or a spillway is included.
- Vegetation – The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas shall be stabilized and planted, preferably with grass, in accordance with stormwater site plan (see Volume I, Minimum Requirement #1). Without healthy vegetation the surface soil pores would quickly plug. Treatment infiltration basins must have sufficient vegetation established on the basin floor and side slopes to prevent erosion and sloughing and to provide additional pollutant removal. Select suitable vegetative materials for the basin floor and side slopes. Refer to detention pond guidance in Section 3.12.1 for recommended vegetation. Use the seed mixtures recommended in Table 3.8.

3.7.4 Construction Criteria

Most of the construction requirements for small scale infiltration facilities included in Volume II, Section 3.3 apply to all infiltration facilities. Specific construction criteria for infiltration basins are provided below.

- Initial basin excavation must be conducted to within 2 feet of the final elevation of the basin floor. Excavate infiltration trenches and basins to final grade only after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation must remove all accumulation of silt in the infiltration facility before putting it in service.
- Generally, it is preferable to avoid using infiltration facilities as temporary sediment traps during construction. If an infiltration basin is to be used as a

sediment trap, do not excavate to final grade until after stabilizing the upgradient drainage area. Remove any accumulation of silt in the basin before putting it in service.

3.7.5 Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements. Additional maintenance considerations for infiltration basins are provided below.

- Maintain basin floor and side slopes to promote dense turf with extensive root growth. This enhances infiltration, prevents erosion and consequent sedimentation of the basin floor, and prevents invasive weed growth.
- Apply fertilizers only as necessary and in limited amounts to avoid contributing to groundwater pollution. Consult the local agricultural or gardening resources such as Washington State University Extension for appropriate fertilizer type, including slow release fertilizers, and application rates.

3.8 Rain Gardens (Ecology BMP T5.14A)

3.8.1 Description

Rain gardens are shallow stormwater systems with compost amended soil or imported bioretention soil and plants adapted to the local climate and soil moisture conditions. Like bioretention, rain gardens are designed to mimic a forested condition by controlling stormwater through detention, infiltration, and evapotranspiration. Rain gardens also provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation.

Rain gardens function by storing stormwater as surface ponding before it filters through the underlying amended soil. Stormwater that exceeds the surface storage capacity overflows to an adjacent drainage system. Treated water is infiltrated into the underlying soil.

The terms bioretention and rain garden are sometimes used interchangeably. However, in the City of Gig Harbor (in accordance with the Washington State Department of Ecology's distinction), the term bioretention is used to describe an engineered facility that includes designed soil mixes and perhaps underdrains and control structures. The term, rain garden, is used to describe a landscape feature that serves to capture stormwater on small project sites that only trigger Minimum Requirements #1-#5.

Rain gardens are similar to bioretention areas (refer to Section 3.4) with the following exceptions:

- Rain gardens may only be used to meet onsite stormwater management requirements (List #1) and must not be used on projects that trigger water quality treatment or flow control requirements (i.e., they are only applicable for projects that only trigger MR #1 through MR #5)

- Rain gardens may not have a liner or underdrain
- The maximum ponding depth is 6 inches
- A certified landscape architect is not required for vegetation design

Rain gardens must not receive runoff from a public roadway

3.8.2 Applications and Limitations

Bioretention areas and rain gardens are applications of the same LID concept and can be highly effective for reducing surface runoff and removing pollutants.

Rain gardens are an onsite stormwater management BMP option for projects that have to comply with Minimum Requirements #1 through #5, but not Minimum Requirements #1 through #10.

- Rain gardens may be utilized as an on-lot stormwater system, even in areas where underlying soils may not be conducive to rapid infiltration (such as underlying glacial till), but where the area does have a surface soil cover that allows the migration of stormwater through the upper soil horizon as interflow.
- Underdrains may not be used for rain gardens. For sites with poorly draining soils (e.g., 0.3 to 0.6 inches per hour), applicants are encouraged to contact an engineer for other recommended options (e.g., designing a bioretention area for the site).
- Rain gardens should be used to receive rooftop runoff in areas where infiltration facilities are not feasible and in preference to dispersing runoff, and may be integrated into the landscaped areas of the lot.
- Rain gardens shall not accept runoff from a public roadway.

3.8.3 Infeasibility Criteria

Infeasibility criteria describe conditions that make rain gardens not required for consideration in the List #1 option of Minimum Requirement #5. Infeasibility criteria for rain gardens are the same as for bioretention. See bioretention area infeasibility criteria in Section 3.4.3. In addition, other rain garden design criteria and site limitations that make rain gardens infeasible (e.g., setback requirements) may also be used to demonstrate infeasibility, subject to approval by the city. See also Appendix III-D for a summary of infeasibility criteria for all BMPs.

3.8.4 Modeling and Sizing

Sizing of a **rain garden** (lot-scale facility, contributing area less than twice the area for which it is sized to a maximum of 5,000 square feet of impervious surface) can be done by relating the square footage of the surface area of the rain garden to the size of the area contributing runoff. For design on projects subject to Minimum Requirement #5, and choosing to use List #1 of that requirement, rain gardens shall have a horizontally projected surface area below the overflow which is at least 5 percent of the total impervious surface area draining to it. If lawn/landscape area will also be draining to the rain garden, the rain garden's horizontally projected surface area below the overflow shall be increased by 2 percent of the lawn/landscape area.

It is recommended that the rain garden bottom not be oversized because the vegetation in oversized rain gardens may not receive sufficient stormwater runoff for irrigation, increasing O&M requirements. Stormwater flows from other areas (beyond the area for which the rain garden is sized) should be bypassed around the rain garden in order to reduce sediment loading and the potential for clogging. While it is preferred that rain gardens be sized to manage only the area draining to it, excess flows may be routed through a rain garden designed for the onsite stormwater management standard with the following limitations:

- The maximum impervious drainage area that may be routed to a rain garden must not exceed twice the area for which it is sized to a maximum of 5,000 square feet. Additional runoff contributions from pervious areas are acceptable. No onsite stormwater management credit is given for runoff from areas beyond the design area.
- Additional runoff routed to a rain garden must be clearly noted on submitted plans.

3.8.5 Field and Design Procedures

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

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

Determining Design Infiltration Rate

Infiltration rates are determined through soil infiltration tests. Infiltration tests should be run at the anticipated elevation of the top of the native soil beneath the rain garden area. A small-scale PIT, or other methods outlined in Appendix III-A, shall be performed at each potential rain garden site. Test hole or test pit explorations shall be conducted during mid to late in the wet season (December 1 through April 30) to provide accurate groundwater saturation and groundwater information. Note that to demonstrate infeasibility for Minimum Requirement #5, only the small scale PIT may be used (i.e., measured infiltration rate of less than 0.3 inches per hour). Also determine whether the site has at least 1 foot minimum clearance to the seasonal high groundwater or other impermeable layer. Note that when using the field testing procedures outlined in Appendix III-A, a safety factor is not required for rain gardens.

Prepare Soils Report

A soils report must be prepared by a professional soil scientist certified by the Soil Science Society of America (or an equivalent national program), a locally licensed onsite sewage designer, or by other suitably trained persons working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington. Refer to Volume I, Section 3.2.8 for Abbreviated Plan Soils Report Requirements.

3.8.6 Rain Garden Design Criteria

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

Setbacks and Site Constraints

Setbacks and site constraints for rain gardens are the same as those for infiltrating bioretention areas (see Section 3.4.6).

Flow Entrance

Flow entrances should be sized to capture flow from the catchment area and designed to both reduce the potential for clogging at the inlet and prevent inflow from causing erosion in the rain garden. See the Rain Garden Handbook for Western Washington, page 29 for additional details and information.

Cell Ponding Area

Cell ponding area design criteria for rain gardens are the same as those specified in the Rain Garden Handbook for Western Washington, except for the following:

- The ponding depth for rain gardens shall be a maximum of 6 inches.
- The minimum freeboard measured from the invert of the overflow pipe or earthen channel to facility overtopping elevation shall be 6 inches.
- If berming is used to achieve the minimum top elevation needed to meet ponding depth and freeboard needs, the maximum slope on berm shall be 3H:1V, and the minimum top width of design berm shall be 1 foot. Soil used

for berming shall be imported bioretention soil, rain garden soil, or amended native soil.

Bottom Area and Side Slopes

Rain gardens are highly adaptable and can fit various rural and urban settings by adjusting bottom area and side slope configuration. Recommended maximum and minimum dimensions include:

- The planted side slope shall be no steeper than 3H:1V. If steeper side slopes are necessary rockeries, concrete walls or soil wraps may be effective design options
- The bottom width shall be no less than 2 feet.

Overflow

An overflow route must be identified for stormwater flows that overtop the rain garden area when infiltration capacity is exceeded or the facility becomes plugged and fails. The overflow route must flow to the downstream conveyance system or other acceptable discharge point without posing a health or safety risk or causing property damage.

Rain garden overflow can be provided by a drain pipe installed at the designed maximum ponding elevation and connected to a downstream BMP or an approved discharge point.

See the Rain Garden Handbook for Western Washington for additional details and information.

Rain Garden Soil Mix

See the Rain Garden Handbook for Western Washington for soil mix information. For amending the native soil within the rain garden, the city recommends use of compost that meets the compost specification for bioretention (see Section 3.4.6). Compost that includes biosolids or manure shall not be used.

Planting

Refer to the Rain Garden Handbook for Western Washington for guidance on plant selection and recommendations for increasing survival rates. The minimum requirements associated with the vegetation design include the following:

- The design plans must specify that vegetation coverage of selected plants will achieve 90 percent coverage within 2 years or additional plantings will be provided until this coverage requirement is met.
- Plant spacing and plant size must be designed to achieve specified coverage.
- The plants must be sited according to sun, soil, wind, and moisture requirements.

- At a minimum, provisions must be made for supplemental irrigation during the first two growing seasons following installation.

Signage

The City of Gig Harbor recommends that rain garden installations include informational signage upon completion of the installation to help identify the area as a stormwater BMP and to inform the general public about protecting the facility’s function.

Mulch Layer

Refer to the Rain Garden Handbook for Western Washington for mulch layer requirements. Properly selected mulch material also reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to soil. Mulch should consist of compost in the bottom of the facilities (compost is less likely to float than wood chip mulch and is a better source for organic materials).

3.8.7 Rain Garden Construction Criteria

During construction, it is critical to prevent clogging and over-compaction of the native soil, bioretention soils, rain garden soils, or amended soils. Additionally, excavation, soil placement, or soil amendment must not be allowed during wet or saturated conditions.

See Volume II, Section 3.3, and Section 3.4.7 of this volume for additional infiltration facility and bioretention area construction requirements that also apply to rain gardens.

Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements.

3.9 Roof Downspout Controls

Description

Roof downspout controls include smaller, dispersed stormwater systems designed to infiltrate and/or disperse runoff from roof areas. Large lots in rural areas typically have enough area to infiltrate or disperse roof runoff. Lots created in urban areas will typically be smaller and have a limited amount of area in which to incorporate infiltration or dispersion trenches.

This section presents an overview of the types and applications of roof downspout controls. Additional details on specific BMPs are provided in subsequent sections.

3.9.1 Selection of Roof Downspout Controls

The feasibility or applicability of downspout infiltration and dispersion must be evaluated for all subdivision single-family lots. Single family subdivision projects subject to Minimum Requirement #5 or #7 (Volume I, Chapter 2) must provide for individual downspout infiltration, bioretention, rain garden, dispersion systems, or perforated stub-out connection systems where practicable.

3.9.2 Applications to Minimum Requirements

The feasibility and applicability of roof downspout controls must be evaluated for all projects subject to Minimum Requirement #5 (see Volume I, Chapter 2). Projects must provide for individual downspout infiltration, bioretention, rain garden, dispersion systems, or perforated stub-out connection systems where practicable. Where roof downspout controls are required or planned, the following three types must be considered in order of preference, per Minimum Requirement #5 (Note some of the following BMPs are discussed in other sections):

- Full Dispersion (see Volume VI, Section 2.3)
- Downspout infiltration systems (Section 3.9.3)
- Bioretention cells, swales and planter boxes (Section 3.4) or rain gardens (Section 3.8)
- Downspout dispersion systems (Section 3.9.4).
- Perforated stub-out connections (Section 3.9.5).

Other innovative downspout control BMPs such as rain barrels, ornamental ponds, downspout cisterns, or other downspout water storage devices may also be used with prior approval by the City. Any alternative methods proposed will be required to meet the performance criteria of all applicable minimum requirements, particularly Minimum Requirements #5 or #7.

Downspout disconnection, dispersion, or perforated stub-outs will not be allowed in situations where the action could cause erosion or flooding problems, either on site or on adjacent lots. The design engineer must demonstrate that the proposed release rate will not have an adverse downstream impact. The City will review each proposal on a case-by-case basis due to the uniqueness of each site condition.

The following sections outline design information specific to roof downspout infiltration (Section 3.9.3), roof downspout dispersion (Section 3.9.4), and perforated stub-out connections (Section 3.9.5).

3.9.3 Downspout Infiltration Systems (Ecology BMP T5.10A)

Description

Downspout infiltration systems are trench or drywell designs intended only for use in infiltrating runoff from roof downspout drains. They are not designed to directly infiltrate runoff from pollutant-generating impervious surfaces. See Volume V, Chapter 6 for infiltration treatment requirements.

Applications and Limitations

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

Modeling and Sizing

- If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the project area used for sizing stormwater facilities.
- Pierce County has developed standardized tables that can be used in the City of Gig Harbor to facilitate sizing of infiltration trenches and drywells for smaller site applications. See Table 3.5 at the end of this section.
- All sites have the option to do their own engineered design in lieu of using Table 3.5 at the end of this section (in accordance with the design requirements presented below), subject to approval by the city.

Procedure for Evaluating Feasibility

Downspout infiltration is considered feasible on lots or sites that meet all the following:

- Site-specific tests must indicate that soils are not silty clay loam, clay loam, clay, or any other soil having a percolation rate slower than 1 inch per hour.
- Site-specific tests must indicate 12 inches or more of permeable soil from the proposed bottom (final grade) of the infiltration system to the seasonal high groundwater table or other impermeable layer. (Refer to the soil investigation requirements below.)
- The downspout infiltration system can be designed to meet the minimum design criteria specified below.

A soils report must be prepared by one of the following professionals to determine if soils suitable for infiltration are present on the site:

- A professional soil scientist certified by the Soil Science Society of America (or an equivalent national program)
- A licensed onsite sewage designer
- A suitably trained person working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington.

Refer to Volume I, Section 3.2.8 for general Soils Report content requirements. In addition, for downspout infiltration the soils investigation and report must evaluate the following:

1. Individual lot or site tests must consist of at least one soils log at the location of the infiltration system, a minimum of 4 feet in depth (from proposed grade), identifying the Natural Resources Conservations Service (NRCS – formerly the SCS) series of the soil and the USDA textural class of the soil horizon through the depth of the log, and noting any evidence of high groundwater level, such as mottling

2. Document that soils in the location of the proposed infiltration system are not silty clay loam, clay loam, clay, or any other soil having a percolation rate slower than 1 inch per hour.

3. For sites that use the sizing tables presented in Table 3.5 at the end of this section, no further soils infiltration testing is required

For sites that do not use the sizing tables presented in Table 3.5, the site infiltration rates must be determined using the procedures outlined in Appendix III-A.

Downspout Infiltration System Design Criteria

The following standardized design criteria are intended to guide the applicant in providing an acceptable design for an individual downspout infiltration system. The standardized design criteria can only be used under the following conditions:

- The proposed site development does not result in a net increase in impervious surfaces of 5,000 square feet or more.

- The project has prepared a soils report as outlined above.

- The system is sized according to the sizing chart shown in Table 3.5 at the end of this section and the general guidelines below for trench or drywell designs.

- For sites with onsite or adjacent septic systems, the discharge point must be at least 30 feet upgradient, or 10 feet downgradient, of the drainfield primary and reserve areas. This requirement may be modified by the Tacoma-Pierce County Health Department if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

- Systems shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on the slope. The geotechnical assessment may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

- All systems shall be a minimum of 10 feet away from any structure or property line.

Downspout Infiltration Trench System Design Criteria

The trench system is to be constructed according to the standard design shown in Attachments Section A, Detail 11.1.

Any deviation in design or construction from the items above or the standardized design criteria detailed below will result in it being required that the individual downspout infiltration be designed by a professional engineer in accordance with the guidelines presented in this volume.

Table 3.5 outlines an approved prescriptive design for downspout infiltration trenches that meet City of Gig Harbor flow control requirements. The tables present trench footprint areas based on various depths, contributing areas, and infiltration rates. All trenches must be constructed according to the standard design shown in Attachments Section A, Detail 11.1. Note that for roof areas that fall between the areas represented by each column in the table, the required trench footprint area may be interpolated based on the information in the tables. However, for infiltration rates that fall between the rates represented in each table, the designer must use the more conservative (i.e., lower) infiltration rate in their design. As noted previously, all sites have the option to do their own engineered design for infiltration trenches in lieu of using Table 3.5 at the end of this section, subject to approval by the City. In addition to the sizing requirements outlined in Table 3.5, the following design requirements apply to downspout infiltration trenches:

- Maximum length of trench must not exceed 100 feet from the inlet sump.
- Minimum spacing between distribution pipe centerlines must be 6 feet.
- Maximum spacing between distribution pipe centerlines must be 10 feet.
- The aggregate material for the infiltration trench shall consist of 0.75-inch to 1.5 inch diameter washed round rock that meets WSDOT Specification 9-03.12(5).
- Geotextile filter fabric shall be wrapped entirely around trench drain rock prior to backfilling EXCEPT that a 6-inch layer of sand below the trench bottom may be used in-lieu of a geotextile filter fabric liner on the bottom.
- Infiltration trenches may be placed in fill material if the fill is placed and compacted under the direct supervision of a geotechnical engineer or professional civil engineer with geotechnical expertise, and if the measured infiltration rate is at least 8 inches per hour. Infiltration rates can be tested using the methods described in Appendix III-A.
- Provide a structure or cleanout at each end of the infiltration trench for accessibility to conduct inspections and maintenance.

- A structure with a sump (see Attachments Section A, Details 11.0 and 11.1) shall be located upstream of the trench, which provides a minimum of 12 inches of depth below the outlet riser. The outlet riser pipe bottom shall be designed so as to be submerged at all times, and a screening material shall be installed on the pipe outlet.

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

Downspout Infiltration Drywell System Design Criteria

- The drywell system is to be constructed according to the standard design shown in Attachments Section A, Detail 14.0.
- The drywell shall include a settling chamber (as shown in Detail 11.1), or its equivalent for particulate removal. If non-roof runoff is also draining to the drywell system, the contributing flows must also pass through a catch basin structure with a sump (see examples in Attachments Section A, Details 11.1 and 11.0).
- Typically drywells are 48 inches in diameter (minimum) and have a depth of 5 feet (4 feet of gravel and 1 foot of suitable cover material).
- Filter fabric (geotextile) must be placed on top of the drain rock and on trench or drywell sides prior to backfilling.
- Spacing between drywells must be a minimum of 4 feet measured from edge of gravel backfill.

Construction Criteria

See Volume II, Section 3.3 for infiltration facility construction requirements.

Verification of Performance

The project engineer or designee shall inspect infiltration systems before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place. If the project designee or City inspection indicate the facility will not function as designed, the City may require verification of performance testing as required for infiltration trenches in Section 2.5.2, as well as design modifications if needed.

Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements.

Table 3.5. Sizing Table for Downspout Infiltration Trenches.

Square Feet of Trench Bottom for Gravel/Type A Soils (30 in/ hour)

Total Depth Below Ground Surface [1] (ft)	Roof Area (square feet)									
	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	4,999
2.5	15	29	44	59	74	88	103	118	132	147
3.0	13	26	39	52	65	78	91	104	117	130
3.5	12	24	37	49	61	73	85	97	110	122
4.0	11	23	34	45	57	68	79	91	102	113
4.5	11	22	33	44	55	66	76	87	98	109
5.0	11	21	32	42	53	63	74	84	95	105
5.5	10	20	30	40	50	60	71	81	91	101

Square Feet of Trench Bottom for Medium Sand/Type A Soils (12 in/hour)

Total Depth Below Ground Surface [1] (ft)	Roof Area (square feet)									
	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	4,999
2.5	23	45	68	91	113	136	159	181	204	227
3.0	21	42	63	84	105	126	147	168	189	210
3.5	20	39	59	79	99	118	138	158	178	197
4.0	18	37	55	74	92	111	129	148	166	185
4.5	17	34	50	67	84	101	118	134	151	168
5.0	16	33	49	66	82	98	115	131	147	164
5.5	16	31	47	62	78	93	109	124	140	155

Square Feet of Trench Bottom for Loamy Sand/Type A Soils (4 in/hour)

Total Depth Below Ground Surface [1] (ft)	Roof Area (square feet)									
	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	4,999
2.5	43	87	130	173	216	260	303	346	389	433
3.0	40	80	120	160	200	239	279	319	359	399
3.5	37	74	111	148	185	222	259	296	333	370
4.0	34	69	103	138	172	207	241	276	310	344
4.5	33	66	98	131	164	197	229	262	295	328
5.0	31	62	93	124	155	187	218	249	280	311
5.5	29	59	88	118	147	176	206	235	265	294

Table 3.5 (continued). Sizing Table for Downspout Infiltration Trenches.

Square Feet of Trench Bottom for Loam/Type B Soils (2 in/hour)

Total Depth Below Ground Surface [1] (ft)	Roof Area (square feet)									
	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	4,999
2.5	65	130	195	260	326	391	456	521	586	651
3.0	60	121	181	242	302	363	423	484	544	605
3.5	56	113	169	225	281	338	394	450	507	563
4.0	53	106	159	212	265	318	371	423	476	529
4.5	50	101	151	202	252	302	353	403	454	504
5.0	48	96	144	192	239	287	335	383	431	479
5.5	45	91	136	181	227	272	318	363	408	454

Square Feet of Trench Bottom for Porous Silt Loam/Type C Soils (1 in/hour)

Total Depth Below Ground Surface [1] (ft)	Roof Area (square feet)									
	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	4,999
2.5	100	199	299	398	498	597	697	796	896	995
3.0	92	183	275	366	458	549	641	733	824	916
3.5	86	172	258	344	431	517	603	689	775	861
4.0	81	161	242	323	403	484	565	645	726	806
4.5	77	154	231	308	384	461	538	615	692	769
5.0	73	146	219	292	365	439	512	585	658	731
5.5	67	134	202	269	336	403	470	538	605	672

[1] The “total depth below ground surface” is the depth of the trench bottom. The trench consists of gravel covered by 6 inches of compacted backfill. Hence, the gravel thickness is 6 inches less than the depth listed

3.9.4 Downspout Dispersion Systems (Ecology BMP T5.10B)

Description

Downspout dispersion systems are gravel-filled trenches or splashblocks, which serve to spread roof runoff over vegetated areas. Dispersion attenuates peak flows by slowing runoff entering into the conveyance system, allowing some infiltration, and providing some water quality benefits.

Applications and Limitations

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

  - Note that for projects that are underlain by Spanaway soils[2], downspout dispersion systems designed per the requirements of this section may be considered as part of Option #2 in List #1 and List #2 for managing runoff from roof areas.

- The layout of the natural resource protection areas adjacent to and downgradient of individual lots can provide opportunities to disperse runoff into the natural resource protection area. However, when installed over Spanaway soils, the downspout dispersion BMP must have a slope of 10 percent or less.

Modeling and Sizing

If roof runoff is dispersed according to the requirements of this section on lots greater than 22,000 square feet, and over a vegetative flow path that is 50 feet or longer (for splashblocks) through undisturbed native landscape or lawn/landscape area that meets the soils criteria outlined in Section 3.1, the roof area may be modeled as grass/lawn surface. If the available vegetated flow path is 25 to 50 feet, use of a dispersion trench allows modeling the roof as 50 percent impervious/50 percent landscape.

Downspout Dispersion Design Criteria

General Downspout Dispersion Design Criteria

Refer to Section 3.2.1 for general dispersion design criteria. This section provides design criteria for both dispersion trenches and splashblocks:

- Each downspout dispersion trench shall have a separate flow path
- For the purpose of maintaining adequate separation of flows discharged from adjacent dispersion trenches, vegetated flow paths shall be at least 20 feet apart at the upslope end and must not overlap with other flow paths at any point along the flow path lengths
- See additional applicable dispersion area setbacks in Section 3.2.1.

Dispersion Trench Design Criteria

This section provides additional design criteria specific to dispersion trenches.

- Dispersion trenches shall be designed as shown in Figures 3.9a and 3.9b, and Attachments Section A, Detail 1.0.

2 As defined by the Soils Survey of Pierce County Area (1979), and field verified and tested that percolation rates are greater than 30 in/hr by a professional soil scientist certified by the Soil Science Society of America (or an equivalent national program); a locally licensed onsite sewage designer; or by other suitably trained persons working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington.

- A vegetated flow path of at least 25 feet in length must be maintained between the outlet of a trench and any property line; structure; critical area (i.e., stream, wetland), or impervious surface.
- Trenches serving up to 700 square feet of roof area may be simple 10-foot long by 2-foot wide gravel filled trenches as shown in Figures 3.9a and 3.9b. For roof areas larger than 700 square feet, a dispersion trench with notched grade board as shown in Attachments Section A, Detail 1.0 shall be used. It is acceptable to have multiple downspouts routed to a dispersion trench. The total length of this design must not exceed 50 feet and must provide at least 10 feet of trench per 700 square feet of roof area. In both systems it is important to include a cleanout structure prior to discharge into the dispersal area. Although Figure 3.9a and Attachments Section A, Detail 1.0 refer at times to a Type 1 catch basin being used, it is also acceptable to utilize an equivalent type structure which includes a lid, 1-foot minimum sump, and T-type outlet with screen as shown in Attachments Section A, Detail 11. 1.

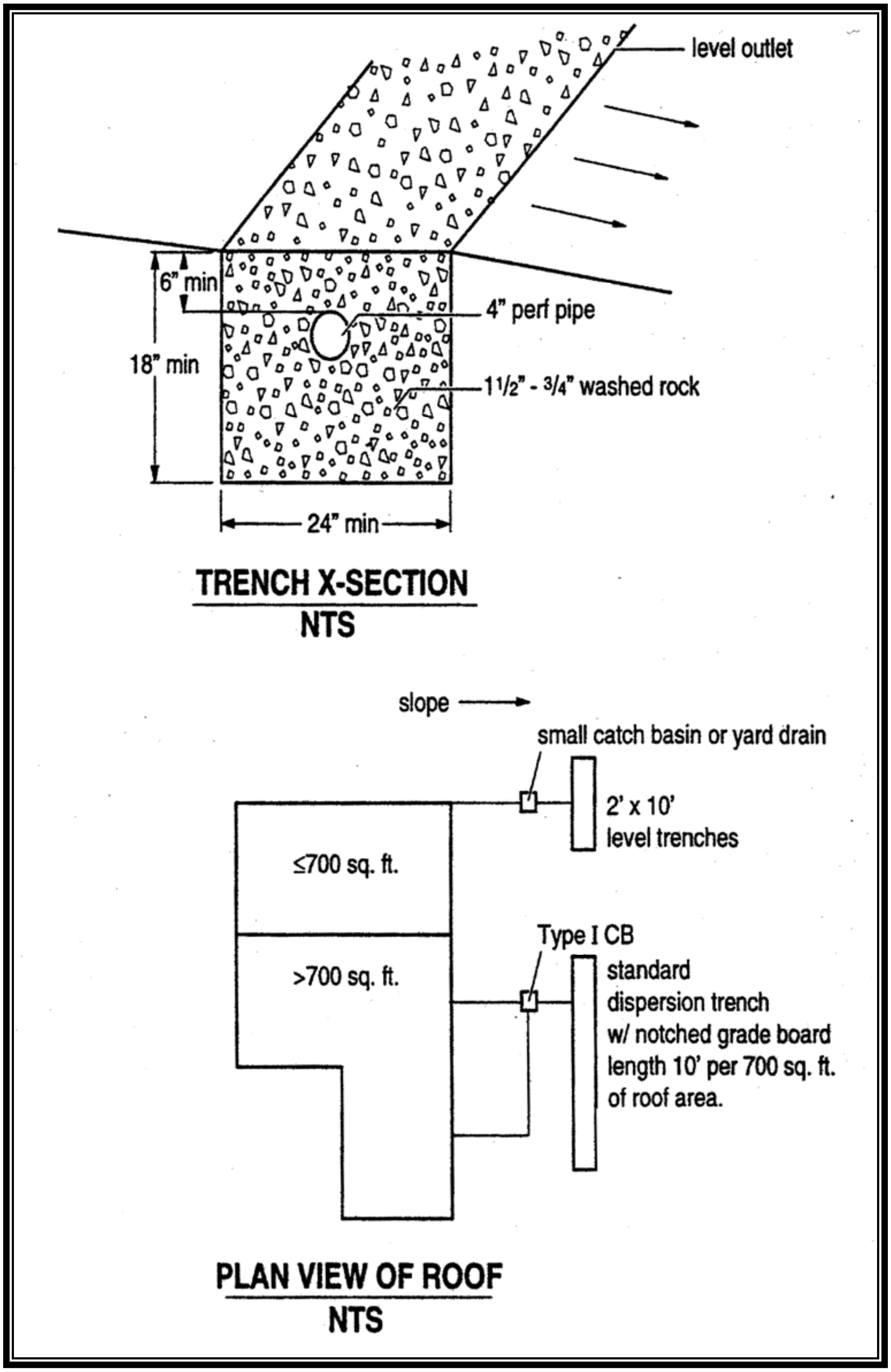


Figure 3.9a. Typical Downspout Dispersion Trench.

See Attachment
Section A, Detail 1.0

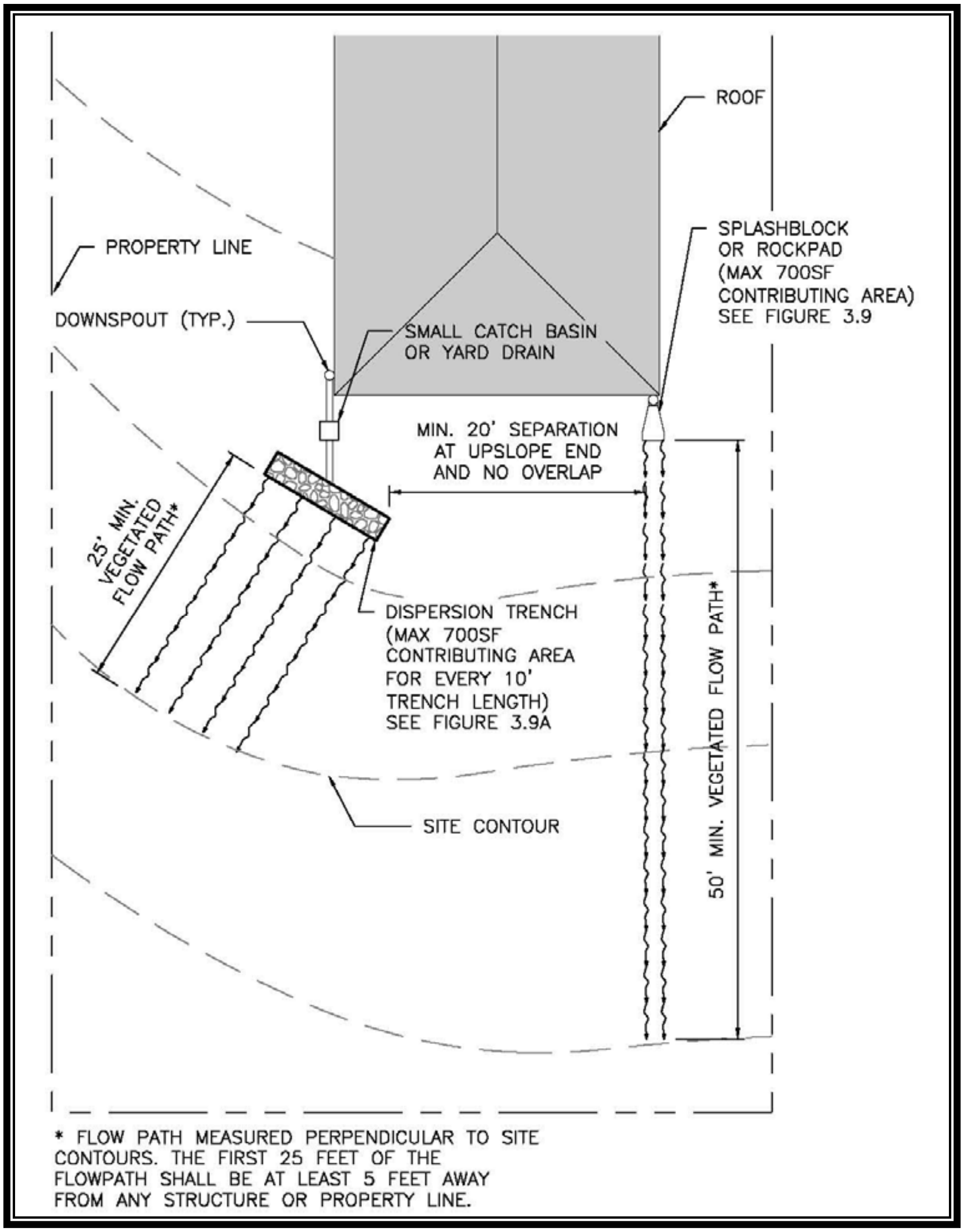


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Figure 3.9b. Typical Downspout Dispersion Trench.

Splashblocks

This section provides additional design criteria specific to splashblocks.

- Splashblocks shown in Figure 3.10 may be used for downspouts discharging to a vegetated flow path at least 10 feet in width and 50 feet in length as measured from the downspout to the downstream property line; structure; critical areas (i.e., stream, wetland), or other impervious surface
- A maximum of 700 square feet of roof area may drain to each splashblock
- A splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) should be placed at each downspout discharge point.

Construction Criteria

See Volume II, Section 3.3 for dispersion facility construction requirements.

Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements.

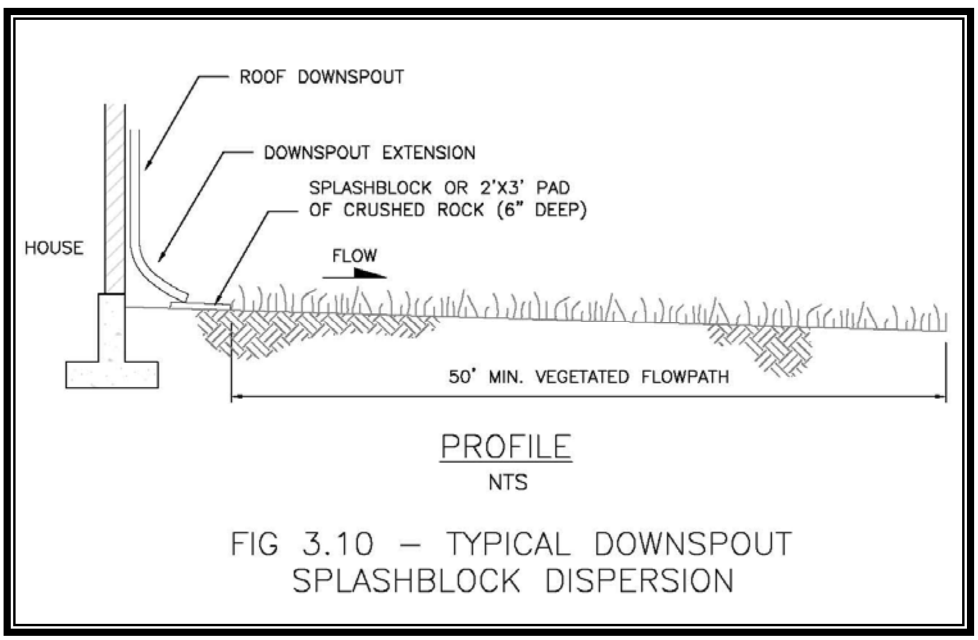

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Figure 3.10. Typical Downspout Splashblock Dispersion.

3.9.5 Perforated Stub-Out Connections (Ecology BMP T5.10C)

Description

A perforated stub-out connection is a length of perforated pipe within a gravel-filled trench that is placed between roof downspouts and a stub-out to the downstream drainage system. Figure 3.11 illustrates a perforated stub-out connection. These systems are intended to provide some infiltration during drier months. During the wet winter months, they may provide little or no flow control.

Applications and Limitations

- Perforated stub-outs are not appropriate where the highest estimated groundwater level or other impermeable layer is less than one foot below the trench bottom. In projects subject to Minimum Requirement #5 (see Volume I), perforated stub-out connections may be used only when all other higher priority onsite stormwater management BMPs are not feasible, per the criteria for each of those BMPs.
- Select the location of the connection to allow a maximum amount of runoff to infiltrate into the ground (ideally a dry, relatively well-drained location).
- To facilitate maintenance, do not locate the perforated pipe portion of the system under impervious or heavily compacted surfaces (e.g., driveways and parking areas). Use the same setbacks as for downspout infiltration systems (see Section 3.9.3), with the following modification to the setback from onsite or adjacent septic systems:
    - Apply the prescribed setbacks from onsite or adjacent septic systems to the perforated portion of the pipe (not the discharge point).
    - The perforated portion of the pipe may not be upgradient of the drainfield primary and reserve areas. This requirement can be waived if site topography will clearly prohibit flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.
- Do not place the perforated portion of the pipe within 300 feet of an erosion hazard area, or a landslide hazard area (as defined by Chapter 18.08 GHMC), or above slopes greater than 20 percent, unless the slope stability impacts of such systems have been analyzed and mitigated by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible
- Perforated stub-outs are not appropriate where connecting pipe discharges to a stormwater facility designed to meet Minimum Requirement #7 Flow Control requirements.

Modeling and Sizing

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

Perforated Stub-Out Design Criteria

Perforated stub-out connections consist of at least 10 feet of perforated pipe per 5,000 square feet of roof area laid in a level, 2-foot wide trench backfilled with 12-inch minimum depth of washed drain rock. Lay the 4 or 6 inch diameter perforated pipe level with 6 to 8 inches of drain rock below the bottom of the pipe. Cover the rock trench with filter fabric and minimum of 6 inches of fill (see Figure 3.11).

Operations and Maintenance Criteria

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements (refer to maintenance requirements for Infiltration Basins and Trenches).

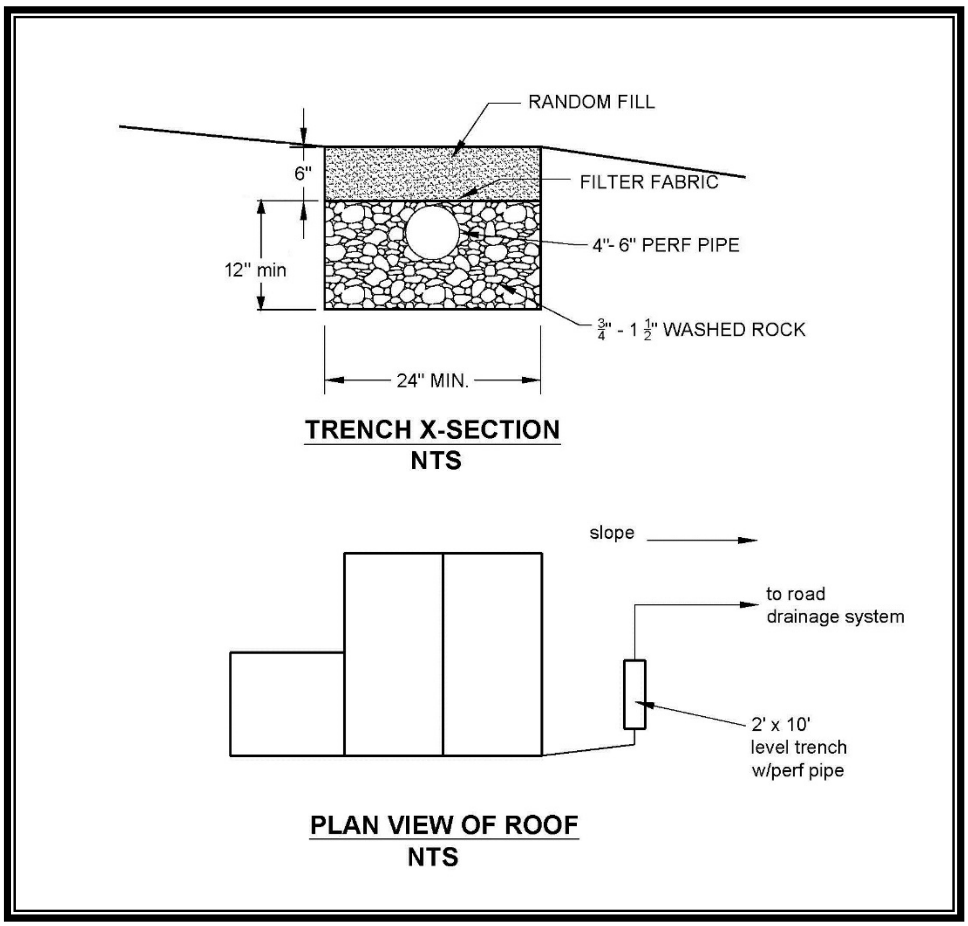

Figure 3.11. Perforated Stub- Out Connection.

3.10 Vegetated Roofs (Ecology BMP T5.17)

3.10.1 Description

Vegetated roofs are areas of living vegetation installed on top of buildings, or other above-grade impervious surfaces. Vegetated roofs are also known as ecoroofs, green roofs, and roof gardens. Because vegetated roofs are an integral component of the building structure, and the design and construction approaches continue to get refined as this technology evolves, this section primarily focuses on the stormwater elements of vegetated roof design. Other technical resources are referenced in this section for additional guidance and information (such as the LID Technical Guidance Manual for Puget Sound).

A vegetated roof consists of a system in which several materials are layered to achieve the desired vegetative cover and stormwater management function (see Figure 3.12). Design components vary depending on the vegetated roof type and site constraints, but may include a waterproofing material, a root barrier, a drainage layer, a separation fabric, a growth medium (soil), and vegetation. Vegetated roofs are categorized by the depth and the types of courses used in their construction.

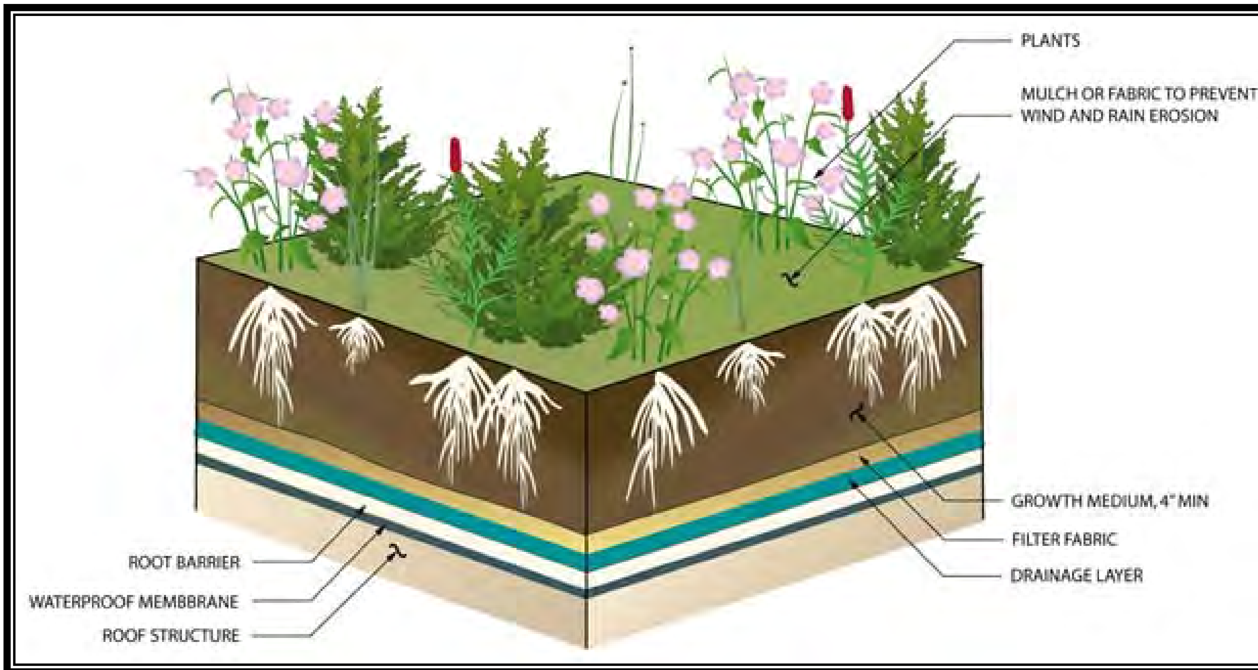

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Figure 3.12. Vegetated Roof.

- **Intensive roofs:** Intensive roofs are deeper installations, comprised of at least 6 inches of growth media and planted with ground covers, grasses, shrubs and sometimes trees.
- **Extensive roofs:** Extensive roofs are shallower installations, comprised of less than 6 inches of growth media and planted with a palette of drought-

tolerant, low maintenance ground covers. Extensive vegetated roofs have lower weight than intensive roofs, and are typically the most suitable for placement on existing structures. Extensive systems are further divided into two types:

  - "Single-course" systems consist of a single media designed to be freely draining and support plant growth
  - "Multi-course" systems include both a growth media layer and a separate, underlying drainage layer.

The following types of vegetated roofs are acceptable for flow control applications in the City of Gig Harbor:

- Extensive multi-course systems (and commercially available modular systems) with at least 4 inches of growth medium
- Extensive single-course systems with at least 4 inches of growth medium for areas less than 1,000 square feet.

3.10.2 Applications and Limitations

- Vegetated roofs can be used to help meet the flow control standards of Minimum Requirement #7.
- When used in combination with other onsite stormwater management BMPs, vegetated roofs can also help achieve compliance with Minimum Requirement #5.
- Vegetated roofs are generally applicable to roof slopes between 1 and 22 degrees (0.2:12 and 5:12).
- A primary consideration for the feasibility of vegetated roofs is the structural capability of the roof and building structure. Related factors, including design load, slipping and shear issues, and wind load, are outside the scope of this manual. Refer to Title 15 GHMC Buildings and Construction and the IBC/IRC for structural requirements.

3.10.3 Modeling and Sizing

When using an approved continuous runoff model to quantify the onsite stormwater management and/or flow control performance of vegetated roofs, the assumptions listed in Table 3.6 must be applied. It is recommended that vegetated roofs be modeled as layers of aggregate with surface flows, interflow, and exfiltrating flow routed to an outlet.

The medium depth can be modified to achieve various degrees of flow control. Because the onsite stormwater management and flow control standards cannot typically be achieved using a vegetative roof, additional downstream flow control measures may be required.

Table 3.6. Continuous Modeling Assumptions for Vegetated Roofs.

Variable	Assumption
Precipitation Series	Gig Harbor
Computational Time Step	15 minutes
Inflows to Facility	None
Precipitation and Evaporation Applied to Facility	Yes
Depth of Material (inches)	Growth medium/soil depth (minimum of 4 inches).
Vegetative Cover	Ground cover or shrubs. Shrubs are appropriate only when growth medium is at least 6 inches.
Length of Rooftop (ft)	The length of the surface flow path to the roof drain
Slope of Rooftop (ft/ft)	The slope of the vegetated roof
Discharge from Facility	Surface flow, interflow and exfiltrated flow from vegetated roof module routed to downstream BMP or point of compliance. Note that the exfiltrated flow (flow infiltrated through the media and collected by the drainage layer) is tracked as “groundwater” in WWHM.

3.10.4 Vegetated Roof Design Criteria

The following sections provide a description and general specifications for the common components of vegetated roofs. Typical components of a vegetated roof are shown in Figure 3.12. Design criteria are provided in this section for the following elements:

- Roof slope
- Vegetation
- Growth medium
- Drainage layer
- Drain system and overflow.

While vegetated roofs will include additional system components (e.g., waterproof membrane, root barrier, separation fabric for multi-course systems), the design and construction requirements for these components are outside of the scope of this manual. Refer to the LID Technical Guidance Manual for Puget Sound for a more detailed description of the components of and design criteria for vegetated roofs, as well as additional references and design guidance.

Roof Slope

Vegetated roofs can be applied to a range of rooftop slopes; however, steeper slopes may result in reduced flow control performance and may warrant a more complicated design (e.g., lateral support measures). Roofs with slopes between 5 and 22 degrees (1:12 and

5:12) are the easiest to install, are the least complex, and generally provide the greatest stormwater storage capacity per inch of growth medium.

For flow control compliance, the roof slope must be between 1 and 22 degrees (0.2:12 and 5:12). Roofs with slopes greater than 10 degrees (2H:12V) require an analysis of engineered slope stability.

Vegetation

Vegetation used on extensive vegetated roofs should be drought tolerant, self-sustaining, low maintenance, and perennial or self-sowing. Appropriate plants should also be able to withstand heat, cold, periodic inundation and high winds. Vegetation with these attributes typically includes succulents, grasses, herbs, and wildflowers that are adapted to harsh conditions. Refer to the LID Technical Guidance Manual for Puget Sound for additional vegetation guidance for vegetated roofs.

Minimum requirements associated with vegetation design include the following:

- Plans must specify that vegetation coverage of selected plants must achieve 90 percent coverage within 2 years or additional plantings must be provided until this coverage requirement is met
- Plant spacing and plant size must be designed to achieve specified coverage by a licensed landscape architect
- Vegetation must be suitable for rooftop conditions (e.g., hot, cold, dry, and windy)
- Plants must not require fertilizer, pesticides or herbicides after 2-year establishment period.

Growth Medium

Vegetated roofs use a light-weight growth medium with adequate fertility and drainage capacity to support plants and allow filtration and storage of water. Growth medium composition (fines content and water holding capacity) is key to flow control performance. Refer to the LID Technical Guidance Manual for Puget Sound for additional guidance on growth medium design.

Minimum requirements associated with the growth medium design include the following:

- The growth medium must be a minimum of 4 inches deep
- Growth medium depth and characteristics must support growth for selected plant species and must be approved by a licensed landscape architect
- Vegetated roofs must not be subject to any use that will significantly compact the growth medium

- Unless designed for foot traffic, vegetated roof areas that are accessible to the public must be protected (e.g., signs, railing, and fencing) from foot traffic and other loads
- Mulch, mat, or other measures to control erosion of growth media must be maintained until 90 percent vegetation coverage is achieved.

Drainage Layer

Intensive and extensive multi-course vegetated roof systems must include a drainage layer below the growth medium. The drainage layer is a multipurpose layer designed to provide void spaces to hold a portion of the water that passes through the growth medium and to channel the water to the roof drain system. The drainage layer can consist of a layer of aggregate or a manufactured mat or board that provides an open free-draining area. Many manufactured products include “egg carton” shaped depressions that retain a portion of the water for eventual evapotranspiration. Refer to the LID Technical Guidance Manual for Puget Sound for additional guidance on drainage layer design.

Drain System and Overflow

Vegetated roofs must be equipped with a roof drainage system capable of collecting subsurface and surface drainage and conveying it safely to a downstream BMP or an approved point of discharge. To facilitate subsurface drainage, interceptor drains are often installed at a regular spacing to prevent excessive moisture build up in the media and convey water to the roof drain. Roof outlets must be protected from encroaching plant growth and loose gravel, and must be constructed and located so that they are permanently accessible.

3.10.5 Construction Criteria

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

3.10.6 Operations and Maintenance Criteria

Vegetated roofs are designed to need very little maintenance and if designed correctly should have a longer lifespan than traditional roofs because of the protective nature of the soil structure. Inspections still should be performed regularly to identify any leakage of the membrane system or blockages of the overflow system. See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for information on maintenance requirements.

3.11 Roof Rainwater Collection Systems (Ecology BMP T5.20)

3.11.1 Description

Roof rainwater collection systems are designed to collect stormwater runoff from non-polluting surfaces (typically roofs), and to make use of the collected water. Reuse of the runoff can be for irrigation, potable, and non-potable uses, but requires different levels of storage and water quality treatment depending on the intended use. Rainwater collection systems have been designed and installed in many locations throughout the northwest, including Pacific Plaza in Tacoma, and the Bullitt Center in Seattle. The most abundant use of water collection and reuse systems in the northwest has been on some of the island communities where potable water is scarce. In these cases, the systems have been sized and designed to capture all rooftop runoff with adequate treatment for reuse as a potable water source. Rainwater collection and reuse systems are also commonly referred to as "rainfall catchment" and "rainwater harvesting" systems.

Because of the wide variety of uses and scenarios that can apply to rooftop rainwater collection and use, this section primarily focuses on the stormwater elements of rainwater collection design. Additional guidance and information on issues such as modeling indoor water use can be found in the LID Technical Guidance Manual for Puget Sound (and other resources).

3.11.2 Applications and Limitations

- Rainwater collection systems can be used to help meet the flow control standards of Minimum Requirement #7.
- When used in combination with other onsite stormwater management BMPs, Rainwater collection systems can also help achieve compliance with Minimum Requirement #5.
- Rainwater collection systems can also be an effective volume reduction practice for projects where infiltration is not permitted or desired.
- Rainwater collection has higher stormwater management benefits when designed for uses that occur regularly through the wet season (e.g., toilet flushing and cold water laundry).
- Highly developed areas or commercial centers where larger buildings, especially multistory buildings, encompass nearly all of the area are highly suitable for rainwater collection systems where it might not be feasible to preserve natural protection areas. In these areas, any type of stormwater management is expensive due to the high cost of land and therefore the cost of a rainwater collection and reuse system can be more competitive.
- Roof rainwater collection systems have the additional benefit of decreasing demands on the treated potable water supply.
- Use of a roof rainwater collection system as a potable source will require approval by the Washington State Department of Health and/or the Tacoma-Pierce County Health Department.

Although use of rain barrels for capturing rainfall can be beneficial for providing a small amount of irrigation and also provide an educational aspect to the benefits of water reuse, they generally do not provide enough storage of seasonal runoff to be considered to meet the performance goals of Minimum Requirement #5 or #7, or the general performance requirements of LID projects, unless prior approval is obtained from the City.

3.11.3 Modeling and Sizing

- Roof rainwater collection systems must be sized according to roof area, monthly rainfall patterns, and anticipated water usage of connected plumbing facilities. To estimate the storage volume required, the volume of rainfall off the roof surface should be plotted over time against curves showing the amount of water use anticipated. Use monthly average rainfall for Gig Harbor, shown in Table 3.7.

Table 3.7. Gig Harbor Monthly Average Rainfall.

January	5.74 inches	**July**	0.96 inches
February	4.21 inches	**August**	1.2 inches
March	4.12 inches	**September**	1.91 inches
April	3.27 inches	**October**	3.27 inches
May	2.49 inches	**November**	6.21 inches
June	2.20 inches	**December**	5.76 inches

Note: The rainfall depths above represent the average monthly rainfall from 1941 – 2013.

- Rainwater collection systems also experience water losses due to roofing material texture, evaporation, and inefficiencies in the collection process, which can account for up to a 25 percent loss of annual rainfall. As noted previously, additional guidance and information on modeling and sizing for indoor water use can be found in the LID Technical Guidance Manual for Puget Sound (and other resources).

3.11.4 General Roof Rainwater Collection System Design Criteria

Rainwater collection systems can be designed as part of the foundation to fit under the house (adding about 1 foot in height), or can be placed next to the house, either above or below ground. When the storage of runoff is incorporated into the building design it shall be approved as part of the building permit. Figure 3.13 provides an illustration of an example cistern installation.

- Rainwater reuse systems that supply non-potable water should be designed to augment the supply of treated water and therefore should be designed to use the stored rainfall runoff first and use the treated water supply when the rainfall runoff is depleted

- Refer to the LID Technical Guidance Manual for Puget Sound for additional guidance for design of rainwater harvesting systems and cistern design requirements specific to indoor use of harvested rainwater.

3.11.5 Construction Criteria

Rainwater harvesting systems must be constructed according to the manufacturer's recommendations, the I-Codes, and all applicable laws.

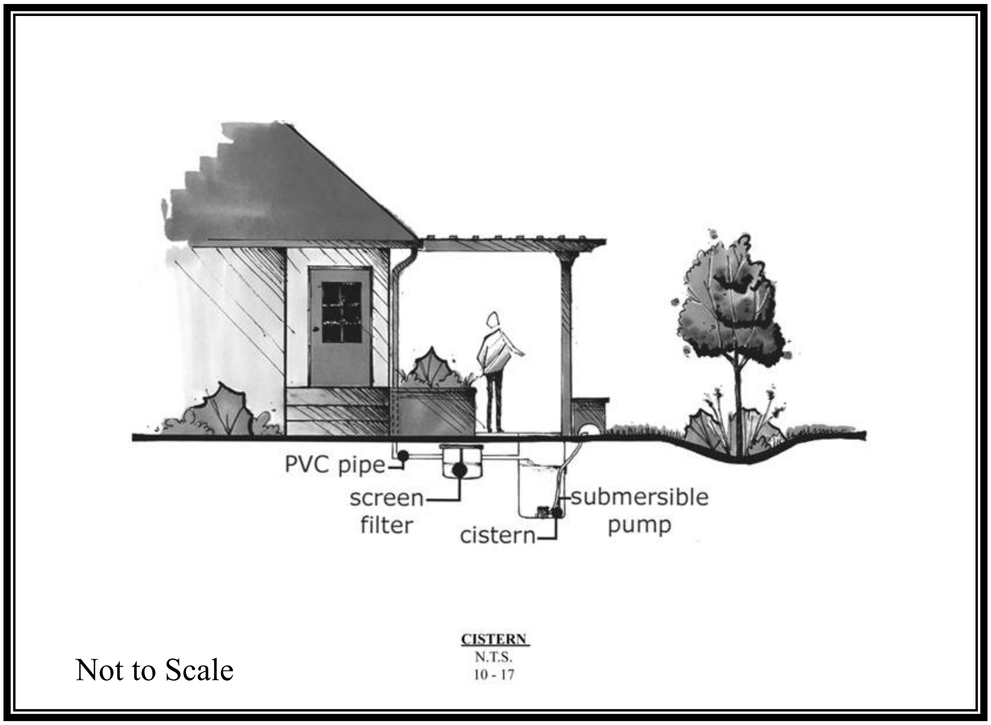


Figure 3.13. Cistern.

3.11.6 Operations and Maintenance Criteria

Maintenance covenants shall provide for annual inspections of systems to assure pumps and filters are working properly and the design level of water quality is being maintained.

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

3.12 Detention Facilities

This section presents the methods, criteria, and details for design and analysis of detention facilities. These facilities provide for the temporary storage of increased surface water runoff resulting from development pursuant to the performance standards set forth in Minimum Requirement #7 for flow control (Volume I).

There are three primary types of detention facilities described in this section: detention ponds, tanks, and vaults.

3.12.1 Detention Ponds

The design criteria in this section apply to detention ponds. However, many of the criteria also apply to infiltration basins (Section 3.7), and water quality wet ponds and combined detention/wet ponds (see Volume V). Standard details for detention ponds and key detention pond structures are provided in Attachments Section A, Details 5.1 (pond detail), 7.0 (overflow spillway detail), and 16.0 (overflow structure detail). Control structure design requirements are provided in Section 3.12.4.

Methods of Analysis

Detention Volume and Outflow. The volume and outflow design for detention ponds must be in accordance with Minimum Requirements #7 in Volume I and the hydrologic analysis and design methods in Chapter 2 of this volume. Design guidelines for restrictor orifice structures are given in Section 3.12.4.

Note: The design water surface elevation is the highest elevation which occurs in order to meet the required outflow performance for the pond.

Detention Ponds in Infiltrative Soils. Detention ponds may occasionally be sited on till soils that are sufficiently permeable for a properly functioning infiltration system (see Section 2.5). These detention ponds have a surface discharge and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of Section 2.5 for infiltration basins, including a soils/geotechnical report, testing, groundwater protection, presettling, and construction techniques.

Emergency Overflow Spillway Capacity. For impoundments under 10-acre-feet, the emergency overflow spillway weir section must be designed to pass the 100-year recurrence interval runoff event for developed conditions assuming a broad-crested weir. The **broad-crested weir equation** for the spillway section (see also Attachments Section A, Detail 7.0), for example, would be:

$$Q_{100} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}(\operatorname{Tan}\theta)H^{5/2}\right] \qquad \text{(equation 1)}$$

Where:

Q_{100} = peak flow for the 100-year recurrence interval runoff event (cubic feet per second) indicated by an approved continuous runoff model using a 15-minute time step.

C = discharge coefficient (0.6)

g = gravity (32.2 ft/sec^2)

L = length of weir (ft)

H = height of water over weir (ft)

θ = angle of side slopes

Assuming C = 0.6 and Tan θ= 3 (for 3:1 slopes), the equation becomes:

$$Q_{100} = 3.21[LH^{3/2} + 2.4 H^{5/2}] \qquad \text{(equation 2)}$$

To find width *L* for the weir section, the equation is rearranged to use the computed Q_{100} and trial values of H (0.2 feet minimum):

$$L = [Q_{100}/(3.21H^{3/2})] - 2.4 H \quad \text{or} \quad \text{6 feet minimum} \qquad \text{(equation 3)}$$

Dam Safety for Detention BMPs

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

In addition to the hydrologic and hydraulic issues related to precipitation and runoff, other dam safety requirements include geotechnical issues, construction inspection and documentation, dam breach analysis, inundation mapping, emergency action planning, and periodic inspections by project owners and by dam safety engineers. It is recommended and requested that dam safety be contacted early in the facilities planning process. Electronic versions of the guidance documents in PDF format are available on Ecology's Web site.

General Detention Design

- Ponds must be designed as flow-through systems (however, parking lot storage may be utilized through a back-up system; see Section 3.12.5). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.

- Pond bottoms must be level and be located a minimum of 0.5 foot (preferably 1 foot) below the inlet and outlet to provide sediment storage.

- Design guidelines for outflow control structures are specified in Section 3.12.4.

- All detention ponds, vaults, and tanks are required to include a crest gauge that will record maximum pond water surface elevation after a storm event. See Attachments Section A, Detail 25.0 for crest gauge details. In addition, project submittals **must** include a table that identifies the design facility stage expected for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval flows.

- A geotechnical assessment and soils report must be prepared for work located within 300 feet of the top of a steep slope, erosion hazard, or landslide hazard area (as defined in Chapter 18.08 GHMC). The scope of the soils report shall include the assessment of impoundment seepage on the stability of the natural slope where the facility will be located within the setback limits set forth in this section.

- Drainage facilities should be made attractive features of the urban environment. To this end, engineers are encouraged to be creative in shaping and landscaping facilities and to consider aesthetics when choosing alternatives for parking lot paving, conveyance systems, detention facilities, weirs, structures, etc.

Side Slopes

- Interior side slopes up to the emergency overflow water surface shall not be steeper than 3H:1V unless a fence is provided (see “fencing”).

- 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, provided: (a) they are constructed of reinforced concrete per Section 3.12.3, Material; (b) a fence is provided along the top of the wall; (c) the entire pond perimeter may be retaining walls, however, it is recommended that at least 25 percent of the pond perimeter be a vegetated soil slope not steeper than 3H:1V; (d) the design is stamped by a licensed civil engineer with structural expertise; (e) an access ramp to the bottom of the pond is provided. Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type wall may be used if designed by a geotechnical engineer or a civil engineer with structural expertise.

Embankments

Pond berm embankments shall satisfy the following criteria:

- Construct pond berm embankments on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical assessment), which is free of loose surface soil materials, roots and other organic debris.

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

- Pond berm embankment cores shall be constructed of compacted soil (a minimum of 95 percent of the maximum dry density, standard proctor method per American Society for Testing and Materials [ASTM] D1557) placed in 6-inch lifts, with the following soil characteristics per the USDA’s textural triangle: a minimum of 30 percent clay, a maximum of 60 percent sand, a maximum of 60 percent silt, with nominal gravel and cobble content or as recommended by a geotechnical engineer. (Note: in general, excavated glacial till will be well-suited for berm embankment material.) The core shall be adequate to make the embankment impervious.

- Place anti-seepage collars on outflow pipes in berm embankments impounding water greater than 8 feet in depth at the design water surface.
- Exposed earth on the pond side slopes shall be sodded or seeded with appropriate seed mixture (see Volume II, Erosion and Sedimentation Control BMPs). Establishment of protective vegetative cover shall be ensured with appropriate surface protection BMPs and reseeded as necessary.
- Where maintenance access is provided along the top of the berm, the minimum width of the top of the berm shall be 15 feet.
- Pond berm embankments greater than 6 feet in height shall be designed by a professional engineer with geotechnical expertise.
- Embankments less than 6 feet in height shall have a minimum 6-foot top width and slopes not to exceed 2H:1V. However, maintenance access for mowing and pond access must still be provided.
- Embankments adjacent to a stream or other body of water shall be sufficiently protected with riprap or bioengineering methods to prevent erosion of the pond embankment. Other control measures may be necessary to protect the embankment.
- Exterior and interior side slopes of retention and detention ponds that are steeper than 2H:1V, must be analyzed for stability by a qualified civil or geotechnical engineer.

Anti-seepage filter-drain diaphragms must be placed on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Dam Safety Guidelines, Part IV, Section 3.3.B. An electronic version of the Dam Safety Guidelines is available on Ecology’s web site.

Overflow

- Provide a primary overflow (usually a riser pipe within the control structure; see Section 3.12.4) in all ponds, tanks, and vaults to bypass the 100-year recurrence interval developed peak flow over or around the restrictor system. This assumes the facility will be full due to plugged orifices or high inflows; the primary overflow is intended to protect against breaching of a pond embankment (or overflows of the upstream conveyance system in the case of a detention tank or vault). The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

- Provide a secondary inlet to the control structure in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A grated opening ("jailhouse window") in the control structure manhole functions as a weir when used as a secondary inlet. *Note: The maximum circumferential length of this opening must not exceed one-half the control structure circumference.* The "birdcage" overflow structure may also be used as a secondary inlet (see also Attachments Section A, Detail 16.0).

Emergency Overflow Spillway

- In addition to the above overflow provisions, 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. For impoundments less than 10 acre-feet, ponds must have an emergency overflow spillway that is sized to pass the 100-year recurrence interval developed peak flow in the event of total control structure failure (e.g., blockage of the control structure outlet pipe) or extreme inflows. Emergency overflow spillways are intended to control the location of pond overtopping and direct overflows back into the downstream conveyance system or other acceptable discharge point.

- Provide emergency overflow spillways for ponds with constructed berms over 2 feet in height, or for ponds located on grades in excess of 5 percent. As an option for ponds with berms less than 2 feet in height and located at grades less than 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a Type II manhole fitted with a birdcage as shown in Attachments Section A, Detail 16.0. The emergency overflow structure must be designed to pass the 100-year recurrence interval developed peak flow, with a minimum 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, consideration shall be given to providing an emergency overflow structure in addition to the spillway.

- Armor the emergency overflow spillway with riprap in conformance with "BMP C209: Outlet Protection" in Volume II. The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system (see Attachments Section A, Detail 7.0).

- Emergency overflow spillway designs must be analyzed as broad-crested trapezoidal weirs as described in Methods of Analysis at the beginning of this section.

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

Access

Pond Access Roads

Pond access roads shall provide access to all drainage structure(s) and alongside the pond for vehicular maintenance access to each pond cell. In addition, pond access roads are required around the entire pond perimeter in order to provide complete vehicular access to all points of the pond requiring regular maintenance, inspection, and repairs. Regular maintenance is considered activities that will be done on a regular basis such as vegetation control where removed vegetation will need to be loaded into a truck for removal. Because each site condition and design is unique there may be cases where the perimeter road is not necessary because no regular maintenance will be anticipated. In these cases the designer may request to waive the perimeter road requirement by submitting a conceptual pond layout and a narrative which demonstrates that where the perimeter road is being eliminated, no regular maintenance activities are anticipated. Approval will be at the discretion of the City Engineer.

Pond access roads shall be located in the same tracts when the ponds themselves are in tracts. When ponds are located in open space, the pond access roads may be located in open space also, provided that they are constructed so as to be aesthetically compatible with the open space use.

Pond Access Road Design Guidelines

Access roads shall be a minimum of 15 feet in width. Perimeter roads may be 12 feet in width where not accessing a structure or being used for a circular loop road in lieu of turn around. Access roads may be constructed with an asphalt, gravel surface, or modular pavers. However, access to all control structures, catch basins, and other drainage structures associated with the pond (e.g., inlet or bypass structures) must be via an asphalt surface designed to support heavy loads including vactor trucks. Access to an emergency spillway is not required to be asphalt surface. A paved apron must be provided where access roads connect to paved public roadways. The inside road radius for access roads to ramps and all drainage structures shall not be less than 40 feet. Inside road radius for perimeter access roads shall not be less than 25 feet.

Manhole and catch basin lids must be in or at the edge of the access road and at least 3 feet from a property line.

When the length of a pond access road to a drainage structure or pond exceeds 75 feet, a vehicle turn-around must be provided, designed to accommodate vehicles having a maximum length of 31 feet and having an inside wheel path radius of 40 feet. The vehicle turn around requirement may be waived if the access road around the perimeter of the pond is entirely paved, and can be used in a continuous drive back to the entrance with no turnarounds.

Access roads to all drainage structures shall have a maximum slope of 12 percent. See Attachments Section A, Detail 21.0 for turn-around details.

Pond Access Gates or Bollards

Vehicle access shall be limited by a double gate if a pond is fenced or by bollards if the pond is not fenced. A minimum of one locking access road gate shall be provided that meets WSDOT State Standard Plan L30.10. Gates may be 14, 16, 18, or 20 feet in width. Bollards shall consist of two fixed bollards, on the outside of the access road and two removable bollards equally spaced between the fixed bollards (or all four removable if placed in the traveled way).

Access gates and bollards must be set 20 feet back from property line where the road it is connecting from is posted 35 mph or greater (Arterials).

Access Ramps

Pond access ramps shall be provided to **all** cells unless all of following conditions apply: cell bottoms are accessible or reachable by trackhoes from the perimeter access road, a truck can be loaded without the truck accessing the bottom of the cell, and no point in the bottom of the cell is more than 40 feet from the center of the access road. Trackhoe maximum reach from an access road is 20 feet. Cell bottoms will be considered accessible where at least one of the side slopes of the cell is no steeper than 3H:1V. Truck loading will be considered achievable where the cell depth (measured as bottom of cell to access road surface) is 4 feet or less at a point along the pond perimeter where a truck can be parked and loaded.

Access Ramp Design Guidelines

The access ramp shall have a minimum width of 15 feet and a maximum grade of 15 percent if paved. If the access ramp happens to be the only access to a control structure, catch basin, or other drainage structure it must be asphalt. An alternate ramp surface can be constructed with a maximum slope of 12 percent by laying a geotextile fabric over the native soil, placing quarry spalls (2- to 4-inch) six inches thick, then providing a 2-inch thick crushed rock surface.

When a ramp is required (see above), the ramp must extend to the pond bottom if the cell bottom is greater than 1,500 square feet (measured without the ramp). If the pond bottom is less than 1,500 square feet (measured without the ramp), the ramp may end at an elevation 4 feet above the cell bottom.

The internal berm of a wet pond or combined detention and wet pond may be considered the maintenance access to the next cell if the following conditions are met:

- The berm is no more than 4 feet above either cell bottom
- The berm is designed to support the weight of a trackhoe (considering the berm is normally submerged and saturated)

- The berm side slopes are no steeper than 3H:1V.

Fencing

- A fence is required around all public stormwater facility tracks. On private facilities fences need only be constructed for those slopes steeper than 3H:1V, at the emergency overflow water surface elevation, or higher.
- A fence is also required where a pond impoundment wall is greater than 24 inches in height.
- Other regulations such as the International Building Code (IBC) may require fencing of vertical walls. If more than 10 percent of slopes are steeper than 3H:1V, it is recommended that the entire pond be fenced.
- Detention ponds on school sites will need to comply with safety standards developed by the Washington State Department of Health (DOH) and the superintendent for public instruction. These standards include what is called a "non-climbable fence." One example of a non-climbable fence is a chain-link fence with a tighter mesh, so children cannot get a foot-hold for climbing. For school sites, and possibly for parks and playgrounds, the designer should consult the DOH's Office of Environmental Programs.
- Fences discourage access to portions of a pond where steep side slopes (steeper than 3:1) increase the potential for slipping into the pond. Fences also serve to guide those who have fallen into a pond to side slopes that are flat enough (flatter than 3:1 and unfenced) to allow for easy escape.
- Fencing of public drainage ponds shall consist of a minimum 6-foot-high chain link fence Type 1, per Attachments Section A, Detail 24.0. Fencing of tracts within the clear zone of roads with design speeds of 35 mph or higher shall use chain link fence Type 3 (modified, per Attachments Section A, Detail 24.1). Access shall be provided as specified in the previous section. Any fencing shall be placed at the tract or easement boundary, and where applicable a minimum of 5 feet from the top slope catch point.
- Any pipe stem access to a basin shall be fenced with a WSDOT Type 4 chain link fence with a 14-foot gate. Access shall be provided as specified in the previous section.
- Pedestrian access gates (if needed) shall be a minimum of 4 feet in width and meet WSDOT State Standard Plan L-3.
- Fence material shall be No. 9 gauge galvanized steel fabric with bonded vinyl coating. Vinyl coating shall be green or black. All posts, cross bars, fasteners, and gates shall be painted or coated the same color as the vinyl clad fence.
- For metal baluster fences, IBC standards apply.

- Wood fences may be used in subdivisions where the fence will be maintained by homeowners' associations or adjacent lot owners.
- Wood fences shall have pressure treated posts (ground contact rated) either set in 24-inch deep concrete footings or attached to footings by galvanized brackets. Rails and fence boards may be cedar, pressure-treated fir, or hemlock.

Signage

Detention ponds, infiltration basins, wet ponds, and combined ponds shall have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. An example of sign specifications for a permanent surface water control pond is illustrated in Attachments Section F. For private facilities show the owner's name and contact information. For homeowners' associations, the contact can be a residence address, P.O. Box, or email address. Contact the City for open space and landscaping criteria.

Right-of-Way

Right-of-way may be needed for detention pond maintenance. It is recommended that any tract not abutting public right-of-way have 15- to 20-foot wide extension of the tract to an acceptable access location.

Setbacks

All setbacks shall be horizontal unless otherwise specified.

All **detention ponds** shall maintain minimum setback distances as follows unless modified with written approval by the TPCHD for wells and septic:

- 1 foot positive vertical clearance from maximum water surface to structures within 25 feet.
- 5 feet from maximum water surface to septic tank or distribution box.
- 10 feet from maximum water surface to property lines and onsite structures.
- 10 feet from maximum water surface to building sewer.
- 10 feet from maximum water level location to nearest tract property boundary lines.
- 30 feet from maximum water surface to septic drainfields and drainfield reserve areas for single family onsite sewage disposal systems.
- 100 feet from maximum water surface to septic drainfields and drainfield reserve areas for community onsite sewage disposal systems.

- 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on the slope. The geotechnical assessment may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.
- 100 feet from well to stormwater control and water quality facility, maximum water surface.

In addition, all stormwater vaults and tanks shall be a setback from any structure or property line a distance equal to the depth of the ground disturbed in setting the structure. Vaults and tanks shall also be within tracts or easements with widths equivalent to those listed for conveyance systems in Section 4.6.

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, more continuous seeps and springs, which extend through longer dry periods, 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 baseflow (unless already considered in design).

Planting Requirements

Sod or seed exposed earth on the pond bottom and interior sides with an appropriate seed mixture. Plant all remaining areas of the tract with grass or landscape and mulch with a 3-inch cover of hog fuel or shredded wood mulch (note: if implementing soil preservation and amendment in replanted areas per Section 3.1, 2-4 inches of hog fuel/woodchip mulch is required). Shredded wood mulch is made from shredded tree trimmings, usually from trees cleared on site. The mulch must be free of garbage and weeds and shall not contain excessive resin, tannin, or other material detrimental to plant growth. Do not use construction materials wood debris or wood treated with preservatives for producing shredded wood mulch.

Landscaping

Landscaping is encouraged for most stormwater tract areas (see below for areas not to be landscaped). However, if provided, landscaping should adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, “naturalistic” stormwater facilities may be placed in open space tracts. In addition, the community plans identified in Title 17 GHMC must be reviewed for possible additional area-specific requirements.

Follow these guidelines if landscaping is proposed for facilities:

- Do not plant trees or shrubs on berms meeting the criteria of dams regulated for safety.
- Do not plant trees and shrubs within a Public stormwater tract.
- Do not plant trees or shrubs within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, shall be avoided within 50 feet of pipes or manmade structures.
- Restrict planting on berms that impound water permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.
    - Do not plant trees or shrubs on portions of water-impounding berms taller than 4 feet high. Plant only grasses on berms taller than 4 feet.
    - Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.
    - Trees planted on portions of water-impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and have a fibrous root system. These trees reduce the likelihood of blow-down trees, or the possibility of channeling or piping of water through the root system, which may contribute to dam failure on berms that retain water.

    Note: The internal berm in a wet pond is not subject to this planting restriction since the failure of an internal berm would be unlikely to create a safety problem.

- Plant all landscape material, including grass, in good topsoil. Native underlying soils may be made suitable for planting if amended with 4 inches of compost tilled into the subgrade. Refer to the Soil Amendment heading in Section 3.1.4 for additional information on soil quality standards.
- Soil in which trees or shrubs are planted may need additional enrichment or additional compost top-dressing. Consult a landscape professional, or arborist for site-specific recommendations.
- For a naturalistic effect as well as ease of maintenance, trees or shrubs should be planted in clumps to form “landscape islands” rather than evenly spaced.
- The landscaped islands should be a minimum of 6 feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet. Where tree foliage extends low to the ground, the 6-foot setback should be counted from the outer drip line of the trees (estimated at maturity).

    This setback allows a 6-foot wide mower to pass around and between clumps.

- Evergreen or columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating. Evergreen trees or shrubs are preferred to avoid problems associated with leaf drop. Columnar deciduous trees (e.g., hornbeam, Lombardy poplar) typically have fewer leaves than other deciduous trees. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Setback trees so the branches will not extend over the pond.

- Drought tolerant species are recommended.

Guidelines for Naturalistic Planting. Stormwater facilities may sometimes be located within open space tracts if “natural appearing.” Two generic kinds of naturalistic planting are outlined below, but other options are also possible. Native vegetation is preferred in naturalistic plantings.

Open Woodland. In addition to the general landscaping guidelines above, the following are recommended:

- Landscaped islands (when mature) should cover a minimum of 30 percent or more of the tract, exclusive of the pond area.

- Underplant tree clumps with shade-tolerant shrubs and groundcover plants. The goal is to provide a dense understory that need not be weeded or mowed.

- Place landscaped islands at several elevations rather than “ring” the pond, and vary the size of clumps from small to large to create variety.

- Not all islands need to have trees. Shrub or groundcover clumps are acceptable, but lack of shade should be considered in selecting vegetation.

  Note: Landscaped islands are best combined with the use of wood-based mulch (hog fuel) or chipped onsite vegetation for erosion control (only for slopes above the flow control water surface). It is often difficult to sustain a low-maintenance understory if the site was previously hydroseeded. Compost or mulch (typically used for constructed wetland soil) can be used below the flow control water surface (materials that are resistant to and preclude flotation). The method of construction of soil landscape systems can also cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations.

Northwest Savannah or Meadow. In addition to the general landscape guidelines above, the following are recommended:

- Landscape islands (when mature) should cover 10 percent or more of the site, exclusive of the pond area.

- Planting groundcovers and understory shrubs is encouraged to eliminate the need for mowing under the trees when they are young.

- Landscape islands should be placed at several elevations rather than "ring" the pond.

The remaining site area should be planted with an appropriate grass seed mix, which may include meadow or wildflower species. Native or dwarf grass mixes are preferred. Table 3.1 below gives an example of dwarf grass mix developed for central Puget Sound. Grass seed should be applied at 2.5 to 3 pounds per 1,000 square feet.

Note: Amended soil or good topsoil is required for all plantings.

Creation of areas of emergent vegetation in shallow areas of the pond is recommended. Native wetland plants, such as sedges (*Carex* sp.), bulrush (*Scirpus* sp.), water plantain (*Alisma* sp.), and burreed (*Sparganium* sp.) are recommended. If the pond does not hold standing water, a clump of wet-tolerant, non-invasive shrubs, such as salmonberry or snowberry, is recommended below the detention design water surface.

Note: This landscape style is best combined with the use of grass or sod for site stabilization and erosion control.

Seed Mixes. The seed mixes listed in Table 3.8 were developed for central Puget Sound. Note that the use of slow-growing, stoloniferous grasses will permit long intervals between mowing.

Table 3.8. Stormwater Tract "Low Grow" Seed Mix.

Seed Name	Percentage of Mix
Dwarf tall fescue	40%
Dwarf perennial rye "Barclay"[1]	30%
Red fescue	25%
Colonial bentgrass	5%

[1] If wildflowers are used and sowing is done before Labor Day, the amount of dwarf perennial rye can be reduced proportionately to the amount of wildflower seed used.

Stormwater Sign Sample Specifications

Size: 48 inches by 24 inches

Material: 0.125-gauge aluminum

Face: Non-reflective vinyl or three coats outdoor enamel (sprayed).

Lettering: Silk screen enamel where possible, or vinyl letters.

Colors: Beige background, teal letters.

Type face: Helvetica condensed. Title: 3-inch. Subtitle: 1.5-inch. Text: 1 inch. Outer border: one-eighth-inch border distance from edge: one-fourth-inch; all text 1.75-inch from border.

Posts: Pressure treated, beveled tops, 1.5-inch higher than sign.

Installation: Secure to chain link fence if available. Otherwise install on two 4 x 4-inch posts, pressure treated, mounted atop gravel bed, installed in 30-inch concrete filled post holes (8-inch minimum diameter). Top of sign no higher than 42 inches from ground surface.

Placement: Face sign in direction of primary visual or physical access. Do not block any access road. Do not place within 6 feet of structural facilities (e.g., manholes, spillways, pipe inlets).

Special Notes: This facility is lined to protect groundwater (if a liner that restricts infiltration of stormwater exists).

Maintenance

Maintenance is of primary importance if detention ponds are to continue to function as originally designed. Hence, provisions to facilitate maintenance operations must be built into the project when it is installed. The City of Gig Harbor, a designated group such as a homeowners' association, or some individual must accept the responsibility for maintaining the structures and the impoundment area. A specific Maintenance and Source Control Manual must be formulated outlining the schedule and scope of maintenance operations. See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

Handle any standing water and sediments removed during the maintenance operation in a manner consistent with Volume IV, Appendix IV-C, and the approved Maintenance and Source Control Manual for the facility.

3.12.2 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Detention tanks are not to be perforated so as to provide infiltration of stormwater. Standard detention tank details are provided in Attachments Section A, Details 19.0 and 19.2. Control structure details are covered in Section 3.12.4.

Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention tanks must be in accordance with Volume I, Minimum Requirement #7 and the hydrologic analysis and design methods in Chapter 2 of this volume. Restrictor and orifice design are given in Section 3.12.4.

Detention Tank Design Criteria

General. Typical design guidelines are as follows:

- Tanks may be designed as flow-through systems with manholes in line to promote sediment removal and facilitate maintenance. Tanks may be designed as back-up systems if preceded by water quality facilities, since little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank.
- The detention tank bottom must be located 0.5 feet below the inlet and outlet to provide dead storage for sediment.
- The minimum pipe diameter for a detention tank is 36 inches.
- Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe.
- Tanks shall not be located under the travel way in public rights-of-way. For single-family plats and planned urban developments (PUDs), planned residential developments, or planning and development district detention tanks shall be located in separate tracts.
- Details of outflow control structures are given in Section 3.12.4.

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

Materials. Galvanized metals leach zinc into the environment, especially in standing water situations. This can result in zinc concentrations that can be toxic to aquatic life. Therefore, use of galvanized materials in stormwater facilities and conveyance systems is discouraged. Where other metals, such as aluminum or stainless steel, or plastics are available, they should be used.

Pipe material, joints, and protective treatment for tanks shall be in accordance with Section 9.05 of the *WSDOT/ American Public Works Association (APWA) Standard Specification*.

Structural Stability. Tanks must meet structural requirements for overburden support and traffic loading if appropriate. Loads must be accommodated for tanks lying under parking areas and access roads. Design metal tank end plates for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gauge material than the pipe and/or require reinforcing ribs. Place tanks on stable, well consolidated native material with suitable bedding. Do not place tanks in fill slopes, unless analyzed through a geotechnical assessment for stability and constructability.

Buoyancy. In moderately pervious soils where seasonal groundwater may induce flotation, balance buoyancy tendencies either by ballasting with backfill or concrete backfill, providing concrete anchors, increasing the total weight, or providing subsurface drains to permanently lower the groundwater table. Calculations that demonstrate stability must be documented.

Access. The following guidelines for access may be used. See also Attachments Section A, Detail 19.2.

- The maximum depth from finished grade to tank invert shall be 20 feet.
- Position access openings a maximum of 50 feet from any location within the tank.
- All tank access openings shall have round, solid locking lids (usually one-half to five-eighths-inch diameter Allen-head cap screws).
- A 36-inch minimum diameter CMP riser-type manholes of the same gauge 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.
- Make all tank access openings readily accessible by maintenance vehicles.
- Tanks must comply with the Occupational Safety and Health Administration (OSHA) confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Access Roads. Access roads are needed to all detention tank control structures and risers. Design and construct access roads as specified for detention ponds in Section 3.12.1.

Setbacks. All stormwater vaults and tanks shall be a setback from any structure or property line a distance equal to the depth of the ground disturbed in setting the structure. Additional setbacks are listed in Section 3.12.1. Vaults and tanks shall also be within tracts or easements with widths equivalent to those listed for conveyance systems in Section 4.6.

All facilities must be a minimum of 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on a slope steeper than 20 percent. The geotechnical assessment may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

Maintenance. Build provisions to facilitate maintenance operations into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

3.12.3 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. Detention vaults are not intended to infiltrate stormwater and should not be perforated. A standard detention vault detail is provided in Attachments Section A, Detail 19.1. Control structure details are covered in Section 3.12.4.

Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention vaults must be in accordance with Volume I, Minimum Requirement #7 and the hydrologic analysis and design methods in Chapter 2 of this volume. Restrictor and orifice design are given in Section 3.12.4.

Detention Vault Design Criteria

General. Typical design guidelines are as follows:

- Detention vaults may be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet shall be maximized (as feasible).
- The detention vault bottom may slope at least 5 percent from each side towards the center, forming a broad “V” to facilitate sediment removal. More than one “V” may be used to minimize vault depth. However, the vault bottom may be flat with 0.5 to 1 foot of sediment storage if removable panels are provided over the entire vault. It is recommended that the removable panels be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- The invert elevation of the outlet must be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet must also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.
- Details of outflow control structures are given in Section 3.12.4.
- Vaults shall not be located under the travel way in public rights-of-way. For single-family plats and planned urban developments (PUDs), planned residential developments, or planned development district detention vaults shall be located in separate tracts.

Materials. Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. Provide all construction joints with water stops.

Structural Stability. All vaults must meet structural requirements for overburden support and traffic loading (see Chapter 15 GHMC for current standards). Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed civil engineer with structural expertise. Place vaults on stable, well-consolidated native material with suitable bedding. Do not place vaults in fill slopes, unless analyzed through a geotechnical assessment for stability and constructability.

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

- Position access openings a maximum of 50 feet from any location within the tank. Additional access points may be needed on large vaults. Provide access to each “V” if more than one “V” is provided in the vault floor.
- For vaults with greater than 1,250 square feet of floor area, provide a 5 x 10-foot removable panel over the inlet pipe (instead of a standard frame, grate and solid cover). Or, provide a separate access vault.
- Ladders and hand-holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified below.
- All access openings, except those covered by removable panels, shall have round, solid locking lids, or 3-foot square, locking diamond plate covers.
- Vaults with widths 10 feet or less must have removable lids.
- The maximum depth from finished grade to the vault invert must be 20 feet.
- Internal structural walls of large vaults shall be provided with openings sufficient for maintenance access between cells. Size and situate the openings to allow access to the maintenance “V” in the vault floor.
- The minimum internal height must be 7 feet from the highest point of the vault floor (not sump), and the minimum width must be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. Also the minimum internal height requirement may not be needed for any areas covered by removable panels.
- Vaults must comply with the OSHA confined space requirements, including clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.
- Provide ventilation pipes (minimum 12-inch diameter or equivalent) in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Or, provide removable panels over the entire vault.

Setbacks. All stormwater vaults and tanks shall be a setback from any structure or property line a distance equal to the depth of the ground disturbed in setting the structure. Additional setbacks are listed in Section 3.12.1. Vaults and tanks shall also be within tracts or easements with widths equivalent to those listed for conveyance systems in Section 4.6.

All facilities must be a minimum of 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical assessment and soils report must be prepared addressing the potential impact of the facility on a slope steeper than 20 percent. The geotechnical assessment may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

Maintenance. Build provisions to facilitate maintenance operations into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

3.12.4 Control Structures

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 ("Ts" 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 and/or a weir section sized to meet performance requirements. Several publicly available and proprietary stormwater modeling programs are capable of sizing control structures. As such, the Methods of Analysis section (methods and equations for design of control structure restrictor devices) is included at the end of this section, rather than the beginning, as with the flow control BMPs above. Note that all detention and infiltration ponds, basins, vaults, tanks, and trenches **are required to include a crest gauge** that will record maximum pond water surface elevation after a storm event. The designer may submit alternative crest recording device for city approval. See Attachments Section A, Detail 25.0 for crest gauge details. In addition, project submittals **must** include a table that identifies the design facility stage expected for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval flows.

Standard control structure details are provided in Attachments Section A, Details 12.0 and 13.0.

Multiple Orifice Restrictor

In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

- Minimum orifice diameter is 0.5 inches. Note: In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards. A smaller orifice diameter may be permitted if a screen, per Attachments Section A, Details 12.0, is utilized to protect the orifice from fouling.

- Orifices may be constructed on a T-section or on a baffle, as shown in Attachments Section A, Details 12.0 and 13.0 respectively.

- In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g., a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements (see Figure 3.15, presented later in this section).

- 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.

Riser and Weir Restrictor

- Properly designed weirs may be used as flow restrictors (see Figure 3.15 through Figure 3.17, presented later in this section). However, they must be designed to provide for primary overflow of the developed 100-year recurrence interval 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 recurrence interval peak flow assuming all orifices are plugged. Figure 3.18 can be used to calculate the head in feet above a riser of given diameter and flow.

Access. The following guidelines for access may be used.

- Provide an access road to the control structure for inspection and maintenance. Design and construct the access road as specified for detention ponds in Section 3.12.1.

- Manhole and catch basin lids for control structures must be locking, and rim elevations must match proposed finish grade.

- Manholes and catch basins must meet the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser, just under the access lid.

Information Plate. It is recommended that a brass or stainless steel plate be permanently attached inside each control structure with the following information engraved on the plate:

- Name and file number of project
- Name and company of (1) developer, (2) engineer, and (3) contractor
- Date constructed
- Date of manual used for design
- Outflow performance criteria
- Release mechanism size, type, and invert elevation
- List of stage, discharge, and volume at 1-foot increments
- Elevation of overflow
- Recommended frequency of maintenance.

Maintenance. Control structures and catch basins have a history of maintenance-related problems and it is imperative that a good maintenance program be established for their proper functioning. Typically sediment builds up inside the structure, which blocks or restricts flow to the inlet. To prevent this problem, routinely clean out these structures at least twice per year. Conduct regular inspections of control structures to detect the need for non-routine cleanout, especially if construction or land-disturbing activities occur in the contributing drainage area.

Install a 15-foot wide access road to the control structure for inspection and maintenance.

See Minimum Requirement #9 in Volume I; Volume I, Section 3.3.6; and Volume I, Appendix I-A for additional information on maintenance requirements.

Methods of Analysis

This section presents the methods and equations for design of **control structure restrictor devices**. Included are details for the design of orifices, rectangular sharp-crested weirs, V-notch weirs, sutro weirs, and overflow risers.

Orifices. Flow-through orifice plates in the standard T-section or turn-down elbow may be approximated by the general equation:

$$Q = C\,A\sqrt{2gh} \qquad \text{(equation 4)}$$

where:

Q	=	flow (cubic feet per second)
C	=	coefficient of discharge (0.62 for plate orifice)
A	=	area of orifice (ft^2)

h = hydraulic head (ft)

g = gravity (32.2 ft/sec^2)

Figure 3.14 illustrates this simplified application of the orifice equation.

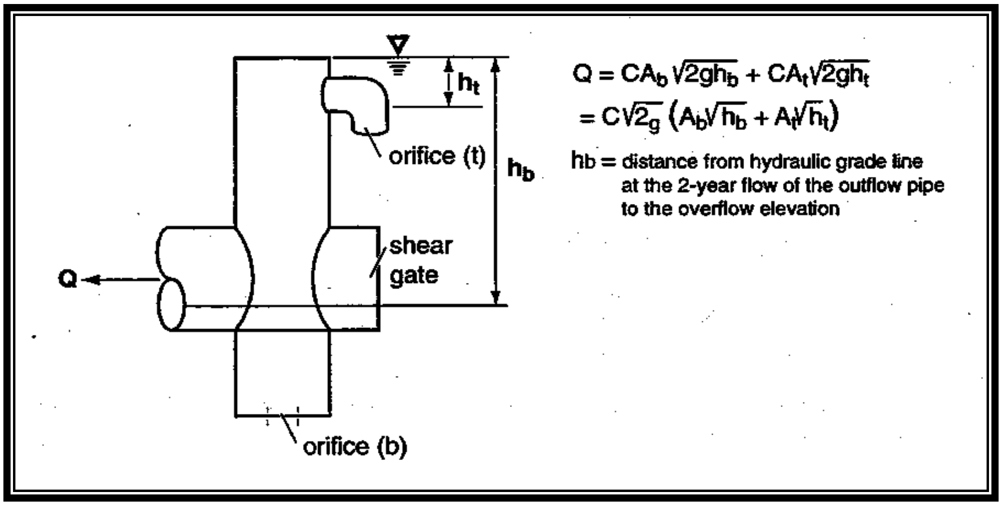


Figure 3.14. Simple Orifice.

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(equation 5)}$$

Where:

d = orifice diameter (inches)

Q = flow (cubic feet per second)

h = hydraulic head (ft)

Rectangular Sharp-Crested Weir. The rectangular sharp-crested weir design shown in Figure 3.15 may be analyzed using standard weir equations for the fully contracted condition.

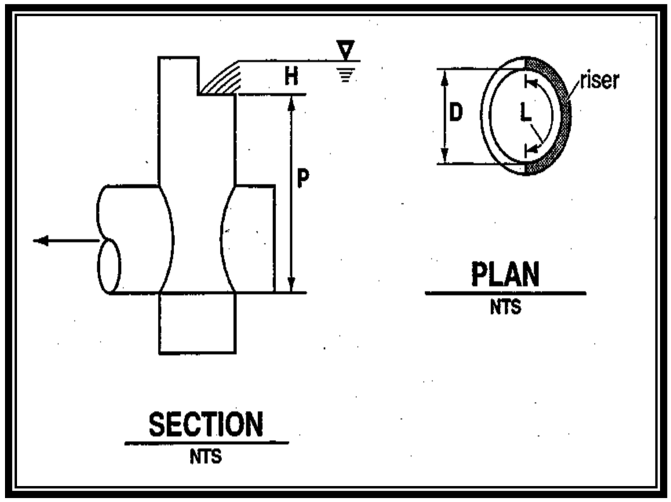


Figure 3.15. Rectangular, Sharp-Crested Weir.

$$Q=C\,(L - 0.2H)H^{3/2} \qquad \text{(equation 6)}$$

Where:

Q = flow (cubic feet per second)

C = 3.27 + 0.40 H/P (ft)

H, P are as shown above

L = length (ft) of the portion of the riser circumference as necessary not to exceed 50 percent of the circumference

D = inside riser diameter (ft)

Note that this equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.

V-Notch Sharp – Crested Weir. V-notch weirs as shown in Figure 3.16 may be analyzed using standard equations for the fully contracted condition.

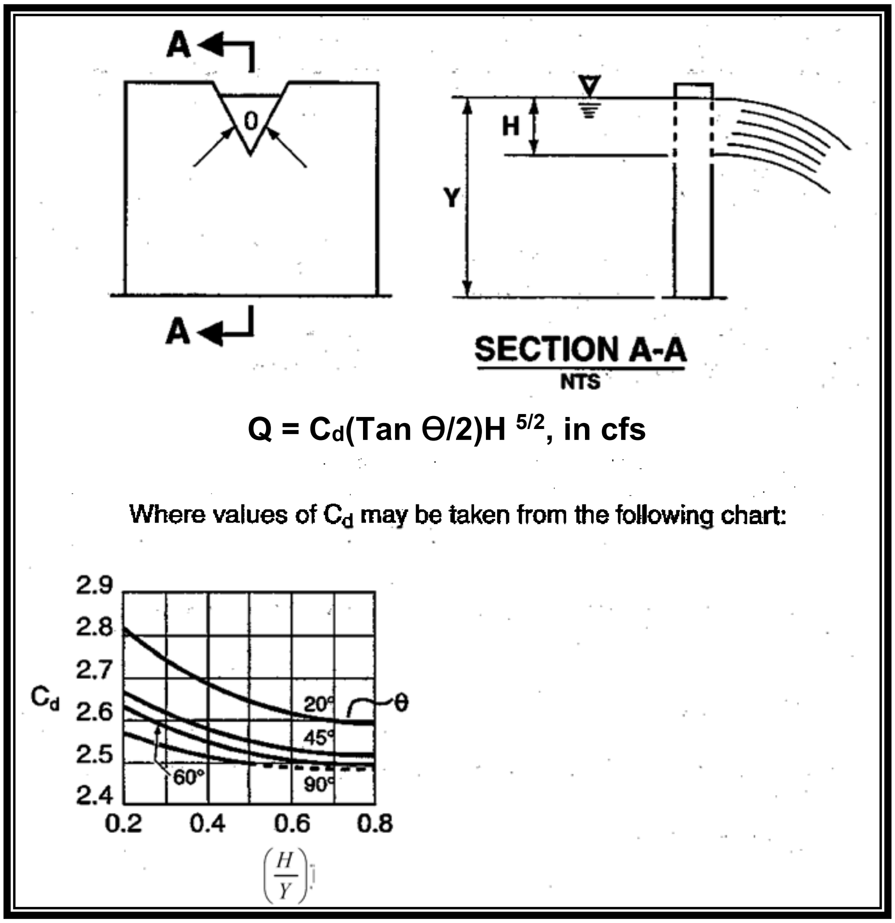


Figure 3.16. V-Notch, Sharp-Crested Weir.

Proportional or Sutro Weir. Sutro weirs are designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet performance requirements.

The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B (see Figure 3.17). The weir may be symmetrical or non-symmetrical.

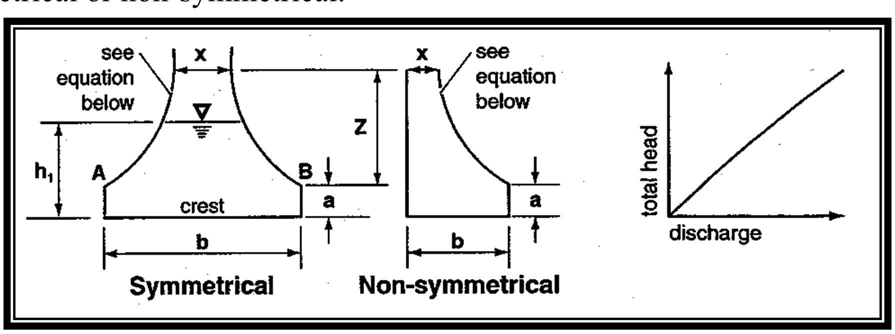


Figure 3.17. Sutro Weir.

For this type of weir, the curved portion is defined by the following equation (calculated in radians):

$$\frac{x}{b} = 1 - \frac{2}{\pi} Tan^{-1} \sqrt{\frac{Z}{a}} \qquad \text{(equation 7)}$$

where a, b, x and Z are as shown in Figure 3.17. The head-discharge relationship is:

$$Q = C_d \, b \sqrt{2ga} \left(h_1 - \frac{a}{3}\right) \qquad \text{(equation 8)}$$

Values of C_d for both symmetrical and non-symmetrical sutro weirs are summarized in Table 3.9.

Table 3.9. Values of C_d for Sutro Weirs.

C_d Values, Symmetrical					
	b (ft)				
a (ft)	0.50	0.75	1.0	1.25	1.50
0.02	0.608	0.613	0.617	0.6185	0.619
0.05	0.606	0.611	0.615	0.617	0.6175
0.10	0.603	0.608	0.612	0.6135	0.614
0.15	0.601	0.6055	0.610	0.6115	0.612
0.20	0.599	0.604	0.608	0.6095	0.610
0.25	0.598	0.6025	0.6065	0.608	0.6085
0.30	0.597	0.602	0.606	0.6075	0.608
C_d Values, Non-Symmetrical					
	b (ft)				
a (ft)	0.50	0.75	1.0	1.25	1.50
0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.603	0.608	0.612	0.6135	0.614

Note: When b > 1.50 or a > 0.30, use C_d=0.6.

Riser Overflow. The nomograph in Figure 3.18 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year recurrence interval peak flow for developed conditions).

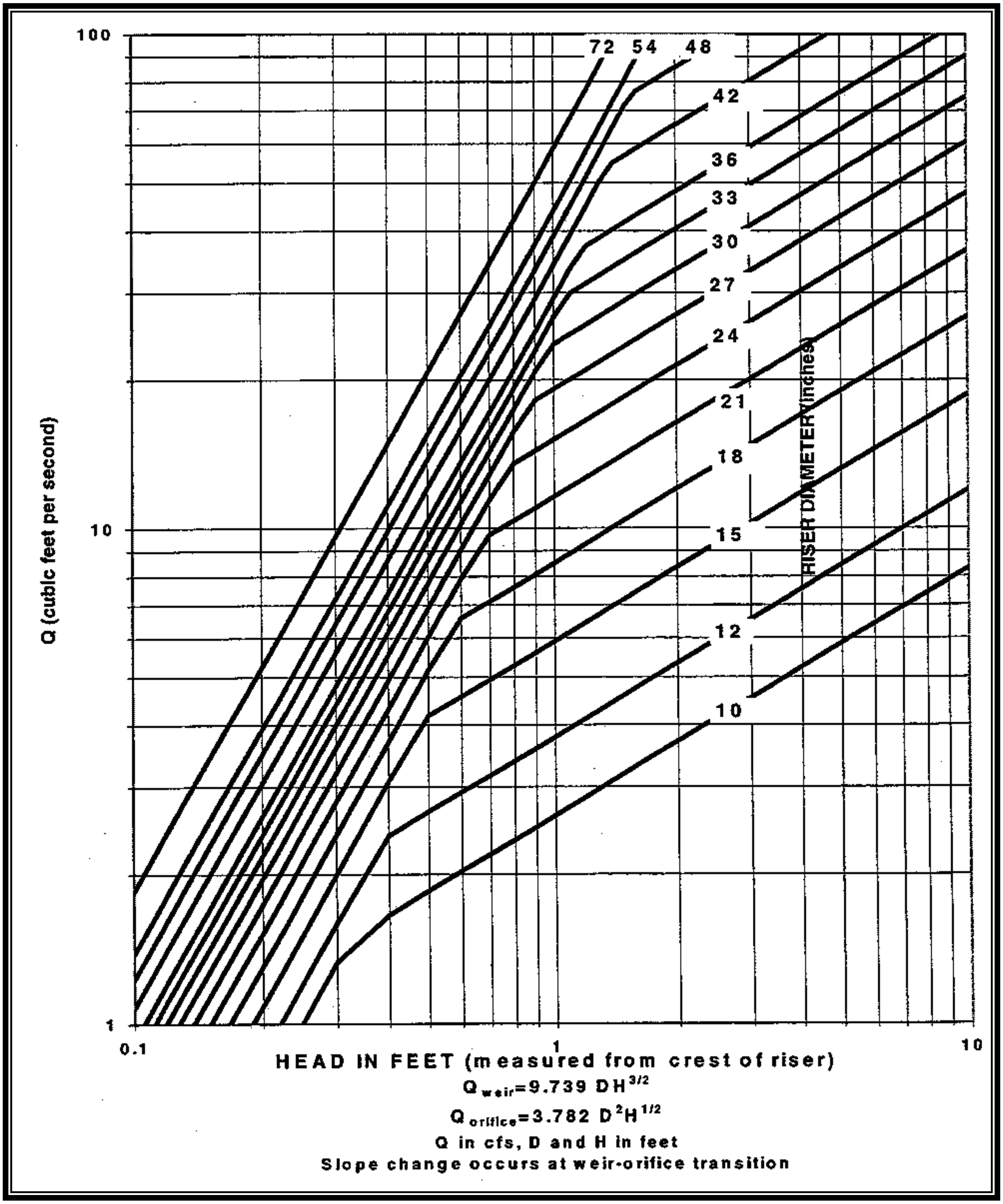


Figure 3.18. Riser Inflow Curves.

3.12.5 Other Detention Options

This section presents other design options for detaining flows to meet flow control facility requirements.

Use of Parking Lots for Additional Detention. Private parking lots may be used to provide additional detention volume for runoff events greater than the 2-year recurrence interval runoff event provided all of the following are met:

- The depth of water detained does not exceed 1 foot at any location in the parking lot for runoff events up to and including the 100-year recurrence interval event.
- The gradient of the parking lot area subject to ponding is 1 percent or greater.
- The emergency overflow path is identified and noted on the engineering plan. The overflow must not create a significant adverse impact to downhill properties or drainage system.
- Fire lanes used for emergency equipment are free of ponding water for all runoff events up to and including the 100-year recurrence interval event.

3.12.6 Use of Roofs for Detention

Detention ponding on roofs of structures may be used to meet flow control requirements provided all of the following are met:

- The roof support structure is analyzed by a structural engineer to address the weight of ponded water
- The roof area subject to ponding is sufficiently waterproofed to achieve a minimum service life of 30 years
- The minimum pitch of the roof area subject to ponding is one-fourth-inch per foot
- An overflow system is included in the design to safely convey the 100-year recurrence interval peak flow from the roof
- A mechanism is included in the design to allow the ponding area to be drained for maintenance purposes or in the event the restrictor device is plugged.

Chapter 4 - Conveyance Systems and Hydraulic Structures

4.1 Overview

This section presents acceptable methods for the analysis and design of conveyance systems. It also includes sections on hydraulic structures which link the conveyance system to the runoff treatment and flow control BMPs.

This section can be separated into the following eight categories:

- Design and analysis methods (Sections 4.2 through 4.6)
- Pipe systems (Section 4.7)
- Outfalls (Section 4.8)
- Flow spreaders (Section 4.9)
- Culverts (Section 4.10)
- Open conveyances (Section 4.11)
- Private drainage systems (Section 4.12)
- Floodplains/floodways (covered in Chapter 18.08 GHMC).

Where space and topography permit, open conveyances are the preferred means of collecting and conveying stormwater.

4.2 Design Event Storm Frequency

Ideally every conveyance system and hydraulic structure would be designed for the largest possible amount of flow that could ever occur. Unfortunately this would require unusually large structures and would add an unjustifiable cost to the projects; therefore hydraulic structures are analyzed for a specific storm frequency. When selecting a storm frequency for design purposes, consideration is given to the potential degree of damage to adjacent properties, potential hazard and inconvenience to the public, the number of users, and the initial construction cost of the conveyance system or hydraulic structure. The way in which these factors interrelate can become quite complex.

The design event recurrence interval is related to the probability that such an event will occur in any one year. For example, a peak flow having a 25-year recurrence interval has a 4 percent probability of being equaled or exceeded in any future year. A peak flow having a 2-year recurrence interval has a 50 percent probability of being equaled or exceeded in any future year. The greater the recurrence interval is, the lower the probability that the event will occur in any given year.

The design event for each conveyance system category is as follows:

The project's internal conveyance system shall be designed for a 25-year storm event. Culverts for and bridges over natural channels must convey the 100-year storm event under fully developed conditions. Culverts and bridges must also be designed to meet fish passage and scour criteria, where applicable. All conveyances within public roads or right-of-way shall be designed to pass a 25-year storm event from the contributing area under fully developed conditions.

4.3 Determination of Design Flows

All existing and proposed conveyance systems shall be analyzed and designed using the peak flows from the hydrographs developed through the hydrologic analysis in Chapter 2 and the release rates specified under Minimum Requirement #7. In general, either event-based or continuous runoff hydrologic modeling may be used for conveyance sizing. See Chapter 2 for full details.

Exception: For drainage subbasins 25 acres or less, and having a time of concentration of less than 100 minutes, the capacity of conveyance elements may be determined using the rational method.

If the City determines that, as a result of the project, runoff for any event from the 2-year through the 100-year recurrence interval event would cause damage or interrupt vital services, the city may require a backwater analysis.

4.4 Backwater Analysis

When a backwater calculation is required, the design engineer shall analyze for the 25- and 100-year, 24-hour design storm events.

For the 25-year event, there shall be a minimum of one-half a foot of freeboard between the water surface and the top of any manhole or catch basin.

For the 100-year event, overtopping of the pipe conveyance system may occur; however, the additional flow shall not extend beyond half the lane width of the outside lane of the traveled way and shall not exceed 4 inches in depth at its deepest point. Off-channel storage on private property is allowed with recording of the proper easements (see Section 4.6). The additional flow shall be analyzed by open channel flow methods.

A backwater profile analysis computer program such as the King County Backwater computer program by King County Department of Natural Resources is recommended over hand calculations. The subroutine, BPIPE, of King County Backwater may be used for quick computation of backwater profiles, given a range of flows through the existing or proposed pipe system.

4.5 Conveyance System Route Design

All pipes shall be located under the pavement flow line or lie outside of the pavement, unless otherwise specified below. Perpendicular crossings and cul-de-sacs are exempted from this requirement. For curved sections only of local road minors and local road cul-de-sacs, pipe placement may be located underneath pavement areas, but no closer than 6 feet from the roadway centerline. Pipes under permeable pavement sections will need to ensure flows are prevented from short circuiting through the pipe zone bedding.

New conveyance system alignments that are not in dedicated tracts or right-of-way shall be located in drainage easements that are adjacent and parallel to property lines. The width of the permanent easement must be completely within a single parcel or tract and not split between adjacent properties. Topography and existing conditions are the only conditions under which a drainage easement may be placed not adjacent and parallel to a property line. Requirements for conveyance system tracts and easements are discussed in Section 4.6 below.

Exception: Streams and natural drainage channels cannot be relocated to meet this routing requirement.

4.6 Easements, Access, and Dedicated Tracts

4.6.1 Natural Channels and Stormwater Facilities

All man-made drainage facilities and conveyances and all natural channels (on the project site) used for conveyance of altered flows due to development (including swales, ditches, stream channels, lake shores, wetlands, potholes, estuaries, gullies, ravines, etc.) shall be located within easements or dedicated tracts as required by the city. Easements shall contain the natural features and facilities and shall allow city access for purposes of inspection, maintenance, repair or replacement, flood control, water quality monitoring, and other activities permitted by law.

All drainage facilities such as detention or retention ponds or infiltration systems to be maintained by the city shall be located in separate tracts dedicated to the City. Conveyance systems can be in easements. Drainage facilities shall not be located in dedicated public road right-of-way areas, with the exception of city and highway facilities.

Drainage facilities that are designed to function as multi-use recreational facilities shall be located in separate tracts or in designated open space and shall be privately maintained and owned, unless accepted by and dedicated to the city.

4.6.2 Maintenance Access

A maintenance access road (and easement) must be provided for all manholes, catch basins, vaults, or other underground drainage facilities. This requirement does not apply to onsite stormwater management BMPs. A minimum 15-foot wide access easement shall be provided to the facilities from a public street or right-of-way. Access easements shall be surfaced with a minimum 12-foot width of crushed rock, or other approved surface to allow year-round equipment access to the facility. See also Section 3.12.1 for pond access requirements.

Maintenance shall be through an access easement or dedicated tract. Drainage structures for conveyance without vehicular access must be channeled.

4.6.3 Access to Conveyance Systems

All publicly and privately maintained conveyance systems shall be located in dedicated tracts, drainage easements, or public rights-of-way in accordance with this manual. Exception: roof downspout, minor yard, and footing drains unless they serve other adjacent properties.

Conveyance systems to be maintained and operated by the City of Gig Harbor must be located in a dedicated tract or drainage easement granted to the City of Gig Harbor. Any new conveyance system located on private property designed to convey drainage from other private properties must be located in a private drainage easement granted to the contributors of stormwater to the systems to convey surface and stormwater and to permit access for maintenance or replacement in the case of failure.

All drainage tracts and easements, public and private, must have a minimum width of 15 feet. In addition, all pipes and channels must be located within the tract, easement, or rights-of-way so that each pipe face or top edge of channel is no closer than 5 feet from its adjacent easement boundary. Pipes greater than 5 feet in diameter and channels with top widths greater than 5 feet shall be placed in easements adjusted accordingly, so as to meet the required dimensions from the boundaries.

Easements as shown in Table 4.1 are minimums for drainage facilities.

Table 4.1. Minimum Easement Widths for Conveyance Systems for Access, Inspection and Maintenance.

Conveyance Width	Easement Width
Channels ≤ 30 feet wide	Channel Width + 15 feet from top, one side
Channels > 30 feet wide	Channel Width + 15 feet from top, both sides
Pipes/Outfalls ≤ 36 inches	15 feet centered on pipe
Pipes/Outfalls ≤ 60 inches	20 feet centered on pipe[1]
Pipes/Outfalls > 60 inches	30 feet centered on pipe[1]

[1] May be greater, depending on depth and number of pipes in easement.

4.7 Pipe System Design Criteria

Pipe systems are networks of storm drain pipes, catch basins, manholes, and inlets designed and constructed to convey storm and surface water. These generally do not include individual stormwater management BMPs, but rather serve to route flows into or away from BMPs. The hydraulic analysis of flow in storm drain pipes typically is limited to "gravity flow;" however, in analyzing existing systems it may be necessary to address pressurized conditions.

4.7.1 Analysis Methods

Two methods of hydraulic analysis using Manning's Equation are used for the analysis of pipe systems. The first method is the Uniform Flow Analysis Method, commonly referred to as the Manning's Equation, and is used for the design of new pipe systems and analysis of existing pipe systems. The second method is the Backwater Analysis Method (see Section 4.4) and is used to analyze the capacity of both proposed, and existing, pipe systems. If the City determines that, as a result of the project, runoff for any event up to and including the 100-year, 24-hour event would cause damage or interrupt vital services, a backwater (pressure sewer) analysis shall be required. Results shall be submitted in tabular and graphic format showing hydraulic and energy gradient.

When using the Manning's Equation for design, each pipe within the system shall be sized and sloped such that its barrel capacity at normal full flow is equal or greater than the required conveyance capacity as identified in Section 4.5. Table 4.2 provides the recommended Manning's "n" values for preliminary design for pipe systems. (Note: The "n" values for this method are 15 percent higher in order to account for entrance, exit, junction, and bend head losses.) Manning's "n" values used for final pipe design must be documented in the Drainage Control Plan.

Table 4.2. Recommended Manning's "n" Values for Preliminary Pipe Design.

Type of Pipe Material	Analysis Method	
	Backwater Flow	Manning's Equation Flow
A. Concrete pipe and CPEP-smooth interior pipe	0.012	0.014
B. Annular Corrugated Metal Pipe or Pipe Arch:		
1. 2⅔ x ½ inch corrugation (riveted)		
a. plain or fully coated	0.024	0.028
b. paved invert (40% of circumference paved):		
(1) flow full depth	0.018	0.021
(2) flow 0.8 depth	0.016	0.018
(3) flow 0.6 depth	0.013	0.015
c. treatment 5	0.013	0.015
2. 2.3 x 1-inch corrugation	0.027	0.031
3. 3.6 x 2-inch corrugation (field bolted)	0.030	0.035
C. Helical 2⅔ x ½-inch corrugation and CPEP-single wall	0.024	0.028
D. Spiral rib metal pipe and PVC pipe	0.011	0.013
E. Ductile iron pipe cement lined	0.012	0.014
F. High density polyethylene pipe (butt fused only)	0.009	0.009

Nomographs may also be used for sizing the pipes. For pipes flowing partially full, the actual velocity may be estimated from engineering nomographs by calculating Q_{full} and V_{full} and using the ratio of Q_{design}/Q_{full} to find V and d (depth of flow). Appendix III-C includes several nomographs that may be useful for culvert sizing.

4.7.2 Acceptable Pipe Sizes

All storm drainage pipe, except as otherwise provided for in these standards, must have a minimum of 12-inch diameter. One exception is for cross-street connections from a concrete inlet to a Type 1 or 2 catch basin or manhole (CB leads). Under these conditions, plain concrete, 8-inch diameter, storm sewer pipe may be used. Storm sewer pipe used for private roof/footing/yard drain systems or other onsite stormwater management BMPs can be less than 12-inch diameter and sized according to the application and design standards presented in Chapter 3.

4.7.3 Pipe Materials

All storm drainage pipe, except as otherwise provided for in these standards, shall be as per current WSDOT Standard Specifications 9-05. When extreme slope conditions or other unusual topographic conditions exist, pipe materials and methods such as, but not limited to, PVC, HDPE, or ductile iron pipe should be used.

4.7.4 Pipe Slope and Velocity

Minimum velocity is 2 feet per second at design flow. The city may waive these minimums in cases where topography and existing drainage systems make it impractical to meet the standard.

Maximum slopes, velocities, and anchor spacings are shown in Table 4.3. If velocities exceed 15 feet per second for the conveyance system design event, provide anchors at bends and junctions. See Attachments Section A, Detail 20.0.

Table 4.3. Maximum Pipe Slopes and Velocities.

Pipe Material	Pipe Slope Above Which Pipe Anchors Required and Minimum Anchor Spacing	Max. Slope Allowed	Max. Velocity @ Full Flow
Spiral Rib, PVC, CPEP-single wall[1]	20% (1 anchor per 100 L.F. of pipe)	30%[3]	30 fps
Concrete or CPEP-smooth interior[1]	10% (1 anchor per 50 L.F. of pipe)	20%[3]	30 fps
Ductile Iron	40% (1 anchor per pipe section)	None	None
HDPE[2]	50% (1 anchor per 100 L.F. of pipe – cross slope installations only)	None	None

1 Not allowed in landslide hazard areas.
2 Butt-fused pipe joints required. Above-ground installation is required on slopes greater than 40% to minimize disturbance to steep slopes.

[3] Maximum slope of 200% allowed for these pipe materials with no joints (one section) with structures at each end and properly grouted.
Key: PVC = Polyvinyl chloride pipe
CPEP = Corrugated high density polyethylene pipe
HDPE = High density polyethylene

Pipe direction changes or size increases or decreases are allowed only at manholes and catch basins. This does not apply to detention tanks or vaults.

Downsizing of pipes is only allowed under special conditions (i.e., no hydraulic jump can occur; downstream pipe slope is significantly greater than the upstream slope; velocities remain in the 3 to 8 fps range, etc.).

Downsizing of downstream culverts within a closed system with culverts 18-inches in diameter or smaller will not be permitted.

Pipes connecting into a structure shall match crown elevations.

4.7.5 Pipes on Steep Slopes

Steep slopes (greater than 20 percent) shall require all drainage to be piped from the top to the bottom in HDPE pipe (butt fused) or ductile iron pipe welded or mechanically restrained. Additional anchoring design is required for these pipes.

4.7.6 Pipe System Layout Criteria

Pipes must be laid true to line and grade with no curves, bends, or deflections in any direction (except for HDPE and Ductile Iron with flanged restrained mechanical joint bends, not greater than 30 degrees, on steep slopes).

A break in grade or alignment or changes in pipe material shall occur only at catch basins or manholes.

Connections to a pipe system shall be made only at catch basins or manholes. No wyes or tees are allowed except on private roof/footing/yard drain systems on pipes 8-inches in diameter, or less, with cleanouts upstream of each wye or T.

Provide 6 inches minimum vertical and 3 feet minimum horizontal clearance (outside surfaces) between storm drain pipes and other utility pipes and conduits. Gig Harbor Sewer Utility criteria will apply for crossings of or parallel runs with City of Gig Harbor sewer lines. For crossings of water lines the City of Gig Harbor Public Works Standards will apply. Contact the City of Gig Harbor Public Works Department at (253) 851-6170 for more information.

Suitable pipe cover over storm pipes in road rights-of-way shall be calculated for loading by the Project Engineer that meet the standards in Chapter 15 GHMC. Pipe cover is measured from the finished grade elevation down to the top of the outside surface of the pipe. Pipe manufacturers' recommendations are acceptable if verified by the Project Engineer.

PVC, SDR 35, minimum cover shall be 3 feet in areas subject to vehicular traffic. Unless calculated for loading by the Project Engineer that meet the standards in Chapter 15 GMC, pipe cover is measured from the finished grade elevation down to the top of the outside surface of the pipe. Pipe manufacturers' recommendations are acceptable if verified by the Project Engineer; maximum cover shall be 25 feet per WSDOT/APWA Standard Specifications Section 7-04.

Pipe cover in areas not subject to vehicular loads, such as landscape planters and yards, may be reduced to a 1 foot minimum.

Access barriers are required on all pipes 18 inches and larger exiting a closed pipe system. Debris barriers (trash racks) are required on all pipes entering a pipe system. See Attachments Section A, Details 17.0 and 17.1 for required debris barriers on pipe ends outside of roadways and for requirements on pipe ends (culverts) projecting from driveways or roadway sideslopes.

Where a minimal fall is necessary between inlet and outlet pipes in a structure, pipes must be aligned vertically by one of the following in order of preference:

- Match pipe crowns
- Match 80 percent diameters of pipes
- Match pipe inverts.

Where inlet pipes are higher than outlet pipes, drop manhole connections may be required or increased durability in the structure floor may be required.

High Density Polyethylene (HDPE) pipe systems longer than 100 feet must be anchored at the upstream end if the slope exceeds 25 percent and the downstream end placed in a minimum 4 foot long section of the next larger pipe size. This sliding sleeve connection allows for the high thermal expansion/contraction coefficient of the pipe material.

4.7.7 Pipe Structure Criteria

Catch Basins and Manholes

For the purposes of this manual, all catch basins, manholes, and connecting pipe sizes shall meet current WSDOT Standard Specifications and Plans. The following criteria shall be used when designing a conveyance system which utilizes catch basins or manholes:

Unless otherwise required by the city, Type 1 catch basins shall be used at the following locations or for the following situations:

- When overall structure height does not exceed 8 feet or when invert does not exceed 5 feet
- When all pipes tying into the structure connect at or very near to right angles.

Unless otherwise required by the City, Type 1L catch basins must be used at the following locations or for the following situations:

- When overall structure height does not exceed 8 feet or when invert does not exceed 5 feet

Unless otherwise required by the City, Type 2 (48-inch minimum diameter) catch basins shall be used at the following locations or for the following situations:

- When overall structure height does not exceed 15 feet.
- When all pipes tying into the structure do not exceed the limits set forth by the manufacturers. Type 2 catch basins over 4 feet in height shall have standard ladders.

Where an approved connection of a private stormwater drainage system into a city system occurs, a minimum of a Type 1 catch basin shall be used in the City of Gig Harbor.

Catch basin (or manhole) diameter shall be determined by pipe diameter and orientation at the junction structure. A plan view of the junction structure, drawn to scale, will be required when more than four pipes enter the structure on the same plane, or if angles of approach and clearance between pipes is of concern. The plan view (and sections if necessary) must ensure a minimum distance (of solid concrete wall) between pipe openings of 8 inches for 48 inch and 54 inch diameter catch basins and 12 inches for 72 inch and 96 inch diameter catch basins.

Catch basin evaluation of structural integrity for loading defined in Chapter 15 GHMC will be required for multiple junction catch basins and other structures which exceed the recommendations of the manufacturers.

The WSDOT Hydraulics Manual can be used in determining the capacity of inlet grates when capacity is of concern. When verifying capacity, assume grate areas on slopes are 80 percent free of debris, and “vaned” grates are 95 percent free. In sags or low spots, assume grates are 50 percent free of debris, and “vaned” grates, 75 percent free.

The maximum slope of the ground surface for a radius of 5 feet around a catch basin grate shall be 3:1.

Catch basins shall be provided within 50 feet of the entrance to a pipe system to provide for silt and debris removal.

Maximum spacing of structures for storm drainage conveyance lines shall be 350 feet for pipe grades greater than 0.3 percent and 200 feet for grades less than 0.3 percent. Structures not acting as points of entry for stormwater shall have locking lids and have solid covers.

Locking lids will be installed on all structures containing restrictor or flow devices. Locking lids shall use WSDOT Standard Plan B-30.70-04 with the lettering of “STORM” or other city pre-approved design.

Maximum surface runs between inlet structures on the paved roadway surface shall be as stated in the latest publication of the City of Gig Harbor Public Works Standards.

A metal frame and grate for catch basin and inlet, most current version of WSDOT Standard Plan B-30.10-03 and B-30.15-00 or preapproved city standard grate that is deemed bicycle safe, shall be used for all structures collecting drainage from the paved roadway surface. Bolt-down grates must be provided on all structures in public tracts and rights-of-ways.

When the road profile equals or exceeds 6 percent between structures , an asphalt berm per detail found in Attachment Section A, Detail 10.0 shall be installed near the inlet of the structure or spacing between catch basins must be shortened to account for decreased inflow.

All catch basins, inlets, etc., shall be marked as shown in Attachments Section A, Detail 22.0.

Flow Splitter Designs

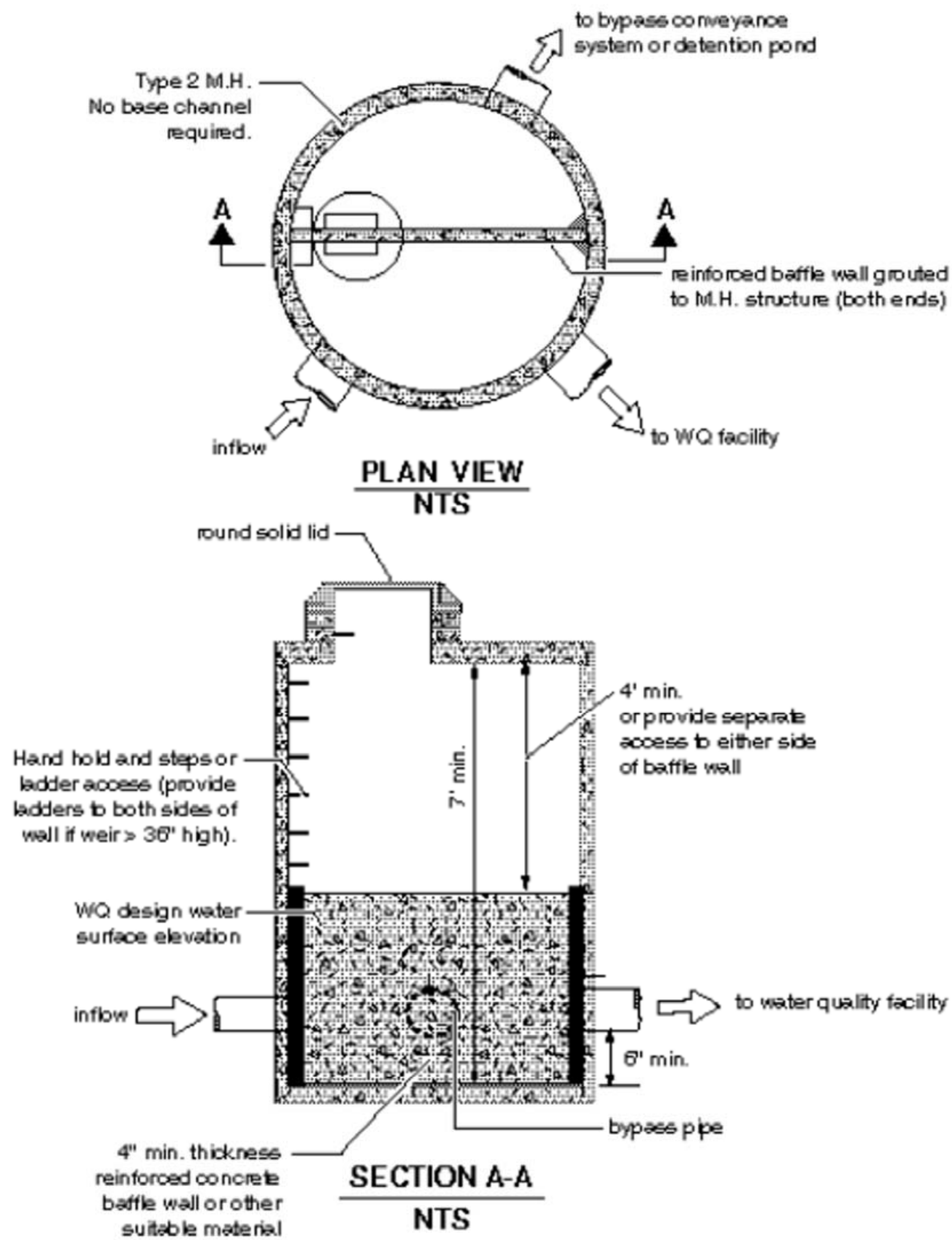
Many water quality facilities can be designed as flow-through or on-line systems with flows above the water quality design flow or volume simply passing through the facility at a lower pollutant removal efficiency. However, it is sometimes desirable to restrict flows to water quality treatment facilities and bypass the remaining higher flows around them through off-line facilities. This can be accomplished by splitting flows in excess of the water quality design flow upstream of the facility and diverting higher flows to a bypass pipe or channel. The bypass typically enters a flow control facility or the downstream receiving drainage system, depending on flow control requirements. In most cases, it is a designer’s choice whether water quality 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 that low flows are delivered to the treatment facility up to the water quality 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 water quality facility under high flow conditions. Flow splitters may be used for purposes other than diverting flows to water quality facilities. However, the following discussion is generally focused on using flow splitters in association with water quality facilities.

Flow splitters are typically manholes or vaults with concrete baffles. In place of baffles, the splitter mechanism may be a half T-section with a solid top and an orifice in the bottom of the T-section. A full T option may also be used as described below in the “General Design Criteria.” Two possible design options for flow splitters are shown in Figure 4.1 and Figure 4.2 (source: King County). Other equivalent designs that achieve the result of splitting low flows and diverting higher flows around the facility are also acceptable.

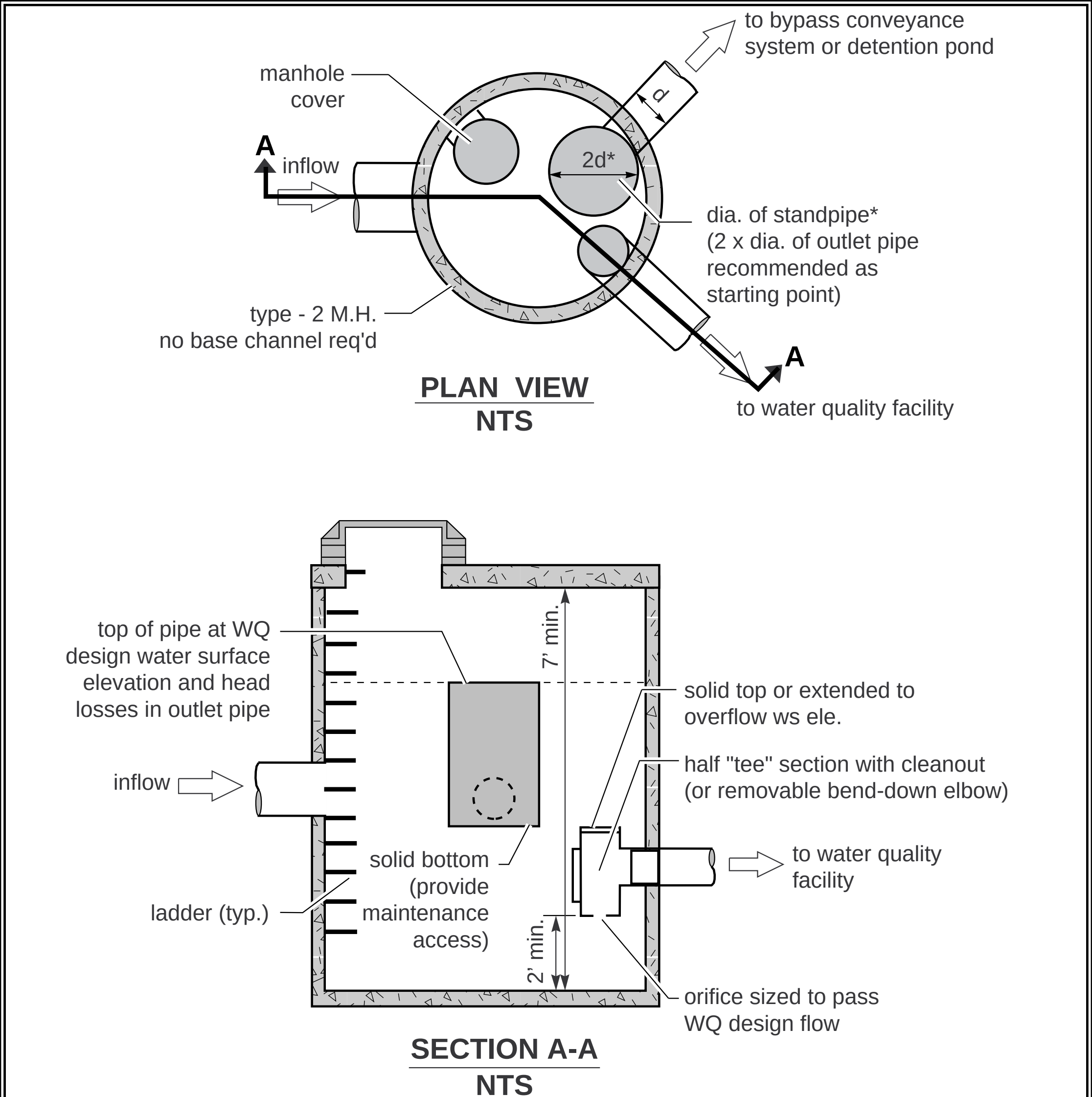
General Design Recommendations

- Unless otherwise specified, a flow splitter should be designed to deliver the water quality design flow rate specified to the water quality treatment facility (see also Volume V). Flows modeled using a continuous simulation runoff model shall use 15-minute time steps.



Note: The water quality discharge pipe may require an orfice plate be installed on the outlet to control the height of the design water surface (weir height). The design water surface should be set to provide a minimum headwater/diameter ratio of 2.0 on the outlet pipe.

Figure 4.1. Flow Splitter, Option A.



*** NOTE:** Diameter (d) of standpipe should be large enough to minimize head above W.Q. design W.S. and to keep W.Q. design flows from increasing more than 10% during 100-year flows.

Figure 4.2. Flow Splitter, Option B.

- The top of the weir should be located at the water surface for the design flow. Remaining flows enter the bypass line.
- The maximum head should be minimized for flow in excess of the water quality design flow. Specifically, flow to the water quality facility at the 100-year water surface should not increase the design water quality flow by more than 10 percent.
- Either design shown in Figure 4.1 or Figure 4.2 or an equivalent design may be used.
- As an alternative to using a solid top plate in Figure 4.2, a full T-section may be used with the top of the T-section at the 100-year water surface. This alternative would route emergency overflows (if the overflow pipe were plugged) through the water quality facility rather than back up from the manhole.
- Special applications, such as roads, 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 included 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 to either side of the wall, should be used.

Materials

- The splitter baffle may be installed in a Type 2 manhole or vault.
- The baffle wall should 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 should 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. Zinc and galvanized materials are discouraged because of aquatic toxicity. Painted metal parts should not be used because of poor longevity.

4.8 Outfalls

All piped discharges to streams, rivers, ponds, lakes, or other open bodies of water are designated outfalls and shall provide for energy dissipation to prevent erosion at or near the point of discharge. Properly designed outfalls are critical to reducing the chance of adverse impacts as the result of concentrated discharges from pipe systems and culverts, both onsite and downstream. Outfall systems include rock splash pads, flow dispersal trenches, gabion or other energy dissipaters, and tightline systems. A tightline 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.

4.8.1 General Design Criteria for Outfall Features

All energy dissipation at outfalls shall be designed for peak flows from a 100-year, 24-hour storm event. For outfalls with a maximum flow velocity of less than 10 feet per second, a rock splash pad is acceptable. For velocities equal to or greater than 10 feet per second, an engineered energy dissipater must be provided. See Table 4.4 and Attachments Section A, Details 8.0 and 9.0 for a summary of the rock protection requirements at outfalls.

Table 4.4. Rock Protection at Outfalls.

Discharge Velocity at Design Flow in feet per second (fps)	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				

Footnotes:

(1) **Rock lining** shall be quarry spalls with gradation as follows:
Passing 8-inch square sieve: 100%
Passing 3-inch square sieve: 40 to 60% maximum
Passing 0.75-inch square sieve: 0 to 10% maximum

(2) **Riprap** shall 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 governed by side slopes on outlet channel is assumed to be approximately 3:1.

The following sections provide general design criteria for various types of outfall features.

General Design Criteria to Protect Aquatic Species and Habitat

Outfall structures should be located where they minimize impacts to fish, shellfish, and their habitats. However, new pipe outfalls can also 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, over widened to the upstream side, from the outfall to the stream. 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 (WDFW) biologist prior to inclusion in design.

Bank stabilization, bioengineering, and habitat features may be required for disturbed areas. Outfalls that discharge to the Puget Sound or a major water body may require tide gates. Contact the City for specific requirements.

Rock Splash Pad

At a minimum, all outfalls must be provided with a rock splash pad (see Attachments Section A, Detail 8.0) except as specified below and in Table 4.4.

Flow Dispersal Trench

The flow dispersal trenches (see also Attachments Section A, Detail 1.0) should only be used when both criteria below 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 one-half of a cubic foot per second.

4.8.2 Tightline Systems

Tightline systems may be needed to prevent aggravation or creation of a downstream erosion problem. The following general design criteria apply to tightline systems:

- Outfall tightlines may be installed in trenches with standard bedding on slopes up to 20 percent. In order to minimize disturbance to slopes greater than 20 percent, it is recommended that tightlines be placed at grade with proper pipe anchorage and support.
- Except as indicated above, tightlines or conveyances that traverse the marine intertidal zone and connect to outfalls should be buried to a depth sufficient to avoid exposure of the line during storm events or future changes in beach elevation. If non-native material is used to bed the tightline, such material should be covered with at least 3 feet of native bed material or equivalent.

- High density polyethylene pipe (HDPP) tightlines 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 pipe (SWPE) is on the order of 0.001 inch per foot per Fahrenheit degree. Sliding sleeve connections should 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. These sleeve connections should be located as close to the discharge end of the outfall system as is practical.
- Due to the ability of HDPP tightlines to transmit flows of very high energy, special consideration for energy dissipation must be made. Details of a sample gabion mattress energy dissipater have been provided in Attachments Section A, Detail 9.0. Flows of very high energy will require a specifically engineered energy dissipater structure.

4.9 Flow Spreading Options

Flow spreaders function to uniformly spread flows across the inflow portion of several types of stormwater management facilities (e.g., sand filters, biofiltration swales, filter strips, bioretention areas). There are five flow spreader options 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, and in some cases must be used, such as to correct for moderate grade changes along a filter strip.

Options D and E are only for flows that are already unconcentrated and enter a filter strip, bioretention area or continuous inflow biofiltration swale. Other flow spreader options are possible with approval from the reviewing authority.

4.9.1 General Design Criteria

- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.

- For higher inflows (velocities greater than 5 feet per second for the 100-year recurrence interval 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.

Option A – Anchored Plate (Figure 4.3)

- An anchored plate flow spreader should be preceded by a sump having a minimum depth of 8 inches and minimum width of 24 inches. If not otherwise stabilized, the sump area should be lined to reduce erosion and to provide energy dissipation.
- The top surface of the flow spreader plate should be level, projecting a minimum of 2 inches above the ground surface of the water quality facility, or V-notched with notches 6 to 10 inches on center and 1 to 6 inches deep (use shallower notches with closer spacing). Alternative designs may also be used.
- A flow spreader plate should extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The horizontal extent should be such that the bank is protected for all flows up to the 100-year recurrence interval flow or the maximum flow that will enter the water quality facility.
- Flow spreader plates should be securely fixed in place.
- Flow spreader plates may be made of either wood, metal, fiberglass reinforced plastic, or other durable material. If wood, pressure treated 4- by 10-inch lumber or landscape timbers are acceptable.
- Anchor posts should be 4-inch square concrete, tubular stainless steel, or other material resistant to decay.

Option B – Concrete Sump Box (Figure 4.4)

- The wall of the downstream side of a rectangular concrete sump box should 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 should have “wing walls” at both ends. Side walls and returns should 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 should be reinforced with wire mesh for cast-in-place sumps.
- Sump boxes should be placed over bases that consists of 4 inches of crushed rock, five-eighths-inch minus to help assure the sump remains level.

Option C – Notched Curb Spreader (Figure 4.5)

Notched curb spreader sections should be made of extruded concrete laid side-by-side and level. Typically five “teeth” per 4-foot section provide good spacing. The space between adjacent “teeth” forms a V-notch.

Option D –Through-Curb Ports (Figure 4.6)

Unconcentrated flows from paved areas entering filter strips, bioretention areas, or continuous inflow biofiltration swales can use curb ports or interrupted curbs (Option E) to allow flows to enter the strip or swale. Curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the water quality facility.

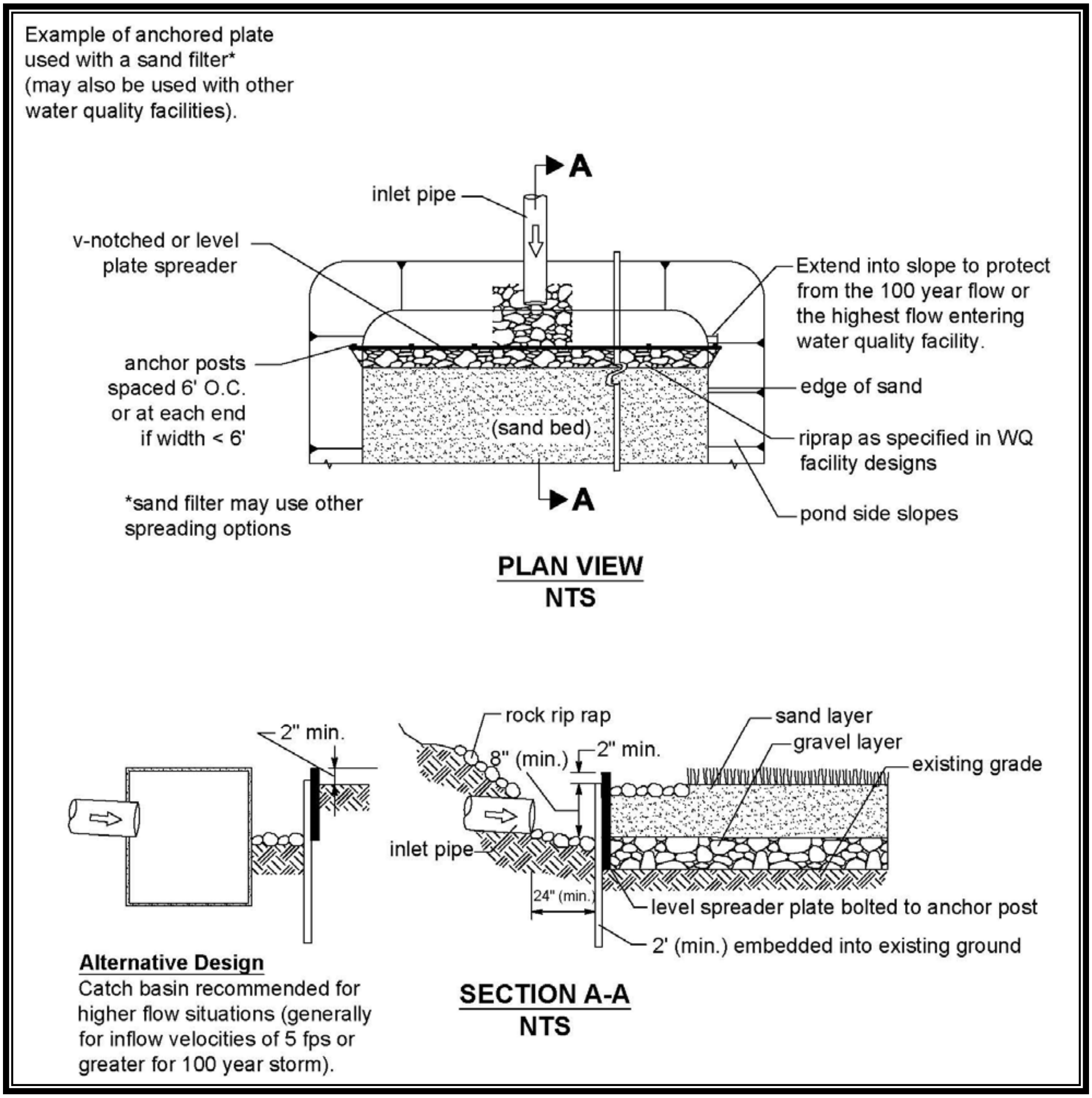


Figure 4.3. Flow Spreader Option A: Anchored Plate.

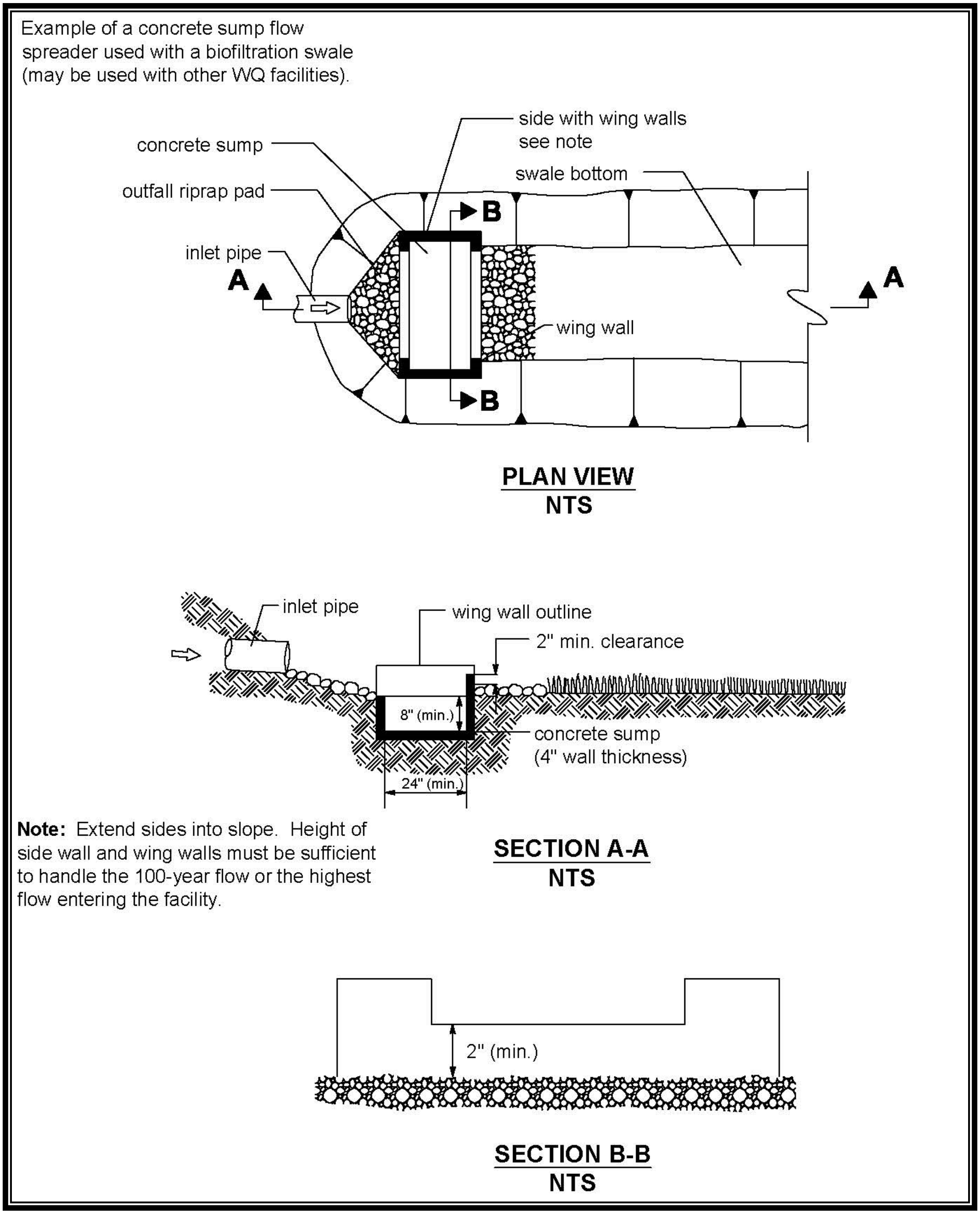


Figure 4.4. Flow Spreader Option B: Concrete Sump Box.

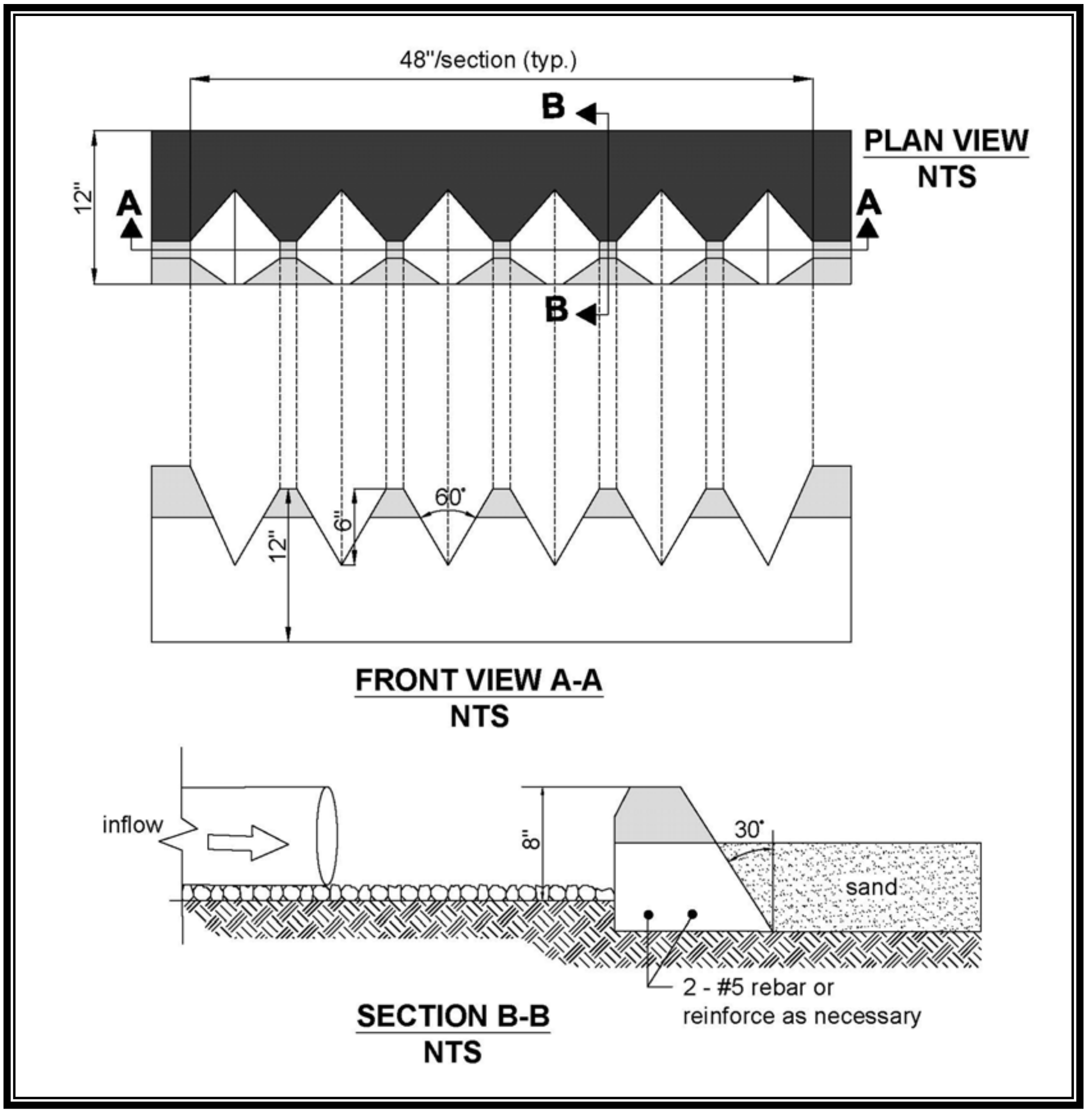


Figure 4.5. Flow Spreader Option C: Notched Curb Spreader.

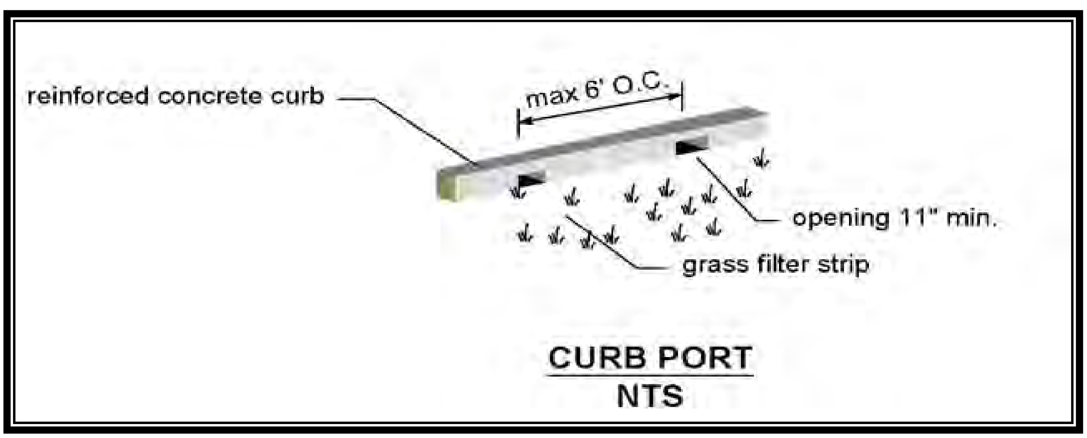


Figure 4.6. Flow Spreader Option D: Through-Curb Port.

Openings in the curb should be at regular intervals but at least every 6 feet (minimum). The width of each curb port opening should be a minimum of 11 inches. Approximately 15 percent or more of the curb section length should be in open ports, and no port should discharge more than about 10 percent of the flow.

Option E – Interrupted Curb (No Figure)

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on facility) of the treatment area. At a minimum, gaps should be every 6 feet to allow distribution of flows into the treatment facility before they become too concentrated. The opening should be a minimum of 12 inches. As a general rule, no opening should discharge more than 10 percent of the overall flow entering the facility. This option is not allowed along roadways.

4.10 Culvert Criteria

For the purpose of this manual, culverts are single runs of pipe that are open at each end and have no structures such as manholes or catch basins.

Approved pipe materials are detailed in Section 4.7.3. Galvanized or aluminized pipe are not permitted in marine environments or where contact with salt water may occur, even infrequently through backwater events.

4.10.1 Culvert Design Criteria

Flow capacity shall be determined by analyzing inlet and outlet control for headwater depth. Nomographs used for culvert design shall be included in the submitted engineering Report. Appendix III-C also includes several nomographs that may be useful for culvert sizing.

All culverts shall be designed to convey the flows per Section 4.2. The maximum design headwater depth shall be 1.5 times the diameter of the culvert with no saturation of roadbeds. Minimum culvert diameters are as follows:

- For cross culverts under public roadways – minimum 18 inches, 12 inches if grade and cover do not allow for 18 inches
- For roadside culverts, including driveway culverts, minimum 12 inches
- For culverts on private property, minimum 8 inches.

Inlets and outlets shall be protected from erosion by rock lining, riprap, or biostabilization as detailed in Table 4.5.

Debris and access barriers are required on inlet and outlet ends of all culverts greater than 18 inches in diameter. Culverts greater than 36 inches in diameter within stream corridors are exempt.

Table 4.5. Open Conveyance Protection.

Velocity at Design Flow (fps)				
Greater Than	**Less Than or Equal To**	**Protection**	**Thickness**	**Min. Height Required Above Design Water Surface**
0	5	Grass Lining[3]	N/A	0.5 ft.
5	8	Riprap[1,3]	1 ft.	2 ft.
8	12	Riprap[2]	2 ft.	2 ft.
12	20	Slope mattress, gabion, etc.	Varies	1 ft.

[1]Riprap shall be in accordance with Section 9-13.1 of the WSDOT/APWA standard specifications.
Riprap shall be a reasonably well graded assortment of rock with the following gradation:
Maximum stone size 12”
Median stone size 8“
Minimum stone size 2“
[2]Riprap shall be reasonably well graded assortment of rock with the following gradation:
Maximum stone size 24“
Median stone size 16“
Minimum stone size 4“
Note: Riprap sizing governed by side slopes on channel, assumed ~3.1.
[3]Bioengineered lining allowed for design flow up to 8 fps.

Minimum culvert velocity shall be 2 feet per second and maximum culvert velocity shall be 15 feet per second. Thirty (30) feet per second may be used with an engineered outlet protection designed. No maximum velocity for ductile iron or HDPE pipe shall be established but outlet protection shall be provided.

All CPEP and PVC culverts and pipe systems shall have concrete or rock headwalls at exposed pipe ends.

Bends are not permitted in culvert pipes.

The following minimum cover shall be provided over culverts:

- 2 feet under roads
- 1 foot under roadside applications and on private property, exclusive of roads
- If the minimum cover cannot be provided on a flat site, use ductile iron pipe and analyze for loadings
- Maximum culvert length: 250 feet
- Minimum separation from other pipes:
  - 6 inches vertical (with bedding) and in accordance with the the City of Gig Harbor Public Works Standards
  - 3 feet horizontal.

Trench backfill shall be bankrun gravel or suitable native material compacted to 95 percent Modified Proctor test to a depth of 2 feet; 90 percent below 2 feet compacted in 8 inch to 12 inch lifts.

All driveway culverts shall be of sufficient length to provide a minimum 3:1 slope from the edge of the driveway to the bottom of the ditch. Culverts shall have beveled end sections to match the side slope.

4.10.2 Fish Passage Criteria

Culverts in stream corridors must meet any fish passage requirements of the WDFW.

4.11 Open Conveyances

Open conveyances can be either roadside ditches, grass lined swales, or a combination thereof. Consideration must be given to public safety when designing open conveyances adjacent to traveled ways and when accessible to the public. Where space and topography permit, open conveyances are the preferred means of collecting and conveying stormwater.

Open conveyances shall be designed by one of the following methods:

- Manning's Equation (for uniform flow depth, flow velocity, and constant channel cross-section)
- Direct Step Backwater Method (utilizing the energy equation)
- Standard Step Backwater Method (utilizing a computer program).

Velocities must be low enough to prevent channel erosion based on the native soil characteristics or the compacted fill material. For velocities above 5 feet per second, channels shall have either rock-lined bottoms and side slopes to the roadway shoulder top with a minimum thickness of 8 inches, or shall be stabilized in a fashion acceptable to the city. Water quality shall not be degraded due to passage through an open conveyance. See Table 4.5.

Channels having a slope less than 6 percent and having peak velocities less than 5 feet per second shall be lined with vegetation.

Channel side slopes shall not exceed 2:1 for undisturbed ground (cuts) as well as for disturbed ground (embankments). All constructed channels shall be compacted to a minimum 95 percent compaction as verified by a Modified Proctor test. Channel side slopes adjacent to roads shall not exceed 4:1 and will meet all other AASHTO and City road standards.

Channels shall be designed with a minimum freeboard of one-half-foot when the design flow is 10 cubic feet per second or less and 1 foot when the design discharge is greater than 10 cubic feet per second.

Check dams for erosion and sedimentation control may be used for stepping down channels being used for biofiltration.

4.12 Private Drainage Systems

The engineering analysis for a private drainage system is the same as for a City system.

4.12.1 Discharge Locations

Stormwater will not be permitted to discharge directly onto City roads or into a City system without the prior approval of the City. Discharges to a City system shall be into a structure such as an inlet, catch basin, manhole, through an approved sidewalk underdrain or curb drain, or into an existing or created City ditch. Concentrated drainage will not be allowed to discharge across sidewalks, curbs, or driveways.

4.12.2 Drainage Stub-Outs

If drainage outlets (stub-outs) are to be provided for each individual lot, the stub-outs shall conform to the requirements outlined below. Note that all applicable Minimum Requirements in Volume I, in particular Minimum Requirement #5, must also be addressed for the project site.

- Each outlet shall be suitably located at the lowest elevation on the lot, so as to service all future roof downspouts and footing drains, driveways, yard drains, and any other surface or subsurface drains necessary to render the lots suitable for their intended use. Each outlet shall have free-flowing, positive drainage to an approved stormwater conveyance system or to an approved discharge location.
- Outlets on each lot shall be located with a 5-foot-high, 2- x 4-inch stake marked “storm” or “drain.” For stub-outs to a surface drainage, the stub-out shall visibly extend above surface level and be secured to the stake.
- The developer and/or contractor is responsible for coordinating the locations of all stub-out conveyance lines with respect to the utilities (e.g., power, gas, telephone, television).
- All individual stub-outs shall be privately owned and maintained by the lot home owner including from the property line to the riser on the main line.

Volume III References and Information Sources

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