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Acknowledgements

This manual volume largely incorporates the contents of Ecology’s 2005 Stormwater Management Manual for Western Washington, Volume III.

Acronym Glossary

<table>
<thead>
<tr>
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<tr>
<td>AKART</td>
<td>All known, available, and reasonable means have been taken</td>
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<tr>
<td>ATB</td>
<td>Asphalt Treated Base</td>
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<tr>
<td>BFM</td>
<td>Bonded Fiber Matrix</td>
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<tr>
<td>BMPs</td>
<td>Best Management Practices</td>
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<tr>
<td>CESCL</td>
<td>Contractor Erosion and Spill Control Lead</td>
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<tr>
<td>CESCP</td>
<td>Contractor’s Erosion and Sediment Control Plan</td>
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<tr>
<td>CPESC</td>
<td>Certified Professional in Erosion and Sediment Control</td>
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<tr>
<td>Ecology</td>
<td>Washington State Department of Ecology</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>ESA</td>
<td>Endangered Species Act</td>
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<td>ESC</td>
<td>Erosion and Sediment Control</td>
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<td>FCWA</td>
<td>Federal Clean Water Act</td>
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<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
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<tr>
<td>IECA</td>
<td>International Erosion Control Association</td>
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<tr>
<td>MBFM</td>
<td>Mechanically Bonded Fiber Matrix</td>
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<tr>
<td>NOEC</td>
<td>No observed effects concentration</td>
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<td>NOI</td>
<td>Notice of Intent</td>
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<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
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<tr>
<td>NRCS</td>
<td>Natural Resources Conservation Service</td>
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<tr>
<td>PAM</td>
<td>Polyacrylamide</td>
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<tr>
<td>RUSLE</td>
<td>Revised Universal Soil Loss Equation</td>
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<tr>
<td>SCS</td>
<td>Soil Conservation Service</td>
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<tr>
<td>SWPPP</td>
<td>Stormwater Pollution Prevention Plan</td>
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<tr>
<td>TESC</td>
<td>Temporary Erosion and Sediment Control</td>
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<tr>
<td>TMDLs</td>
<td>Total Maximum Daily Load</td>
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<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
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<td>WSDOT</td>
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Credit for Figures
The figures in Chapter 3 are reproduced, with permission, from King County’s Surface Water Design Manual.
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; and
- 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 of 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.

1.2 Content and Organization of this Volume

Volume III of the stormwater manual contains three chapters. Chapter 1 serves as an introduction. Chapter 2 reviews methods of hydrologic analysis, covers the use of hydrograph methods for designing BMPs, and provides an overview of various computerized modeling methods and analysis of closed depressions. Chapter 3 describes flow control BMPs and provides design specifications for roof downspouts and detention facilities. It also provides design considerations of infiltration facilities for flow control.

The three Appendices to this volume contain the isopluvial maps for western Washington, information and assumptions on the western Washington hydrology model, and more detailed information on pilot infiltration testing.
Design considerations for conveyance systems are not included in the stormwater manual, as this topic is adequately covered in standard engineering references.

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 Chapter 2 of Volume I). After the Minimum Requirements have been determined, this volume should be consulted to design flow management facilities. These facilities can then be included in Stormwater Site Plans (see Volume I, Chapter 3).
Chapter 2 - Hydrologic Analysis

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 ground water 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 base flow 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.

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:

1. For the purpose of designing most runoff treatment and flow control BMPs, the most current version of the Western Washington Hydrology Model (WWHM) with Thurston County enhancements (when available), or an equivalent calibrated continuous simulation hydrologic model based on the EPA’s HSPF (Hydrologic Simulation Program-Fortran), shall be used to calculate runoff and determine the water quality design flow rates and volumes. MGS-Flood (a model developed for WSDOT’s use) appears to provide equivalent results and should also be acceptable.

2. If a basin plan is being prepared, or a large (320 acres or more) master-planned development is being proposed, then the hydrologic analysis must be performed using a continuous simulation model such as the EPA's HSPF model, the EPA's Stormwater Management Model (SWMM), or an equivalent model as approved by the local permitting authority. This requires basin-specific calibrations.

A continuous simulation model has a considerable advantage over the single event-based methods such as the SCSUH, SBUH, or the Rational Method. The single event model 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 model are the result of a considerable effort to introduce local parameters and actual rainfall data into the model and are therefore believed to result in better estimation of runoff than the SCSUH, SBUH, or Rational methods.

2.2 Western Washington Hydrology Model

This section summarizes the assumptions made in creating the western Washington Hydrology Model (WWHM) and discusses limitations of the model. More information on the WWHM and the assumptions can be found in Appendix III-B. The WWHM will be frequently updated, so model users should ensure that they have the most current Thurston County-specific version. WWHM updates may render inaccurate some limitations described below.

**WWHM Limitations**

The WWHM has been created for the specific purpose of sizing stormwater control facilities for new developments in western Washington. The WWHM can be used for a range of conditions and developments; however, certain limitations are inherent in this software. These limitations are described below.

The WWHM uses the 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.

Routing effects become more important as the drainage area increases. For this reason it is recommended that the WWHM not be used for drainage areas greater than one-half square mile (320 acres). The WWHM can be used for small drainage areas less than an acre in size.

**Assumptions made in creating the WWHM**

**Precipitation data.**

- The WWHM uses long-term (43-50 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.
- Numerous precipitation stations are used, representing the different rainfall regimes found in western Washington.
• These stations represent rainfall at elevations below 1500 feet - snowfall and snowmelt are not included in the WWHM.

• The primary source for precipitation data is National Weather Service stations, although Thurston County-managed stations are also included.

• The computational time step used in the WWHM is one hour. The one-hour time step was selected to better represent the temporal variability of actual precipitation than daily data.

**Precipitation multiplication factors.**

• The WWHM uses precipitation multiplication factors to increase or decrease recorded precipitation data to better represent local rainfall conditions.

• The factors are based on the ratio of the 24-hour, 25-year rainfall intensities for the representative precipitation gage and the surrounding area represented by that gage’s record.

• The factors have been placed in the WWHM database and linked to each county’s map. They will be transparent to the general user, however the advanced user will have the ability to change the coefficient for a specific site. Changes made by the user will be recorded in the WWHM output. Minimum factor is 0.8 and maximum is 2.0.

**Pan evaporation data.**

• The WWHM uses pan evaporation coefficients to compute the actual evapotranspiration potential (AET) for a site, based on the potential evapotranspiration (PET) and available moisture supply. AET 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. These changes will be recorded in the WWHM output.

**Soil data.**

• The 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.
• The WWHM represents the vegetation of western Washington with three predominant vegetation categories: forest, pasture, and lawn (also known as grass).
• The predevelopment land conditions are generally set as “forest” (the default condition). However, the user has the option of specifying “pasture” if it is likely that pasture vegetation was native to the predevelopment site.

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.
• Among the land use options, WWHM includes a standard residential development which makes specific assumptions about the amount of impervious area per lot and its division between driveways and rooftops. Streets and sidewalk areas are input separately. The WWHM default is 4200 square feet of impervious area per residential lot, with 1000 square feet of that as driveway, walkways, and patio area, and the remainder as rooftop area.
• The 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 porous pavement for driveway areas. WWHM Version 2 includes an option under “Streets/Sidewalks/Parking” for obtaining credits for using pervious pavements. This credit appears to be too small, but it will not be increased at this time. Instead, model users are advised to employ the LID credit guidance from Appendix III-C.
• For non-standard residential/commercial development the user inputs the roof area, landscape area, street, sidewalk, parking areas, and any appropriate non-developed forest and pasture areas.
• 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 shall be designated as forest or pasture only where tracts, covenants or restrictions protect these areas from future disturbances.**
• The 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 Re-development 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.

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
- The WWHM provides 16 unique PERLND parameters that describe various hydrologic factors that influence runoff and 4 parameters to represent IMPLND.
- These values are based on regional parameter values developed by the U.S. Geological Survey for watersheds in western Washington (Dinicola, 1990) plus additional HSPF modeling work conducted by AQUA TERRA Consultants. Local (Thurston County) parameter values are being developed and should be used when available.
- Surface runoff and interflow will be computed based on the PERLND and IMPLND parameter values. Groundwater flow can also be computed and added to the total development runoff if groundwater surfacing is expected (such as from a cut slope). However, WWHM’s default condition assumes that no groundwater flow from small catchments reaches the surface to become runoff.

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 two flow control standards stated in the Manual: Minimum Requirement #7 - Flow Control and Minimum Requirement #8 - Wetlands Protection (See Volume I).

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% of the 2-year peak flow up to the full 50-year peak flow.

- The WWHM computes the predevelopment 2- through 100-year flow frequency values and computes the post-development runoff 2- through 100-year flow frequency 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% and 100% of the 2-year 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% of the 2-year and 100% of the 50-year 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 specifies that discharges to wetlands must maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated beneficial uses. Criteria for determining maximum allowed exceedences in alterations to wetland hydroperiods are provided in guidelines cited in Guide Sheet 2B of the Puget Sound Wetland Guidelines (Azous and Horner, 1997). Because wetland hydroperiod computations are relatively complex and are site specific they have not yet been included in the WWHM (but will be in a future version). HSPF is required for wetland hydroperiod analysis.

**Guidance for LID flow modeling credits**

The low impact development flow modeling credits shall be as described in Appendix III-C or as calculated by modeling of the BMP within the WWHM.

**2.3 Closed Depression Analysis**

Closed depression analysis requires careful assessment of the existing hydrologic performance in order to evaluate the impacts a proposed project will have. The applicable requirements (see Minimum Requirements #7 and #8) and the local permitting authority’s Critical Areas Ordinance (if applicable) should be thoroughly reviewed prior to proceeding with the analysis. A calibrated continuous simulation hydrologic model, such as the latest version of the WWHM with
Thurston County enhancements, shall be used for closed depression analysis and design of mitigation facilities. The procedures below may be followed.

Analysis and Design Criteria: The infiltration rates used in the analysis of closed depressions shall be determined according to the procedures in Volume III Chapter 3. For closed depressions containing standing water, soil texture tests must be performed on dry land adjacent to, and on opposite sides of the depression (as is feasible). A minimum of two tests must be performed to estimate an average surface infiltration rate. Wet-season water level fluctuations, measured using a datalogger, are also useful in estimating infiltration rates, especially if the depression currently receives runoff.

Projects proposing to modify or compensate for replacement storage in a closed depression must meet the design criteria for detention ponds as described in this volume.

Method of Analysis: Closed depressions are analyzed using WWHM. In assessing the impacts of a proposed project on the performance of a closed depression there are two cases that dictate different approaches to meeting Minimum Requirement #7 and applicable local requirements.

Note that where there is a flooding potential, concern about rising ground water levels, property rights/ownership/use issues, or there are local critical areas ordinances and rules, this analysis may not be sufficient and the local permitting authorities may require more stringent analysis and impose more stringent requirements.

Case 1: The 100-year storm flow from the drainage basin tributary to the closed depression is routed into the closed depression, using only infiltration as outflow. Under this scenario, there is no overflow from closed depression. Determine the predevelopment high water level. The post-development high water level, assuming full build-out of the contributing watershed, shall be no more than 0.1 feet higher than the predevelopment level, unless the development has acquired ownership or discharge rights to the closed depression. Absent ownership or discharge rights, excavate additional storage volume in the closed depression (subject to all applicable requirements, for example, access rights and providing a defined overflow system) or in an upland area, as needed to achieve the development’s contribution to the 0.1-foot maximum water level increase standard.

Case 2: The 100-year storm flow from the drainage basin tributary to the closed depression is routed into the closed depression, using only

---

1 If ownership or discharge rights are acquired, the closed depression may be flooded, subject to any applicable government requirements or conditions, such as for wetlands.
infiltration as outflow. Under this scenario, predevelopment runoff causes overflows from closed depression. In this case, use WWHM to match pre- and post-development flows and durations, determining how much storage must be added to the closed depression. Design an appropriate flow control and overflow structure.
Chapter 3 - Flow Control Design

This chapter presents methods, criteria, and details for hydraulic analysis and design of flow control facilities and roof downspout controls. Flow control facilities are detention or infiltration facilities engineered to meet the flow control standards specified in Volume I (Minimum Requirement #7). Roof downspout controls are infiltration or dispersion systems for use in individual lots, proposed plats, and short plats. Roof downspout controls may be used in conjunction with, and in addition to, any flow control facilities that may be necessary. Implementation of roof downspout controls may reduce the total effective impervious area and result in less runoff from these surfaces. Ecology’s Hydrology Model incorporates flow credits for implementing two types of roof downspout controls. These are:

- If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the total project area used for sizing the stormwater facilities. This is done by clicking on the “Credit” button in the WWHM and entering the roof area percentage that is being infiltrated.

- If roof runoff is dispersed using splashblocks or other approved practices on single-family lots, and the vegetative flow path is 50 feet or longer, the roof area may be modeled as grassed surface. This is done by clicking on the “Credit” button in the WWHM and entering the roof area percentage that is being dispersed.

This chapter also provides a description of the use of infiltration facilities for flow control. Additional design considerations and general limitations of the infiltration facilities and small site BMPs are covered in Volume V.

Roof downspout controls and small site BMPs should be applied to individual commercial lot developments when the percent impervious area and pollutant characteristics are comparable to those from residential lots.

3.1 Roof Downspout Controls

This section presents the criteria for design and implementation of roof downspout controls. Roof downspout controls are simple pre-engineered designs for infiltrating and/or dispersing runoff from roof areas for the

---

* Vegetative flow path is measured from the downspout or dispersion system discharge point to the downstream property line, stream, wetland, discharge outlet, or other impervious surface. Lesser flow path distances may be allowed if soils are amended using BMP T5.13 Post-Construction Soil Quality and Depth, and BMP T5.35, Engineered Soil/Landscape Systems (see Volume V, Chapter 5). Contact the local permitting authority for applicability and requirements.
purposes of increasing opportunities for groundwater recharge and reduction of runoff volumes from new developments.

Selection of Roof Downspout Controls

Large lots in rural areas (5 acres or greater) typically have enough area to disperse or infiltrate roof runoff. Lots created in urban areas will typically be smaller (about 8,000 square feet) and have a limited amount of area in which to site infiltration or dispersion trenches. Downspout infiltration may be used in soils that readily infiltrate, while dispersion BMPs may be used in less permeable soils. Where dispersion is not feasible because of very small lot size, or where there is a potential for creating drainage problems on adjacent lots, downspouts should be connected to the street storm drain system, thereby preventing damage to adjoining properties or flow across sidewalks. Roof downspout controls are not required if roof runoff is routed to a properly sized infiltration facility.

3.1.1 Downspout Infiltration Systems

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.

On lots or sites with more than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, downspout infiltration is considered feasible if soils and the infiltration trench can be designed to meet the minimum design criteria specified below.

Flow Credit for Roof Downspout Infiltration

If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the project area used for sizing the stormwater facilities. This is done by clicking on the “Credit” button in the WWHM and entering the roof area percentage that is being infiltrated.
**Procedure for Evaluating Feasibility**

1. An engineer, soil scientist, or other licensed or certified professional with appropriate training (as determined by the local permitting authority) shall evaluate soils to determine if they are suitable for infiltration.

2. On lots or sites with more than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, downspout infiltration is considered feasible if the soils are outwash type soils and the infiltration trench can be designed to meet the minimum design criteria specified below.

**Design Criteria for Infiltration Trenches**

Figure 3.1 shows a typical downspout infiltration trench system, and Figure 3.2 presents an alternative infiltration trench system for sites with coarse sand and cobble soils. **Local permitting authorities may require different designs. Where used, these systems shall be designed as specified below.**

**General**

1. The following minimum total trench volumes, including rock backfill, are required per 1,000 square feet of roof area. For subdivisions, calculate sizes and provide a schedule, by lot number, with the engineered plans:
   - Hydrologic Group A and B (sand, loamy sand, sandy loam), 125 cubic feet
   - Hydrologic Group C (loam, silt loam, sandy clay loam, layered sandy loam soils, till soils with Group A or B surface soils), 250 cubic feet
   - Hydrologic Group D soils (silt, clays, rock outcroppings, till soils with Group C or D surface soils, most fill materials), 750 cubic feet. Infiltration is not recommended in these soils.

2. Maximum length of trench must not exceed 100 feet from the inlet sump.

3. Minimum spacing between trench centerlines must be 6 feet.

4. Filter fabric must be placed over the drain rock as shown on Figure 3.2 prior to backfilling. Do not place fabric on trench bottom.

5. Minimum infiltration trench setbacks are as follows:
   - Water supply wells, building crawl spaces, or basements shall be at least 10 feet upgradient or 30 feet downgradient from the trench.
   - Infiltration trenches in till or layered soils must be located downgradient of crawl spaces or basements.
   - Top of slopes over 15 percent, 25 feet. May be increased if landslide hazards are present.
• Septic systems shall be per Thurston County Health Department requirements.

• In case of conflict among setback requirements, the more stringent shall prevail.

6. Trenches may be located under pavement if a small yard drain or catch basin with grate cover is placed at the end of the trench pipe such that overflow would occur out of the catch basin at an elevation at least one foot below that of the pavement, and in a location which can accommodate the overflow without creating a significant adverse impact to downhill properties or drainage systems. This is intended to prevent saturation of the pavement in the event of system failure.
Figure 3.1 Typical Downspout Infiltration Trench

Source: King County. A filter basket may substitute for the fine mesh screen.
Figure 3.2 Alternative Downspout Infiltration Trench System For Coarse Sand And Gravel

Source: King County
3.1.2 Downspout Dispersion Systems (Splashblocks)

All lots shall use splashblocks for downspout dispersion, and lots shall be graded to drain to approved outlets, unless otherwise approved by the local permitting authority. Lot grading and drainage shall comply with applicable codes, including building and plumbing codes, and the criteria below.

**Application**

Downspout dispersion must be used on all residential subdivision single-family lots, which meet one of the following criteria:

1. Lots greater than or equal to 22,000 square feet where downspout infiltration is not being provided according to the requirements in Section 3.1.1.

2. Lots smaller than 22,000 square feet where soils are not suitable for downspout infiltration (as determined in Section 3.1.1) and where the design criteria below can be met.

**Flow Credit for Roof Downspout Dispersion**

If roof runoff is dispersed and the vegetative flow path is 50 feet or longer, the roof area may be modeled as landscaped surface - rather than impervious surface - when sizing the stormwater facilities. This is done by clicking on the “Credit” button in the WWHM and entering the roof area percentage that is being dispersed.

**Design Criteria**

Downspout infiltration trenches shall be used for all downspout dispersion applications except where splash blocks are allowed.

**Design Criteria for Splashblocks**

A typical downspout splashblock is shown in Figure 3.3. In general, if the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion, splashblocks will adequately disperse storm runoff. If the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions may be a better choice because the discharge point is moved away from the foundation. Downspout extensions can include piping to a splashblock/discharge point a considerable distance from the downspout, as long as the runoff can travel through a well-vegetated area as described below.

*Vegetative flow path is measured from the downspout or dispersion system discharge point to the downstream property line, stream, wetland, discharge outlet, or other impervious surface. Lesser flow path distances may be allowed if soils are amended using BMP T5.13 Post-Construction Soil Quality and Depth, and BMP T5.35, Engineered Soil/Landscape Systems (see Volume V, Chapter 5). Contact the local permitting authority for applicability and requirements. In Olympia, for flow paths between 20 and 50 feet, the credit may be claimed if the compost-amended soils meeting BMP T5.13 and T5.35 are used throughout the discharge area.*
The following criteria apply to the use of splashblocks:

1. A vegetated flowpath of at least 50 feet (20 feet on compost-amended soils) should be maintained between the discharge point and any property line, structure, steep slope, stream, wetland, lake, discharge outlet, or other impervious surface. Sensitive area buffers may count toward flowpath lengths.

2. A maximum of 700 square feet of roof area may drain to each splashblock.

3. A splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep with geotextile) should be placed at each downspout discharge point.

4. No erosion or flooding of downstream properties may result.

5. Runoff discharged towards landslide hazard areas must be evaluated by a professional engineer with geotechnical expertise or a qualified geologist. Splashblocks may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or qualified geologist and jurisdiction approval.

6. For sites with septic systems, the discharge point must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc) indicate that this is unnecessary.
Roof downspout serves up to 700 sf. Of roof

50' min. Vegetated flow path

Splash block

Downspout extension

Figure 3.3 Typical Downspout Splashblock Dispersion
3.2 Detention Facilities

This section presents the methods, criteria, and details for design and analysis of detention and retention 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 four primary types of facilities described in this section: detention ponds, retention ponds, tanks, and vaults.

3.2.1 Detention and Retention Ponds

The design criteria in this section are for detention and retention ponds. However, many of the criteria also apply to water quality wetponds and combined detention/wetponds (Volume V).

**Dam Safety for Detention BMPs**

Stormwater detention facilities that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more with the water level at the embankment crest are subject to the state’s dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)).

In the interest of providing a smooth integration of dam safety requirements into the stormwater detention project and streamlining Dam Safety’s engineering review and issuance of the construction permit, it is recommended and requested that Dam Safety be contacted early in the facilities planning process. The Dam Safety Office is located in the Ecology headquarters building in Lacey. Electronic versions of the guidance documents in PDF format are available on the Department of Ecology Web site at [http://www.ecy.wa.gov/programs/wr/dams/dss.html](http://www.ecy.wa.gov/programs/wr/dams/dss.html).

**Design Criteria**

Ponds shall be designed to comply with the following criteria. Standard details for detention ponds are shown in Figure 3.4 through Figure 3.6. Control structure details are provided in Section 3.2.4.

**General**

1. Ponds must be designed as flow-through systems (however, parking lot storage may be utilized through a back-up system; see Section 3.2.5). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Place inlets and outlet the maximum practicable distance apart.

2. Pond bottoms shall be level and include one foot of dead storage below the outlet to provide sediment storage and to maximize small storm/dry season capture and infiltration.
3. Design guidelines for outflow control structures are specified in Section 3.2.4.

4. A geotechnical analysis and report must be prepared for steep slopes (i.e., slopes over 15%), or if the pond is located within 200 feet of the top of a steep slope or landslide hazard area. The scope of the geotechnical report should 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.

**Side Slopes**

1. Interior side slopes up to the emergency overflow water surface shall not be steeper than 3H:1V unless a retaining wall is used.

2. Exterior side slopes must not be steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.

3. Pond walls may be vertical retaining walls, provided: (a) they are constructed of an architectural faced reinforced concrete per Section 3.2.3, Material; (b) a fence is provided along the top of the wall; (c) the retaining wall is less than 50% of the perimeter of the pond; (d) the design is stamped by a licensed civil engineer with structural expertise. Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type wall may be used if designed by a geotechnical engineer or a civil engineer with structural expertise; (e) there are no structures or roadways placed above the structural elements of the walls; and, (f) the wall height is limited to 4 feet unless a 4 feet wide bench is used between section of the wall and then each section must be limited to 4 feet high. (Structural elements of the wall include all the elements of the wall needed to maintain their structural integrity-this includes reinforcing material placed behind.)

**Embankments**

1. Pond berm embankments higher than 6 feet must be designed by a professional engineer with geotechnical expertise.

2. For berm embankments 6 feet or less, the minimum top width should be 6 feet or as recommended by a geotechnical engineer.

3. Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of seepage plains, loose surface soil materials, roots, and other organic debris.

4. Pond berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and top width (minimum 3 feet) unless specified otherwise by a geotechnical engineer.
Embarkment compaction should be accomplished in such a manner as to produce a dense, low permeability engineered fill that can tolerate post-construction settlements with a minimum of cracking. The embankment fill should be placed on a stable subgrade and compacted to a minimum of 95% of the Standard Proctor Maximum Density, ASTM Procedure D698. Placement moisture content should lie within 1% dry to 3% wet of the optimum moisture content. The referenced compaction standard may have to be increased to comply with local regulations.

The embankment should be constructed of soils with the following characteristics per the United States Department of Agriculture’s Textural Triangle: a minimum of 20% silt and clay, a maximum of 60% sand, a maximum of 60% silt, with nominal gravel and cobble content. Soils outside this specified range can be used, provided the design satisfactorily addresses the engineering concerns posed by these soils. The paramount concerns with these soils are their susceptibility to internal erosion or piping and to surface erosion from wave action and runoff on the upstream and downstream slopes, respectively.

Anti-seepage filter-drain diaphragms must be placed on outflow pipes in embankments impounding water with depths greater than 8 feet at the design water surface.


**Overflow**

1. In all ponds, tanks, and vaults, a primary overflow (usually a riser pipe within the control structure; see Section 3.2.4) must be provided to bypass the 100-year developed peak flow. 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.

2. A secondary inlet to the control structure must be provided in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A “birdcage” or “beehive” inlet is required (Figure 3.6) and a grated opening (“jailhouse window”) in the control structure manhole, which functions as a weir (see Figure 3.5) may also be included as a secondary inlet.
Note: The maximum circumferential length of this grated opening must not exceed one-half the control structure circumference.

Emergency Overflow Spillway

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

2. Emergency overflow spillways must be provided 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 Figure 3.6. The emergency overflow structure must be designed to pass the 100-year developed peak flow, with a minimum 10% overvolume and 1 foot 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 should be given to providing an emergency overflow structure in addition to the spillway.

3. The emergency overflow spillway must be armored with riprap in conformance with the “Outlet Protection” BMP in Volume II. The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system (see Figure 3.5).

4. Emergency overflow spillway designs must be analyzed as broad-crested trapezoidal weirs as described in Methods of Analysis at the end of this section (Section 3.2.1). Either one of the weir sections shown in Figure 3.5 may be used.

5. For large ponds with high length-to-width ratios, wave run-up may be a factor and must be assessed. Spillways shall be raised to be a minimum of 6 inches above the wave run-up height attained for a 50-mile per hour wind blowing parallel to the pond’s long side.
Access

The following requirements apply:

1. Maintenance access road(s) shall be provided to the control structure, the base of the detention retention facility, and other drainage structures associated with the pond (e.g., inlet or bypass structures). It is recommended that manhole and catch basin lids be in or at the edge of the access road and at least three feet from a property line.

2. If a fence is required, access shall be limited by a double-posted gate or by bollards – that is, two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards.

Design of Access Roads

Access road design requirements are given below:

1. Maximum grade, 15 percent.
2. Outside turning radius, minimum of 40 feet.
3. Fence gates located only on straight sections of road.
4. Access roads 15 feet wide on curves and 12 feet wide on straight sections.
5. A paved apron where access roads connect to paved public roadways.

The access road must extend to the pond bottom if the cell bottom is greater than 1,500 square feet (measured without the road). If the pond bottom is less than 1,500 square feet (measured without the road), the road may end at an elevation 4 feet above the cell bottom.

Construction of Access Roads

Access roads may be constructed with an asphalt or gravel surface, or modular grid pavement. All surfaces must conform to the jurisdictional standards and manufacturer's specifications.

Fencing

1. A fence is needed at the emergency overflow water surface elevation, or higher, where a pond interior side slope is steeper than 3H:1V, or where the impoundment is a wall greater than 24 inches in height. The fence need only be constructed for those slopes steeper than 3H:1V. Note, however, that other regulations such as the Building Code 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.
Also note that detention ponds on school sites will need to comply with safety standards developed by the Department of Health (DOH) and the Superintendent for Public Instruction (SPI). 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.

A fence is needed to 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.

2. Fences shall be a minimum of 42 inches high, of such materials that would effectively prevent entry by small children, and complying with local permitting authority requirements (such as building codes).

3. Access road gates shall be a minimum of 16 feet wide, consisting of two swinging sections 8 feet in width. Additional vehicular access gates may be needed to facilitate maintenance access.

4. Pedestrian access gates (if needed) should be 4 feet in width.

5. Vertical metal balusters or 9 gauge galvanized steel fabric with bonded vinyl coating can be used as fence material. For steel fabric fences, the following aesthetic features may be considered:
   a) Vinyl coating that is compatible with the surrounding environment (e.g., green in open, grassy areas and black or brown in wooded areas). All posts, cross bars, and gates may be painted or coated the same color as the vinyl clad fence fabric.
   b) Fence posts and rails that conform to WSDOT Standard Plan L-2 for Types 1, 3, or 4 chain link fence.

6. For metal baluster fences, Building Code standards apply.

7. Wood fences may be used in subdivisions where the fence will be maintained by homeowners associations or adjacent lot owners. Other materials may be used with local government approval.

8. Wood fences should 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.

9. Fences installed along public rights-of-way and adjoining public spaces shall be of “see-through” construction or materials, such that a person could not effectively hide behind the fence.
**Signage**
Detention ponds, infiltration ponds, wetponds, and combined ponds shall have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. Contact the local permitting authority for required sign specifications.

**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 15-20 foot wide extension of the tract to an acceptable access location.

**Setbacks**
All facilities must be a minimum of 50 feet from the top of any steep (greater than 15 percent) slope. A geotechnical analysis and report may be prepared to justify a smaller setback.

Other codes, such as health and building, should be consulted for setbacks from detention facilities.

**Groundwater, 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 base flow (unless already considered in design). Setbacks may be required for seeps that classify as critical (such as landslide hazard) areas.

The base of retention and detention facilities shall be placed above the seasonally high groundwater elevation of the site. Pond liners may not be used to place detention facilities below the seasonally high groundwater elevation.

Where there is less than 3 feet of separation from the base of the detention facility and the seasonally high groundwater elevation, and the pond site is within a wellhead protection area, the base of the detention facility shall be lined to protect the drinking water aquifer.

**Planting Requirements**
The entire pond site, including the interior side slopes and below the design water surface elevation, shall be amended with compost or topsoil 12 inches deep to BMP T5.13 or equivalent, and planted and sodded or seeded with an appropriate seed mixture.
Landscaping

All remaining pond areas shall be landscaped and mulched. Submit a landscaping plan for local permitting authority review and approval that complies with the following landscaping requirements and any other applicable local permitting authority landscaping standards. The minimum coverage of landscape islands shall meet or exceed 10 percent of the site area (when mature).

1. No trees or shrubs may be planted 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, should be avoided within 50 feet of pipes or manmade structures.

2. Planting shall be restricted on berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.
   a) Trees or shrubs may not be planted on portions of water-impounding berms taller than four feet high. Only grasses may be planted on berms taller than four feet.
      Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.
   b) 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. Table 3.1 gives some examples of trees with these characteristics developed for the central Puget Sound.
      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 wetpond is not subject to this planting restriction since the failure of an internal berm would be unlikely to create a safety problem.

3. All landscape material, including grass, shall be planted in good topsoil. Native underlying subsoils may be made suitable for planting if amended with 4 inches of well-aged compost tilled into the subgrade. Compost used shall meet specifications for Grade A compost quality, as described in the most current version of Ecology publication 94-38.

4. Soil in which trees or shrubs are planted may need additional enrichment or additional compost top-dressing. Consult a nurseryman, landscape professional, or arborist for site-specific recommendations.

5. For a naturalistic effect as well as ease of maintenance, trees or shrubs shall be planted in clumps to form “landscape islands” rather than being evenly spaced.
6. The landscaped islands shall be a minimum of six feet apart, and if set back from fences or other barriers, the setback distance shall also be a minimum of 6 feet. Where tree foliage extends low to the ground, the six feet setback shall 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.

7. Evergreen trees and trees which produce relatively little leaf-fall (such as Oregon ash, mimosa, or locust) are preferred in areas draining to the pond.

8. Drought tolerant species are recommended, unless an irrigation system is installed.

<table>
<thead>
<tr>
<th>Table 3.1</th>
<th>Small Trees and Shrubs with Fibrous Roots</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Small Trees / High Shrubs</strong></td>
<td><strong>Low Shrubs</strong></td>
</tr>
<tr>
<td><em>Red twig dogwood (Cornus stolonifera)</em></td>
<td><em>Snowberry (Symphoricarpus albus)</em></td>
</tr>
<tr>
<td><em>Serviceberry (Amelanchier alnifolia)</em></td>
<td><em>Salmonberry (Rubus spectabilis)</em></td>
</tr>
<tr>
<td><em>Filbert (Corylus cornuta, others)</em></td>
<td>Rosa rugosa (avoid spreading varieties)</td>
</tr>
<tr>
<td>Highbush cranberry</td>
<td>Rock rose</td>
</tr>
<tr>
<td>(Vaccinium opulus)</td>
<td>(Cistus spp.)</td>
</tr>
<tr>
<td>Blueberry</td>
<td>Ceanothus spp.</td>
</tr>
<tr>
<td>(Vaccinium spp.)</td>
<td>choose hardier varieties</td>
</tr>
<tr>
<td>Fruit trees on dwarf rootstock</td>
<td>New Zealand flax (Phormium penax)</td>
</tr>
<tr>
<td>Rhododendron</td>
<td>Ornamental grasses</td>
</tr>
<tr>
<td>(native and ornamental varieties)</td>
<td>(e.g., Miscanthis, Pennisetum)</td>
</tr>
</tbody>
</table>

*Native species

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.

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

2. Tree clumps should be underplanted with shade-tolerant shrubs and groundcover plants. The goal is to provide a dense understory that need not be weeded or mowed.
3. Landscaped islands should be placed at several elevations rather than “ring” the pond, and the size of clumps should vary from small to large to create variety.

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

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

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

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

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

3. 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 3.2 below gives an example of dwarf grass mix developed for central Puget Sound. Grass seed should be applied at 2.5 to 3 pounds per 1,000 square feet.

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

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

Note: This landscape style is best combined with the use of grass or sod for site stabilization and erosion control.
Seed Mixes. The seed mixes listed below were developed for central Puget Sound.

<table>
<thead>
<tr>
<th>Seed Name</th>
<th>Percentage of Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwarf tall fescue</td>
<td>40%</td>
</tr>
<tr>
<td>Dwarf perennial rye “Barclay”*</td>
<td>30%</td>
</tr>
<tr>
<td>Red fescue</td>
<td>25%</td>
</tr>
<tr>
<td>Colonial bentgrass</td>
<td>5%</td>
</tr>
</tbody>
</table>

* 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.
Figure 3.4 Typical Detention Pond

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

SECTION B-B has 2 options

SECTION C-C

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

Figure 3.5 Typical Detention Pond Sections
Figure 3.6 Overflow Structure

**NOTES:**
1. Dimensions are for illustration on 54" diameter CB. For different diameter CB's adjust to maintain 45° angle on "vertical" bars and 7" o.c. maximum spacing of bars around lower steel band.
2. Metal parts must be corrosion resistant; steel bars must be galvanized.
3. This debris barrier is also recommended for use on the inlet to roadway cross-culverts with high potential for debris collection (except on type 2 streams).
**Maintenance**

**General.** Maintenance is of primary importance if detention ponds are to continue to function as originally designed. **Unless otherwise approved by the local permitting authority, the facility owner shall accept the responsibility for maintaining the structures and the impoundment area.** A specific maintenance plan must be formulated outlining the **schedule and scope of maintenance operations.** See Volume I Appendix G for specific maintenance requirements.

Any standing water removed during the maintenance operation must be disposed of per local government requirements. Residuals must be disposed in accordance with state and local solid waste regulations (See Minimum Functional Standards For Solid Waste Handling, Chapter 173-304 WAC).

**Vegetation.** If a shallow marsh is established, then periodic removal of dead vegetation may be necessary. Since decomposing vegetation can release pollutants captured in the wet pond, especially nutrients, it may be necessary to harvest dead vegetation annually prior to the winter wet season. Otherwise the decaying vegetation can export pollutants out of the pond and also can cause nuisance conditions to occur. If harvesting is to be done in the wetland, a written harvesting procedure should be prepared by a wetland scientist and submitted with the drainage design to the local government.

**Sediment.** Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be continually monitored in the basin. Owners, operators, and maintenance authorities should be aware that significant concentrations of metals (e.g., lead, zinc, and cadmium) as well as some organics such as pesticides, may be expected to accumulate at the bottom of these treatment facilities. Testing of sediment, especially near points of inflow, should be conducted regularly to determine the leaching potential and level of accumulation of potentially hazardous material before disposal.

**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 1 of this Volume. Design guidelines for restrictor orifice structures are given in Section 3.2.4.

*Note: The design water surface elevation is the highest elevation that 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 3.3). 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 3.3 for infiltration ponds.

**Emergency Overflow Spillway Capacity.** For impoundments under 10-acre-feet, the emergency overflow spillway weir section must be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir. The broad-crested weir equation for the spillway section in Figure 3.13, for example, would be:

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

Where \( Q_{100} \) = peak flow for the 100-year runoff event (cfs)

\( C \) = discharge coefficient (0.6)

\( g \) = gravity (32.2 ft/sec²)

\( L \) = length of weir (ft)

\( H \) = height of water over weir (ft)

\( \theta \) = angle of side slopes

\( Q_{100} \) is either the peak 10-minute flow computed from the 100-year, 24-hour storm and a Type 1A distribution, or the 100-year, 1-hour flow estimated by an approved continuous simulation model and multiplied by a factor of 1.6.

Assuming \( C = 0.6 \) and \( \text{Tan } \theta = 3 \) (for 3:1 slopes), the equation becomes:

\[
Q_{100} = 3.21 \left[LH^{3/2} + 2.4 H^{5/2} \right] \quad (equation \ 2)
\]

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 maximum):

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

*Figure 3.7 Weir Section for Emergency Overflow Spillway*
3.2.2 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Standard detention tank details are shown in Figure 3.8 and Figure 3.9. Control structure details are shown in Section 3.2.4.

Design Criteria

General. Tanks shall be designed to comply with the following criteria:

1. Tanks shall be designed as flow-through systems with manholes in line (see Figure 3.8) 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.

2. The detention tank bottom shall be located 1.0 feet below the inlet and outlet to provide dead storage for sediment.

3. The minimum pipe diameter for a detention tank is 36 inches. Perforated pipe shall be used, except in high water table areas, or as otherwise directed by the local permitting authority.

4. 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.

5. Details of outflow control structures are given in Section 3.2.4.

6. If the tank has no access riser, provide an air vent (see Figure 3.8).

Note: Control and access manholes should 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 prohibited, unless no practicable, cost-effective alternative exists. 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 should be in accordance with Section 9.05 of the WSDOT/APWA Standard Specifications.
**Structural Stability.** Tanks must meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads must be accommodated for tanks lying under parking areas and access roads. Metal tank end plates must be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gage material than the pipe and/or require reinforcing ribs. Tanks must be placed on stable, well consolidated native material with a suitable bedding. Tanks must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

**Buoyancy.** In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy tendencies must be balanced 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 requirements apply:

1. Maximum depth from finished grade to tank invert shall be 12 feet.
2. Access openings shall be positioned a maximum of 50 feet from any location within the tank.
3. All tank access openings shall have round, solid locking lids (usually 1/2 to 5/8-inch diameter Allen-head cap screws).
4. Thirty-six-inch minimum diameter type manholes (see example, Figure 3.9) shall 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.
5. All tank access openings must be readily accessible by maintenance vehicles.
6. Tanks must comply with the 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. The access roads must be designed and constructed as specified for detention ponds in Section 3.2.1.

**Right-of-Way.** Right-of-way may be needed for detention tank maintenance. It is recommended that any tract not abutting public
right-of-way have a 15 to 20-foot wide extension of the tract to accommodate an access road to the facility.

**Setbacks.** All facilities must be a minimum of 50 feet from the top of any steep (greater than 15 percent) slope. A geotechnical analysis and report may be prepared to justify a smaller setback. Watertight facilities are not subject to this setback.

Other codes, such as health or building, should be consulted for setbacks from detention tanks.

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

**Methods of Analysis  Detention Volume and Outflow**

The volume and outflow design for detention tanks must be in accordance with Minimum Requirement #7 in Volume I and the hydrologic analysis and design methods in Chapter 2. Restrictor and orifice design are given in Section 3.2.4.
2.2.4 1.0' sediment storage

Figure 3.8 Typical Detention Tank
Figure 3.9 Detention Tank Access Detail

Notes:
1. Use adjusting blocks as required to bring frame to grade.
2. Must be located for access by maintenance vehicles.
3. May substitute WSDOT special Type IV manhole (RCP only).
3.2.3 Detention Vaults

*Detention vaults* are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure 3.10. Control structure details are shown in Section 3.2.4.

**Design Criteria**

**General.** Vaults shall be designed to comply with the following criteria.

1. Detention vaults shall 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 should be maximized (as feasible). Bottom shall be perforated, except in high water table areas, or as otherwise directed by the local permitting authority.

2. The detention vault bottom may slope at least 5 percent from each side towards the center, forming a broad “v” one foot below the outlet to facilitate sediment removal. More than one “v” may be used to minimize vault depth. However, the vault bottom may be flat with 0.5-1 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.

3. The invert elevation of the outlet should be elevated above the bottom of the vault to provide an average 12 inches of sediment storage over the entire bottom. The outlet should also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.

4. Details of outflow control structures are given in Section 3.2.4.

**Materials.** Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. All construction joints must be provided with water stops.

**Structural Stability.** All vaults must meet structural requirements for overburden support and H-20 traffic loading (See Standard Specifications for Highway Bridges, latest edition, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet any live load requirements of the local government. 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. Vaults must be placed on stable, well-consolidated native material with suitable bedding. Vaults must not
be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

**Buoyancy.** In moderately pervious soils where seasonal groundwater may induce floatation, buoyancy tendencies must be balanced 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.** Access must be provided over the inlet pipe and outlet structure. The following requirements apply:

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

2. For vaults with greater than 2,000 square feet of floor area, a 5' by 10' removable panel shall be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided as shown in Figure 3.10.

3. For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided. 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 in Item 10 below.

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

5. Vaults with widths 10 feet or less must have removable lids.

6. The maximum depth from finished grade to the vault invert shall be 20 feet.

7. Internal structural walls of large vaults shall be provided with openings sufficient for maintenance access between cells. The openings should be sized and situated to allow access to the maintenance “v” in the vault floor.

8. The minimum internal height should be 7 feet from the highest point of the vault floor (not sump), and the minimum width should be 4 feet. 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.

9. Vaults must comply with the 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.

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

Access Roads. Access roads are needed to the access panel (if applicable), the control structure, and at least one access point per cell, and they may be designed and constructed as specified for detention ponds in Section 3.2.1.

Right-of-Way. Right-of-way is needed for detention vaults maintenance. It is recommended that any tract not abutting public right-of-way should have a 15 to 20-foot wide extension of the tract to accommodate an access road to the facility.

Setbacks. All facilities shall be a minimum of 50 feet from the top of any steep (greater than 15 percent) slope. A geotechnical analysis and report may be prepared to justify a smaller setback. Watertight facilities are not subject to this setback.

Other codes, such as health or building, should be consulted for setbacks from detention vaults.

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

Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention vaults must be in accordance with Minimum Requirement #7 in Volume I and the hydrologic analysis and design methods in Chapter 1. Restrictor and orifice design are given in Section 3.2.4.
Figure 3.10 Typical Detention Vault

NOTES:
1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment I or better).
2. Provide wall stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.
3. Vaults ≤ 10' wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' × 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.
3.2.4 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 (“tees” or “FROP-Ts”) also provide some incidental oil/water separation to temporarily detain oil or other floatable pollutants in runoff due to accidental spill or illegal dumping.

The restrictor device usually consists of two or more orifices and/or a weir section sized to meet performance requirements.

Standard control structure details are shown in Figure 3.11 through Figure 3.13.

Control structures shall be designed to comply with the following criteria. Proprietary flow control devices that deviate from the following criteria shall be approved on a case by case basis.

Design Criteria

Multiple Orifice Restrictor

The following requirements apply:

1. Minimum orifice diameter is 0.5 inches. Orifices 2 inches in diameter or smaller shall be outfitted with an orifice protection screen. Screen design shall enable easy inspection, removal, and maintenance. Consult the local permitting authority for approved designs or products.

2. Orifices may be constructed on a tee section as shown in Figure 3.11 or on a baffle as shown in Figure 3.12.

3. 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).

4. 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

1. Properly designed weirs may be used as flow restrictors (see Figures 3.16 through 3.18). However, they must be designed to provide for primary overflow of the developed 100-year peak flow discharging to the detention facility.
2. The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design must still provide for primary overflow of the developed 100-year peak flow assuming all orifices are plugged. Figure 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.

1. An access road to the control structure is needed for inspection and maintenance, and must be designed and constructed as specified for detention ponds in Section 3.3.1.

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

3. 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.** A brass or stainless steel plate shall 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
- Orifice sizes and elevations
removable watertight coupling or flange

plate welded to elbow with orifice as specified

ELBOW RESTRICTOR DETAIL

NOTES:
1. Use minimum of a 54" diameter type 2 catch basin.
2. Outlet Capacity: 100-Year developed peak flow.
4. Frame and ladder or steps offset so:
   A. Cleanout gate is visible from top.
   B. Climb-down space is clear of riser and cleanout gate.
   C. Frame is clear of curb.
5. If metal outlet pipe connects to cement concrete pipe; outlet pipe to have smooth O.D. equal to cement pipe I.D. less 1/4".
6. Provide at least one 3" x .090 inch support bracket anchored to concrete wall. (maximum 3'-0" vertical spacing)
7. Locate elbow restrictor(s) as necessary to provide minimum clearance as shown.
8. Locate additional ladder rungs in structures used as access to tanks or vaults to allow access when catch basin is filled with water.

Figure 3.11 Flow Restrictor (TEE)
Figure 3.12 Flow Restrictor (Baffle)

NOTES:
outlet capacity: 100 year developed peak flow
metal parts: corrosion resistant steel parts
galvanized and asphalt coated
catch basin: two 2 minimum 72" diameter

orifices: sized and located as required with
lowest orifice a minimum of 2' from base
Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

Frames, grates and round solid covers marked "DRAIN" with locking bolts.

Design W.S.

I.E. weir, inlet pipe and drain = crown outlet pipe

Shear gate with control red for drain

Frame/grate elevation per plans

SECTION B-B

NTS

Weir shape as needed for performance

6" min.

W

SECTION A-A

NTS

Outlet pipe

Shear gate with control red for drain

2 min. 20 sec.

ISOMETRIC

NTS

Locate additional ladder rungs (in sets) to allow access to tanks or vaults when catch is filled with water.

Plan View

NTS

Handholds, steps or ladder (2 places)

Locate horizontal for clearance with ladder. Attach rod to support bracket on inside of access opening.

B

A

NOTES:

Outlet Capacity: 100-year developed peak flow.
Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.
Catch Basin: type 2 Min. 72" diameter

Baffle Wall: to be designed with concrete reinforcing as required.
Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

Figure 3.13 Control Structure Details
**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. A typical problem is that sediment builds up inside the structure which blocks or restricts flow to the inlet. To prevent this problem these structures should be routinely cleaned out at least twice per year. Regular inspections of control structures should be conducted to detect the need for non-routine cleanout, especially if construction or land-disturbing activities are occurring in the contributing drainage area.

Safe access to the control structure must be provided to facilitate inspection and maintenance.

Refer to the Volume I Appendix G for maintenance recommendations for control structures and catch basins. **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 tee section or turn-down elbow may be approximated by the general equation:

\[ Q = C A \sqrt{2gh} \]  

_(equation 4)_

where

- \( Q \) = flow (cfs)
- \( C \) = coefficient of discharge (0.62 for plate orifice)
- \( A \) = area of orifice (ft²)
- \( h \) = hydraulic head (ft)
- \( g \) = gravity (32.2 ft/sec²)

Figure 3.15 illustrates this simplified application of the orifice equation.
The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

\[
d = \sqrt[3]{\frac{36.88Q}{\sqrt{h}}} \tag{equation 5}
\]

where
- \(d\) = orifice diameter (inches)
- \(Q\) = flow (cfs)
- \(h\) = hydraulic head (ft)

**Rectangular Sharp-Crested Weir.** The rectangular sharp-crested weir design shown in Figure 3.16 may be analyzed using standard weir equations for the fully contracted condition.
Figure 3.16 Rectangular, Sharp-Crested Weir

\[ Q = C (L - 0.2H)H^{\frac{1}{2}} \]  
(equation 6)

where

- \( Q \) = flow (cfs)
- \( C = 3.27 + 0.40 \frac{H}{P} \) (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 3.17 may be analyzed using standard equations for the fully contracted condition.

\[ Q = C_d \left( \tan \frac{\theta}{2} \right) Y^{5/2}, \text{ in cfs} \]

Where values of \( C_d \) may be taken from the following chart:

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 3.18). The weir may be symmetrical or non-symmetrical.
Figure 3.18 Sutro Weir

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

$$\frac{x}{b} = 1 - \frac{2}{\pi} \tan^{-1} \left( \frac{Z}{a} \right)$$  \hspace{1cm} (equation 7)

where a, b, x and Z are as shown in Figure 3.18. The head-discharge relationship is:

$$Q = C_d b \sqrt{2ga(h_1 - \frac{a}{3})}$$  \hspace{1cm} (equation 8)

Values of $C_d$ for both symmetrical and non-symmetrical sutro weirs are summarized in Table 3.3.

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

<table>
<thead>
<tr>
<th>Values of $C_d$ for Sutro Weirs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cd Values, Symmetrical</strong></td>
</tr>
<tr>
<td><strong>b (ft)</strong></td>
</tr>
<tr>
<td>a (ft)</td>
</tr>
<tr>
<td>0.02 0.50 0.608 0.613 0.617 0.6185 0.619</td>
</tr>
<tr>
<td>0.05 0.606 0.611 0.615 0.617 0.6175 0.614</td>
</tr>
<tr>
<td>0.10 0.603 0.608 0.612 0.6135 0.614 0.612</td>
</tr>
<tr>
<td>0.15 0.601 0.6055 0.610 0.6115 0.615 0.612</td>
</tr>
<tr>
<td>0.20 0.599 0.604 0.608 0.6095 0.610 0.610</td>
</tr>
<tr>
<td>0.25 0.598 0.6025 0.6065 0.608 0.6085 0.608</td>
</tr>
<tr>
<td>0.30 0.597 0.602 0.606 0.6075 0.608</td>
</tr>
<tr>
<td><strong>Cd Values, Non-Symmetrical</strong></td>
</tr>
<tr>
<td><strong>b (ft)</strong></td>
</tr>
<tr>
<td>a (ft)</td>
</tr>
<tr>
<td>0.02 0.50 0.614 0.619 0.623 0.6245 0.625</td>
</tr>
<tr>
<td>0.05 0.612 0.617 0.621 0.623 0.6235 0.620</td>
</tr>
<tr>
<td>0.10 0.609 0.614 0.618 0.6195 0.620 0.618</td>
</tr>
<tr>
<td>0.15 0.607 0.6115 0.616 0.6175 0.618 0.618</td>
</tr>
<tr>
<td>0.20 0.605 0.610 0.614 0.6155 0.616 0.616</td>
</tr>
<tr>
<td>0.25 0.604 0.6085 0.6125 0.614 0.6145 0.614</td>
</tr>
<tr>
<td>0.30 0.603 0.608 0.612 0.6135 0.614 0.614</td>
</tr>
</tbody>
</table>
Riser Overflow. The nomograph in Figure 3.19 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions).

Figure 3.19 Riser Inflow Curves
3.2.5 Other Detention Options

This section presents other design options for detaining flows to meet flow control facility requirements. **Other detention options designs shall comply with the following 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 runoff event provided all of the following are met:

1. The depth of water detained does not exceed 1 foot at any location in the parking lot for runoff events up to and including the 100-year event.
2. The gradient of the parking lot area subject to ponding is 1 percent or greater.
3. 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.
4. The local permitting authority’s fire access requirements are met.

**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:

1. The roof support structure is analyzed by a structural engineer to address the weight of ponded water.
2. The roof area subject to ponding is sufficiently waterproofed to achieve a minimum service life of 30 years.
3. The minimum pitch of the roof area subject to ponding is 1/4-inch per foot.
4. An overflow system is included in the design to safely convey the 100-year peak flow from the roof.
5. 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.
3.3 Infiltration for Stormwater Quantity/Flow Control

3.3.1 Purpose

To provide infiltration capacity for stormwater runoff quantity and flow control.

3.3.2 Description

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil (See Figure 3.20). Stormwater infiltration trenches receiving uncontaminated or properly treated stormwater can also be considered as infiltration facilities. (See Underground Injection Control Program, Chapter 173-218 WAC).

Coarser more permeable soils can be used for quantity control provided that the stormwater discharge does not cause a violation of ground water quality criteria. Typically, treatment for removal of TSS, oil, and/or soluble pollutants is necessary prior to conveyance to an infiltration BMP. The hydraulic design goal should be to mimic the natural hydrologic balance between surface and ground water, as needed to protect water uses.

3.3.3 Applications

Infiltration facilities are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Runoff, in excess of the infiltration capacity, must be detained and released in compliance with the flow control requirement in Volume I. Specific applications include:

- Ground water recharge
- Discharge of uncontaminated or properly treated stormwater to infiltration trenches in compliance with Ecology’s UIC regulations (Chapter 173-218 WAC)
- Retrofits in limited land areas: Infiltration trenches can be considered for residential lots, commercial areas, parking lots, and open space areas.
- Flood control
- Streambank erosion control
Figure 3.20 Typical Infiltration Pond/Basin

NOTE:
Detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.
3.3.4 Site Characterization Criteria

Site characterization is required for all stormwater infiltration sites, and includes the following:

*Note: Information gathered during initial geotechnical investigations can be used for the site characterization.*

**Surface Characterization:**

1. Topography within 500 feet of the proposed facility, or to a greater distance if critical to design or site hydrologic function.
2. Anticipated site use (street/highway, residential, commercial, high-use site).
3. Location of water supply wells within 500 feet of proposed facility.
4. If the site is within 500 feet of a groundwater protection area, then provide the location of ground water protection areas and/or 1, 5 and 10 year time of travel zones for municipal well protection areas.

**Subsurface Characterization:**

Option A: Site-specific determination of subsurface characterization.

1. Report the soil profile under the infiltration facility:
   - Provide a summary graphic for each facility which represents the soil borings and infiltration facility.
   - Graphic of pond/trench and soil boring, grain size, Ksat and GW elevation (see sample figure below).
2. Calculate design infiltration rate and verify post-construction infiltration rate consistent with 3.3.4 through 3.3.6.

Option B: Simplified method of subsurface characterization.

1. Determine depth of groundwater relative to facility base. Infiltration facilities shall be installed above groundwater elevations consistent with 3.2.1.
2. Utilize a facility infiltration rate of 0.5 inch/hour in place of site-specific infiltration rate determination and subsequent evaluation.
3. Forego contingency planning and post-construction infiltration rate verification.
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Figure 3.20a

Infiltration Facility Subsurface Exploration Schematic
Minimum Two Per Facility

SAMPLE FIGURE

NOTES:
1. Provide sample figure like the drawing above.
2. Provide separate sheet with calculations for saturated potential hydraulic conductivity and design infiltration rate determination.
3. Groundwater information - Source: a) winter monitoring study, b) observed in borings, and c) other expression of groundwater close by.
4. Soil boring information - boring depth minimum of: 1) 12 feet below base of facility, 2) 5 times water depth below facility, and 3) 2 feet below seasonal high groundwater.

Figure 3.20a  Infiltration Facility Sample Drawing
4. Subsurface explorations (test holes, test pits, or soil borings) to the greatest of 12 feet below the base of the infiltration facility, 5 times the maximum ponded water design depth below the base of the infiltration facility, or 2 feet below the apparent wet-season high groundwater table. The exploration should be terminated at a continuous very low permeability layer (a laterally extensive confining layer, such as glacial till, with a near-zero [less than 0.25 inches per hour] infiltration rate), if encountered at shallower depth.

5. Continuous sampling to obtain representative samples from each soil layer or strata to a depth below the proposed base of the infiltration facility of the greatest of 6 feet below the base of the infiltration facility, 3 times the maximum ponded water design depth below the base of the infiltration facility, or 2 feet below the apparent wet-season high groundwater table, unless a continuous very low permeability layer is encountered at shallower depth. Samples obtained must be adequate for the purpose of soil gradation/classification testing.

6. At least one test pit, test hole, or soil boring per 5,000 ft² of basin infiltrating surface (surface basins), or per 100 feet of trench length (subsurface trenches), with a minimum of two tests. Pits, holes or borings should be located no more than 75 feet apart on a grid pattern in the target stormwater management area.

Note: The depth and number of test holes or test pits, and samples should be increased, if in the judgment of the licensed or certified professional with appropriate training acceptable to the local jurisdiction, the conditions are highly variable or stratified/layered, and such increases are necessary to accurately estimate the performance of the infiltration system. The exploration program may also be decreased if the conditions are relatively uniform. In high water table sites, the subsurface exploration sampling need not be conducted lower than two (2) feet below the apparent wet-season high groundwater level, if known.

7. Prepare detailed logs (written descriptions) for each soil test hole, pit, or boring, and a map showing the locations of the tests. Logs must include at a minimum, test depth and soil descriptions (use SCS/NRCS nomenclature) by layer/strata (note: Logs must describe the extent to which stratification is found). Use the soil log form provided in Volume III Appendix D.

8. Complete laboratory (sieve) analysis of soil grain size for each infiltration facility. At a minimum, complete one soil grain-size analysis for each soil layer/strata below the infiltration facility to the greatest of 6 feet below the base of the infiltration facility, 3 times the maximum ponded water design depth below the base of the infiltration facility, or 2 feet below the apparent wet-season high groundwater table. When assessing the hydraulic conductivity characteristics of the
site, soil layers at greater depths shall be considered if the soils professional conducting the investigation determines that deeper layers will influence the facility’s infiltration rate, requiring soil gradation/classification testing for layers deeper than indicated above.

9. (This is an optional test) Estimate the saturated hydraulic conductivity rates using the Pilot Infiltration Test (PIT) described in Appendix V-B, or another appropriate test. Note that these field tests generally provide a hydraulic conductivity combined with a hydraulic gradient that is close to 1.0; therefore, in effect, the magnitude of the test result is the same as the saturated hydraulic conductivity of that particular soil layer. So, if the test is run in a layer that does not represent the controlling condition, it is inappropriate. Furthermore, it is important to recognize that the rate resulting from the pre-construction test will be greater (sometimes very much so) than the full-scale infiltration facility’s long-term post-construction rate (i.e., after groundwater mounding is fully developed, which can greatly reduce the gradient).

10. For each soil layer, plot a particle size distribution curve highlighting the following factors: D_{10} (particle size in millimeters, for which 10% of particles, by weight, are smaller), D_{60}, D_{90}, and fraction of soil, by weight, that passes the Number 200 sieve (defined as \(f_{\text{fines}}\)).

11. Absent a shallow very low permeability layer (confining layer) and/or apparent wet-season high groundwater level defined through other subsurface explorations, install one or more groundwater monitoring wells to at least 5 times the maximum design water depth, minimum 20 feet and maximum 50 feet depth, to:
   - Monitor the seasonal groundwater levels at the site during at least one wet season (four or more consecutive months between December and May), and
   - Determine aquifer and confining layer depths, and
   - Develop input data for a groundwater flow model, such as MODFLOW, if necessary, and
   - Determine the ambient ground water quality, if necessary.

Other approaches to determine groundwater levels may be used if pre-approved by the local government.

12. Estimate the water holding capacity of the infiltration receptor (in feet), defined as 20% of the soil depth between the pond bottom and the apparent wet-season high water table or confining layer.
13. Determine/estimate (and describe basis for):

- Depth to apparent wet-season high groundwater level or confining layer
- Variation of the wet-season groundwater level based on well water levels and observed mottling (for infiltration facility “failure analysis,” estimate “historic” (100-year) maximum water level)
- Groundwater flow direction, gradient, and existing/likely groundwater discharge locations (e.g., seeps or springs)
Shaded area is applicable for design of infiltration BMPs

Figure 3.21 USDA Textural Triangle

Source: U.S. Department of Agriculture
3.3.5 Saturated Potential Hydraulic Conductivity and Design Infiltration Rate Determination

This section provides guidelines for determining the saturated potential hydraulic conductivity and the design infiltration rate. Designers may avoid the site-specific infiltration rate determination requirements of this section and the contingency planning and verification testing requirements of Section 3.3.6 if infiltration facilities are designed with a facility-design infiltration rate ($f_{\text{design}}$) of 0.5 inches/hour.

The saturated potential hydraulic conductivity is determined as follows:

- For each defined soil layer/stratum below the infiltration facility on which a soil grain-size sieve analysis was performed, estimate the potential saturated hydraulic conductivity using the following empirical equation (see Massmann et al. 2003):

$$K_{\text{sat}} = 2835 \times 10^{(-1.57 + 1.90D_{10} + 0.015D_{60} - 0.013D_{90} - 2.08f_{\text{fines}})}$$

(Equation 1)

where D values are in millimeters, f is a fraction between 0 and 1, and $K_{\text{sat}}$ is in feet per day. The $D_{10}$, $D_{60}$, and $D_{90}$ values are the grain size diameters for which 10%, 60% and 90% of the sample is finer (smaller), and $f_{\text{fines}}$ is the fraction of the soil (by weight) that passes the number-200 sieve.

If the soils professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the facility, soil layers at greater depths must be considered when assessing the site’s hydraulic conductivity characteristics. Massmann (2003) indicates that where the water table is deep, soil or rock strata up to 100 feet below an infiltration facility can influence the rate of infiltration. Generally, only the layers near and above the water table or a laterally extensive very low permeability layer (e.g., a silt or clay, dense glacial till, or rock layer) need to be considered, as the layers below the water table or low permeability zone do not significantly influence the rate of infiltration.

- Once the saturated potential hydraulic conductivity ($K_{\text{sat}}$) for each soil layer has been obtained, determine the effective average saturated potential hydraulic conductivity below the infiltration facility. Hydraulic conductivity estimates from different layers can be combined using the harmonic mean:
\[ K_{\text{equiv}} = \frac{d}{\sum d_n K_n} \]  

(Equation 2)

where \( d \) is the total depth of the sampled soil column below the stormwater facility, \( d_n \) is the thickness of layer “n” in the soil column, and \( K_n \) is the saturated potential hydraulic conductivity of layer “n” in the soil column. The depth of the soil column, \( d \), typically would include all layers between the facility bottom and the water table or laterally extensive very low permeability layer. However, for sites with very deep water tables or confining layers (deeper than 100 feet) where ground water mounding to the base of the facility is unlikely to occur, it is recommended that the total depth of the soil column in Equation 2 be limited to approximately 20 times the maximum water depth of the facility. This is to ensure that the most important and relevant layers are included in the hydraulic conductivity calculations. Deep layers that are not likely to affect the infiltration rate near the facility bottom should not be included in Equation 2.

Equation 2 may over-estimate the effective hydraulic conductivity value at sites with laterally extensive low conductivity layers immediately beneath the infiltration facility. For sites where the lowest conductivity layer is within five feet of the base of the facility, it is suggested that this lowest hydraulic conductivity value be used as the equivalent hydraulic conductivity, rather than the value from Equation 2. The harmonic mean given by Equation 2 is the appropriate effective hydraulic conductivity for flow that is perpendicular to stratigraphic layers, and will produce conservative results when flow has a significant horizontal component such as could occur due to ground water mounding.

- For unusually complex or critical design cases (such as areas with fluctuating groundwater elevations that approach the ground surface, or where infiltration facilities are very large or may affect adjacent property’s developability), it may be necessary to develop input data for a groundwater flow model such as MODFLOW, including trial infiltration facility geometry, continuous hydrograph data, soil stratigraphy data, groundwater data, hydraulic conductivity data, and reduction in hydraulic conductivity due to siltation or biofouling on the surface of the facility. It is expected that this unusually complex modeling approach will be applied only in rare situations. Otherwise, skip this step and develop the data needed to estimate the hydraulic gradient as explained in the following steps.
• Calculate the hydraulic gradient as follows:

\[
\frac{(D_{wt} + D_{pond}) \cdot CF_{size}}{138.62 \cdot (K_{equiv}^{0.1})} = i
\]

(Equation 3a for ponds)

\[
\frac{(D_{wt} + D_{trench})}{78 \cdot (K_{equiv}^{0.05})} = i
\]

(Equation 3b for trenches)

where \(D_{wt}\) is the depth from the base of the infiltration facility to the apparent wet season high groundwater level or confining layer/stratum in feet; \(K\) is the saturated hydraulic conductivity in feet per day from Equation 2; \(CF_{size}\) is a correction factor for ponds, based on the expectation that the larger the pond, the more severe the localized groundwater mounding (see below—and note that while mounding is not considered to be an issue with individual trenches, multiple parallel trenches or infiltration vaults may cause mounding and shall be considered as a pond (use Equation 3(a)) in these calculations), and \(D_{pond}\) and \(D_{trench}\) are the average facility water depths in feet (see Massmann et al., 2003 for the development of these equations). The gradient \(i\) is effectively unitless (actually, feet per foot)

\[
CF_{size} = 0.73 \cdot (A_{pond})^{-0.76}
\]

(Equation 3c) where \(A_{pond}\) is the pond bottom area in acres. \(CF_{size}\) has a maximum value of 1.0. For small ponds (ponds with an area equal to 2/3 acre or less) the CF area correction factor is equal to one.

• Calculate the functional saturated hydraulic conductivity rate using Darcy’s Law as follows:

\[
f = K_{equiv} \cdot \frac{i}{2},
\]

(Equation 4)

where \(f\) is the functional saturated hydraulic conductivity (in length per unit time, L/t, typically inches/hour) corrected for effects of groundwater mounding; \(K_{equiv}\) is the saturated potential hydraulic conductivity (L/t) from Equation 2; and \(i\) is the hydraulic gradient from Equation 3a or 3b.

The reduction factor of 2.0 is to account for the fine layering and relatively shallow depth to groundwater in local soils.
Derive the facility-design infiltration rate \( f_{\text{design}} \) by adjusting the functional saturated hydraulic conductivity rate \( f \), using the Table 3.4 correction factors which account for long-term performance decline. The composite correction factor applied to facility design shall be the product of the three partial correction factors. Divide \( f \) by the composite correction factor to get the design infiltration rate.

\[
f_{\text{design}} = \frac{f}{(\text{CF}_{\text{maintain}})(\text{CF}_{\text{watershed}})} \quad \text{(Equation 5)}
\]

Table 3.5 summarizes the steps followed in estimating the facility design infiltration rate.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Partial Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintainability of infiltration surface performance</td>
<td>• All surface facilities, CF = 1</td>
</tr>
<tr>
<td></td>
<td>• All underground facilities, CF = 1.5</td>
</tr>
<tr>
<td>Watershed effects on infiltration surface performance (fines generation)</td>
<td>• The development will have at least 65% impervious,</td>
</tr>
<tr>
<td></td>
<td>or has soils with mainly Hydrologic Group A or greater than 30% coarse-grained surface (A/B horizon) soils, CF = 1</td>
</tr>
<tr>
<td></td>
<td>• The development will have less than 65% impervious and having mainly: Hydrologic Group B soils, CF = 1.5; Hydrologic Group C or D soils, CF = 2. In both cases, these factors apply only where A/B horizon surface soils have less than 30% coarse fragments.</td>
</tr>
</tbody>
</table>

Composite correction factor = Product of the three partial correction factors. Product range = 1 minimum to 3 maximum. In no case shall the design infiltration rate exceed 20 inches per hour.

These factors reflect the empirical nature of Massmann’s work, and the fact that the field measurements used reflect “average” construction, soil, and maintenance conditions for pond systems.
### Table 3.5: Stormwater Infiltration Checklist

<table>
<thead>
<tr>
<th>Action</th>
<th>Quantity</th>
<th>Description/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Characterize the site</td>
<td>1</td>
<td>Obtain NRCS soils information, topography, site use, and groundwater/confining layer information, if available</td>
</tr>
<tr>
<td>2. Dig soil test pits, holes or borings and report results</td>
<td>2+</td>
<td>Holes to penetrate 12 feet below the proposed infiltration facility bottom, or 5 times the facility’s maximum water depth, or 2 feet below the wet-season high water table or laterally extensive very low permeability layer, whichever is greatest.</td>
</tr>
</tbody>
</table>
| 3. Install monitoring wells                                           | 0, 1, or 3+ | • No wells are needed if adequate groundwater/confining layer information is available.  
• Install one well if apparent wet-season high groundwater level is needed but no groundwater modeling will be done.  
• Install three or more wells in areas of groundwater flooding, or where modeling will be done. |
| 4. Collect soil samples for grain size analysis                       | Varies   | Samples to be taken to 6 feet below facility bottom, or 3 times the facility’s maximum water depth, or 2 feet below the apparent wet-season high water table or laterally extensive very low permeability layer, whichever is greatest. Collect one sample per layer per test pit, hole, or boring. For example, a site with 2 holes, each with 3 layers, would have 6 soil samples. |
| 5. Conduct sieve analysis and produce particle size distribution curves| Same as Action 4 | Curves should show $D_{10}$, $D_{50}$, $D_{90}$, and fraction fines passing Number 200 sieve.                                                                                                                   |
| 6. (Optional) Conduct and report on Pilot Infiltration Test (PIT)    | 1+       | Compare PIT results to calculated $K_{equiv}$, below. They should provide similar results. If not, evaluate and report possible reasons.                                                                                     |
| 7. Estimate soil water holding capacity                               | 1        | Equals 20% of soil depth below pond and above apparent wet-season high groundwater level or confining layer                                                                                                           |
| 8. Estimate groundwater depths and ranges                             | 1        | Estimate wet-season high groundwater levels for normal (average) and abnormal (100-year) rainfall seasons.                                                                                                                                                         |
| 9. Determine confining layer depth                                    | 1        | If applicable.                                                                                                                                                                                                       |
| 10. Calculate saturated potential hydraulic conductivity ($K_{sat}$)  | 1 per layer | Use Equation 1                                                                                                                                                                                                     |
| 11. Calculate overall saturated potential hydraulic conductivity ($K_{equiv}$) | 1        | Use Equation 2                                                                                                                                                                                                     |
| 12. Calculate hydraulic gradient ($i$)                                 | 1        | Use Equation 3a (ponds/parallel trenches/vaults) or 3b (individual trenches). Adjust Equation 3a for pond size effects. Otherwise, set gradient to 1.                                                                 |
| 13. Calculate functional saturated hydraulic conductivity ($f$)        | 1        | Use Equation 4                                                                                                                                                                                                     |
| 14. Calculate facility design rate ($f_{design}$)                     | 1        | Use Equation 5                                                                                                                                                                                                     |
| 15. Calculate infiltration facility size                              | 1        | Use WWHM-TC or other approved model                                                                                                                                                                                   |
The following discussion assists in determining the partial correction factors to apply in Table 3.4.

**Maintainability of infiltration surface performance** - Surface facilities, such as ponds, are easier to maintain and restore infiltration performance than underground facilities, such as vaults. The expectation is that surface facilities will be maintained more frequently, and with better success, than underground ones. Therefore, the partial correction factor is lower for surface facilities than underground ones.

**Watershed effects on infiltration surface performance** - At least three major factors contribute to infiltration surface siltation. These are the watershed soil type, the length of time the watershed soils are exposed during development, and the development’s percent impervious. An infiltration facility is more likely to be negatively affected in watersheds with lengthy development periods, less pavement (more exposed soil), or finer (siltier, few coarse fragments, less well-drained) soils. Local permitting authority experience has been that single-family residential ponds seem to have the most significant problems because of siltation during the home-building process. Therefore, the partial correction factors are higher for low-impervious developments and on less well-drained soils.

### 3.3.6 Site Suitability Criteria (SSC)

This section provides criteria that must be considered and complied with for siting and evaluating infiltration systems. When a site investigation reveals that any of the applicable criteria cannot be met, appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to safety, health, and the environment.

**For site selection and design decisions a geotechnical and hydrogeologic report shall be prepared by an engineer with geotechnical and hydrogeologic experience, or an equivalent licensed or certified professional with appropriate training, under the seal of a registered Professional Engineer.** The design engineer may utilize a team of certified or registered professionals in soil science, hydrogeology, geology, and other related fields.

**SSC-1 Setback Criteria**

Infiltration facility setbacks are as follows (see Section 3.1.1 for downspout infiltration system setbacks):
• From drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies, contact the Thurston County Health Department for requirements.

• Additional setbacks must be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system.

• From building basements, crawl spaces, or foundations; 20 feet if the infiltration facility is downgradient and 100 feet if it is upgradient. Ensure that the infiltration facility’s line of saturation at design depth falls below the basement, crawl space, or foundation.

• From a Native Growth Protection Easement (NGPE); ≥ 20 feet

• From the top of steep slopes (over 15%); ≥ 50 feet. The local permitting authority may require a geotechnical analysis to assess slope stability, such as in known or suspected landslide hazard areas.

• Evaluate on-site and off-site structural stability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps.

• Comply with all other applicable requirements, such as health, building, and plumbing codes.

SSC-2 Ground Water Protection Areas

A site is not suitable if the infiltration facility will cause a violation of Ecology's Ground Water Quality Standards. Local jurisdictions should be consulted for applicable pollutant removal requirements upstream of the infiltration facility, and to determine whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone.

SSC-3 High Vehicle Traffic Areas

An infiltration BMP may be considered for runoff from areas of industrial activity and the high vehicle traffic areas described below. For such applications sufficient pollutant removal (including oil removal) must be provided upstream of the infiltration facility to ensure that ground water quality standards will not be violated and that the infiltration facility is not adversely affected.

High Vehicle Traffic Areas are:

– Commercial or industrial sites subject to an expected average daily traffic count (ADT) ≥100 vehicles/1,000 ft² gross building area (trip generation), and
- Road intersections with an ADT of \( \geq 25,000 \) on the main roadway, or 
  \( \geq 15,000 \) on any intersecting roadway.

**SSC 4-Contingency Planning**

The empirical infiltration assessment methods provided above are expected to yield accurate estimates of ultimate infiltration rates. However, soils, shallow geology, and groundwater conditions can be extremely complex and highly variable, which may cause inaccuracies. Therefore, it is necessary to have a plan for fixing underperformance discovered after facilities are installed (see Verification Testing, below).

All projects using infiltration facilities shall provide a contingency plan for underperformance. The plan shall include a reasonable “worst-case” projection of long-term infiltration performance and describe methods and costs for improving/restoring performance and/or expanding facility size. These costs shall provide one basis for required performance/operation and maintenance bonding (see Volume I, Section 2.6).

**SSC-5 Soil Infiltration Rate/Drawdown Time**

*(Applies to infiltration facilities used as treatment facilities and not to those used as flow control facilities)*

**Infiltration Rates:**

To be categorized as a treatment facility, the facility design infiltration rate shall not exceed 2.4 in/hr. Facilities with higher design rates are categorized as flow control infiltration facilities, and require a basic treatment facility, rather than a pretreatment facility, ahead of infiltration.

This infiltration rate is also typical for soil textures that possess sufficient physical and chemical properties for adequate treatment, particularly for soluble pollutant removal (see SSC-6). It is comparable to the textures represented by Hydrologic Groups B and C. This infiltration rate should also be used for maximum drawdown time and routing calculations.

**Drawdown Time:**

It is recommended that the maximum ponded depth (water quality volume) from the infiltration basin be drained within 24 hours after completion of the design event, in order to meet the following objectives:

- restore hydraulic capacity to receive runoff from a new storm
- maintain infiltration rates
- aerate vegetation and soil to keep the vegetation healthy
- enhance the biodegradation of pollutants and organics in the soil.
SSC-6 Soil Physical and Chemical Suitability for Treatment

(Appplies to infiltration facilities used as treatment facilities and not to those used as flow control facilities)

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

- Cation exchange capacity (CEC) of the treatment soil must be \( \geq 5 \) milliequivalents/100 g dry soil (USEPA Method 9081). *Consider empirical testing of soil sorption capacity, if practicable*. Ensure that soil CEC is sufficient for expected pollutant loadings, particularly heavy metals. CEC values of \( >5 \) meq/100g are expected in loamy sands, according to Rawls, et al. Therefore, soils finer than sands should normally have adequate CEC, and CEC laboratory testing may not be needed. Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is accepted by the local jurisdiction.

- Depth of soil used for infiltration treatment must be a minimum of 18 inches.

- Organic content of the treatment soil (ASTM D 2974): Organic matter can increase the sorptive capacity of the soil for some pollutants. The site professional should evaluate whether the organic matter content is sufficient for control of the target pollutant(s).

- Waste fill materials should not be used as infiltration soil media nor should such media be placed over uncontrolled or non-engineered fill soils.

- Engineered soils may be used to meet the design criteria in this chapter and the performance goals in Chapters 3 and 4. Field performance evaluation(s), using acceptable protocols, would be needed to determine feasibility, and acceptability by the local jurisdiction.

SSC 7-Verification Testing of the Completed Facility

Verification testing of the completed full-scale infiltration facility is required to confirm that the design infiltration rate is being attained. *After project completion, the applicant shall submit a facility monitoring and evaluation report. A licensed civil engineer shall prepare and seal the report. The report shall document field work and assess stormwater infiltration facility performance versus design (e.g., infiltration rates).*
All field work shall be done under the engineer’s direction and supervision. Testing shall consist of automated continuous water level monitoring over a sufficient number of storms to provide an accurate “long-term” infiltration rate. Testing shall either have a minimum of 30 days’ test results with two or more events exceeding 30% of facility volume, or one full wet season’s data (November 1 to March 30). An alternative, with local permitting authority approval, is to simulate storm events using hydrant or trucked water. The report shall specify any actions needed to restore performance, such as sediment removal or facility expansion. Local governments will retain guarantees until the facility’s measured and design infiltration rates are roughly equivalent.

For the purposes of stormwater facility infiltration rate verification roughly equivalent shall be considered to be either above the design infiltration rate or a rate greater than the design infiltration rate minus 25%.

The long term infiltration rate determination shall be based upon the direct measurement of the change in water level with time. In detention/retention facilities the discharge of water through the outlet structure shall be considered to determine the facility infiltration rate. In trench facilities the change in water level in drain rock shall be converted to the change in free water level by multiplying by the void content of the drain rock to determine the infiltration rate. Hydrologic modeling cannot be used to estimate flows into a facility in order to verify the infiltration rate.

The verification report shall include the following list of items:

- The stamp and certification of the professional engineer directing the work.
- A description of the infiltration facility as it was designed, including the design infiltration rate.
- A description of the infiltration facility as it was constructed.
- A description of how and where the performance monitoring was performed.
- Plots of water level in the facility with time.
- Infiltration rate calculations based upon the observed data.
- A statement and conclusions about the performance of the facility and whether it meets its original design.
• Recommendations of modifications to the facility, if required, to either ensure continued operation or comply with the original design requirements.

3.3.7 General Design, Maintenance, and Construction Criteria for Infiltration Facilities

This section covers design, construction and maintenance criteria that apply to infiltration basins and trenches.

Design Criteria – Sizing Facilities

The size of the infiltration facility can be determined by routing the influent runoff file generated by the continuous simulation runoff model through it. In general, an infiltration facility would have 2 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 facility must comply with the Minimum Requirement #7 for flow control in Volume I.

In order to determine compliance with the flow control requirements, Western Washington Hydrology Model, Thurston County Edition (WWHM-TC), or an appropriately calibrated continuous simulation model based on HSPF, must be used.

When using WWHM-TC for simulating flow through an infiltrating facility, the facility is represented by using the Pond Icon and entering the pre-determined infiltration rates. Below are the procedures for sizing a pond (A)- to completely infiltrate 100% of runoff; (B)- to treat 91% of runoff to meet the water quality treatment requirements, and (C)- to partially infiltrate runoff to meet flow duration standard.

(A) For 100% infiltration

(1)- Input dimensions of your infiltration pond,
(2)- Input infiltration rate and safety (rate reduction) factor,
(3)- Input a riser height and diameter (any flow through the riser indicates that you have less than 100% infiltration and must increase your infiltration pond dimensions).
(4)- Run only HSPF for Developed Mitigated Scenario (if that is where you put the infiltration pond). Don't need to run duration.
(5)- Go back to your infiltration pond and look at the Percentage Infiltrated at the bottom right. If less than 100% infiltrated, increase pond dimension until you get 100%.
(B) For 91% infiltration (Water Quality Treatment volume)
The procedure is the same as above, except that your target is 91%.

Infiltration facilities for treatment can be located upstream or downstream of detention and can be off-line or on-line.

**On-line** treatment facilities placed upstream or downstream of a detention facility must be sized to infiltrate 91% of the runoff file volume directed to it.

**Off-line** treatment facilities placed upstream of a detention facility must have a flow splitter designed to send all flows at or below the 15-minute water quality flow rate, as predicted by WWHM-TC, to the treatment facility. Within the WWHM-TC, the flow splitter icon is placed ahead of the pond icon which represents the infiltration basin. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

Off-line treatment facilities placed downstream of a detention facility must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention pond, as predicted by WWHM-TC, to the treatment facility. Within the WWHM-TC, the flow splitter icon is placed ahead of the pond icon which represents the infiltration basin. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

See Chapter 4 for flow splitter design details.

(C) To meet flow duration standard with infiltration ponds

This design will allow something less than 100% infiltration as long as any overflows will meet the flow duration standard. You would need a discharge structure with orifices and risers similar to a detention facility except that, in addition, you also have infiltration occurring from the pond.

Additional Design Criteria

- Slope of the base of the infiltration facility should be less than 3 percent.

- Spillways/Overflow structures- A nonerodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow. Ponding depth, drawdown time, and storage volume are calculated from that reference point. Regarding overflow structures, refer to Chapter 2 for design details

Construction Criteria

- Excavate infiltration trenches and basins to final grade only after construction has been completed and all upgradient soil has been stabilized. Initial basin excavation should be conducted to within 1-foot of the final elevation of the basin floor. Any accumulation of silt
in the infiltration facility must be removed before putting it in service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment.

- Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized.

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

**Maintenance Criteria**

Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, with adequate access. Maintenance should be conducted when water remains in the basin or trench for more than 24 hours. An Operation and Maintenance Plan, approved by the local permitting authority, should ensure maintaining the desired infiltration rate.

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

Seepage Analysis and Control - Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

For more detailed information on maintenance, see Volume I Appendix G.

**Performance Verification**

Ongoing, periodic verification testing (specified in SSC-7) may be required, as an element of the operation and maintenance program that results in achieving expected performance levels.

3.3.8 Infiltration Basins

This section covers design and maintenance criteria specific for infiltration basins also referred to as retention ponds. (See schematic in Figure 3.25). Infiltration basins shall be designed to comply with the requirements of Section 3.2.1 Detention and Retention Ponds and the following criteria.
**Description:**

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

**Design Criteria Specific for Basins**

- Access should 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.

- A minimum of one 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.

- Lining Material – Infiltration basins shall not be lined, except as may be needed to reduce infiltration rates for runoff from high-use sites into very or extremely gravelly soils.

- Vegetation - The embankment, emergency spillways, spoil, and borrow areas, and other disturbed areas should be stabilized and planted. The base of the facility shall be planted with grass, while the side slopes and surrounding area shall be planted with a mixture of shrubs, trees, and grasses. Without healthy vegetation the surface soil pores would quickly plug.

- Over-excavation – if the soils under the infiltration facility are over-excavated in order to increase the infiltration rate in the facility then he following criteria shall be applied:
  1. The area of the over-excavated soils shall be used as the area of the infiltration surface in the sizing of the facility.
  2. The backfilled material shall meet the site suitability criteria physical and chemical requirements of SSC-6 Soil Physical and Chemical Suitability for Treatment for its entire depth.

**Maintenance Criteria for Basins**

- 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. Bare spots are to be immediately stabilized and revegetated.

- Grass growth should not be allowed to exceed 18 inches in height. Mow the slopes periodically and check for clogging, and erosion.
• Seed mixtures should be the same as those recommended in Table 3.2. The use of slow-growing, stoloniferous grasses will permit long intervals between mowing. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to ground water pollution. Consult the local extension agency for appropriate fertilizer types, including slow release fertilizers, and application rates.

3.3.9 Infiltration Trenches

This section covers design, construction, and maintenance criteria specific for infiltration trenches. Infiltration trenches shall be designed to comply with the following criteria.

Description:

Infiltration trenches are generally at least 24 inches wide, and may be 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.

Design Criteria

• Due to accessibility and maintenance limitations, infiltration trenches must be carefully designed and constructed.

• Access ports or open or grated top is required for accessibility to conduct inspections and maintenance.

Infiltration trenches have limited opportunities to rehabilitate the infiltration surface after the facility is built. For this reason infiltration trench facilities should be expected to have shorter life spans and greater rehabilitation costs as compared to stormwater ponds. Rehabilitation of infiltration trenches may require the complete removal and replacement of the facility along with significant surface restoration impacts.

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

• Geotextile fabric liner - The aggregate fill material shall be wrapped on the sides and top with an engineering geotextile material. In the case of an aggregate surface, geotextile should surround all of the
aggregate fill material except for the top one-foot, which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging (see Appendix V-C of Volume V).


- Overflow Channel - Because an infiltration trench is generally used for small drainage areas, an emergency spillway is not necessary. However, a non-erosive overflow path leading to a stabilized outlet shall be provided.
- Surface Cover - A trench can be placed under a porous or impervious surface cover to conserve space.
- Observation Well - An observation well may be needed at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. Figure 3.22 illustrates observation well details. 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 12-36 inch diameter well or port can be installed to facilitate maintenance operations such as pumping out the sediment. The top of the well or port should be capped to discourage vandalism and tampering.

Construction Criteria

- Trench Preparation - Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic. (see Erosion/sediment control Criteria in Volume II).
- Stone Aggregate Placement and Compaction - The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.
- Potential Contamination - Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.
• Overlapping and Covering-Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

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

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

**Maintenance Criteria**

• Sediment buildup should be monitored on the same schedule as the observation well.

• As an element of the operation and maintenance program, the actual infiltration rate should be periodically tested and compared to the design rate. If the actual rate is significantly less than the design rate, remedial action is required.
Volume III References

King County Runoff Time Series (KCRTS), King County Department of Natural Resources, Personal Communication, 1999.
Resource Materials (not specifically referenced in text)


Caraco, D., Claytor, R., Stormwater BMP Design Supplement for Cold Climates USEPA, December 1997


King County, Washington, Surface Water Design Manual, September 1, 1998.


Woodward-Clyde, BMP Design Recommendations, November 1995
Appendix III-A
Isopluvial Maps for Design Storms

Included in this appendix are the 2, 10 and 100-year, 24-hour design storm and mean annual precipitation isopluvial maps for Western Washington. These have been taken from NOAA Atlas 2 “Precipitation - Frequency Atlas of the Western United States, Volume IX, Washington.
Western Washington Isopluvial 2-year, 24 hour

ISOPLUVIALS OF 2-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH
Western Washington Isopluvial 100-year, 24 hour
Appendix III-B
Western Washington Hydrology Model – Information, Assumptions, and Computation Steps

Please access Ecology’s or Thurston County’s website for latest information and updates at http://www.ecy.wa.gov/programs/wq/stormwater/wwhm_training/index.html or http://www.co.thurston.wa.us/wwm/

The information and assumptions used in the Western Washington Hydrology Model (WWHM) are described in this document. Thurston County’s enhancements, as well as Ecology updates, may result in differences from what is written below.

WWHM Limitations

The WWHM has been created for the specific purpose of sizing stormwater control facilities for new development and redevelopment projects in Western Washington. The WWHM can be used for a range of conditions and developments; however, certain limitations are inherent in this software. These limitations are described below.

The WWHM uses the 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.

In addition, the WWHM is limited in its routing capabilities. The user is allowed to input a single stormwater control facility and runoff is routed through this facility. If the proposed development site contains multiple facilities in series or involves routing through a natural lake, pond, or wetland in addition to a stormwater control facility then the user should use HSPF to do the routing computations and additional analysis.

Routing effects become more important as the drainage area increases. For this reason it is recommended that the WWHM not be used for drainage areas greater than one-half square mile (320 acres). The WWHM can be used for small drainage areas down to less than an acre in size.

WWHM Information and Assumptions

1. Precipitation data.

Length of record.
The WWHM uses long-term (43-50 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. A 40 to 50-year record is preferred. The actual length of record of each precipitation station varies, but all exceed 43 years.
Rainfall distribution.  
The precipitation data are representative of the different rainfall regimes found in western Washington. A total of 17 precipitation stations are used. These stations represent rainfall at elevations below 1500 feet. Snowfall and melt are not included in the WWHM.

The primary source for precipitation data is National Weather Service stations. The secondary source is precipitation data collected by local jurisdictions. During development of WWHM, county engineers at 19 western Washington counties were contacted to obtain local precipitation data. Only King County provided local data.

The following precipitation stations have been included in the WWHM:

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<th>Years of Data</th>
<th>County Coverage</th>
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</tr>
<tr>
<td>Blaine</td>
<td>1948-1998 = 50</td>
<td>Whatcom, San Juan</td>
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<td>Darrington</td>
<td>1948-1996 = 48</td>
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<tr>
<td>Everett</td>
<td>1948-1996 = 48</td>
<td>Snohomish (excluding northeast)</td>
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<tr>
<td>Frances</td>
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<td>Pacific</td>
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<td>King (east)</td>
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<td>Cowlitz, Lewis (south)</td>
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<td>1948-1997 = 49</td>
<td>King (west)</td>
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</table>

The records were reviewed for length, quality, and completeness of record. Annual totals were checked along with hourly maximum totals. Using these checks, data gaps and errors were corrected, where possible. A "Quality of Record" summary was produced for each precipitation record reviewed.

The reviewed and corrected data were placed in multiple WDM (Watershed Data Management) files. One WDM file was created per county and contains all of the precipitation data to be used by the WWHM for that particular county.

Computational time step.  
The computational time step used in the WWHM is one hour. The one-hour time step was selected to better represent the temporal variability of actual precipitation than daily data.
2. Precipitation multiplication factors.

Precipitation multiplication factors increase or decrease recorded precipitation data to better represent local rainfall conditions. This is particularly important when the precipitation gage is located some distance from the study area.

Precipitation multiplication factors were developed for western Washington. The factors are based on the ratio of the 24-hour, 25-year rainfall intensities for the representative precipitation gage and the surrounding area represented by that gage’s record. The 24-hour, 25-year rainfall intensities were determined from the NOAA Atlas 2 (*Precipitation-Frequency Atlas of the Western United States, Volume IX – Washington, 1973*).

These multiplication factors were created for the Puget Sound lowlands plus all western Washington valleys and hillside slopes below 1500 feet elevation. The factors were placed in the WWHM database and linked to each county’s map. They are transparent to the general user. The advanced user will have the ability to change the precipitation multiplication factor for a specific site. However, such changes will be recorded in the WWHM output.

3. Pan evaporation data.

Pan evaporation data are used to determine the potential evapotranspiration (PET) of a study area. Actual evapotranspiration (AET) is computed by the WWHM based on PET and available moisture supply. AET accounts for the precipitation that returns to the atmosphere without becoming runoff. Soil moisture conditions and runoff are directly influenced by PET and AET.

Evaporation is not highly variable like rainfall. Puyallup pan evaporation data are used for all of the 19 western Washington counties.

Pan evaporation data were assembled and checked for the same time period as the precipitation data and placed in the appropriate county WDM files.

Pan evaporation data are collected in the field, but PET is used by the WWHM. PET is equal to pan evaporation times a pan evaporation coefficient. Depending on climate, pan evaporation coefficients for western Washington range from 0.72 to 0.82.

NOAA Technical Report NWS 33, *Evaporation Atlas for the Contiguous 48 United States*, was used as the source for the pan evaporation coefficients. Pan evaporation coefficient values are shown on Map 4 of that publication.

As with the precipitation multiplication factors, 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. However, such changes will be recorded in the WWHM output.
4. Soil data.

Soil type, along with vegetation type, greatly influences the rate and timing of the transformation of rainfall to runoff. Sandy soils with high infiltration rates produce little or no surface runoff; almost all runoff is from groundwater. Soils with a compressed till layer slowly infiltrate water and produce larger amounts of surface runoff during storm events.

The WWHM uses three predominate soil type to represent the soils of western Washington: till, outwash, and saturated.

Till soils have been compacted by glacial action. Under a layer of newly formed soil lies a compressed soil layer commonly called "hardpan". This hardpan has very poor infiltration capacity. As a result, till soils produce a relatively large amount of surface runoff and interflow. A typical example of a till soil is an Alderwood soil (SCS class C).

Outwash soils have a high infiltration capacity due to their sand and gravel composition. Outwash soils have little or no surface runoff or interflow. Instead, almost of their runoff is in the form of groundwater. An Everett soil (SCS class A) is a typical outwash soil.

Outwash soils over high groundwater or an impervious soil layer have low infiltration rates and act like till soils. Where groundwater or an impervious soil layer is within 5 feet from the surface, outwash soils may be modeled as till soils in the WWHM.

Saturated soils are usually found in wetlands. They have a low infiltration rate and a high groundwater table. When dry, saturated soils have a high storage capacity and produce very little runoff. However, once they become saturated they produce surface runoff, interflow, and groundwater in large quantities. Mukilteo muck (SCS class D) is a typical saturated soil.

The user will be required to investigate actual local soil conditions for the specific development planned. The user will then input the number of acres of outwash (A/B), till (C), and saturated (D) soils for the site conditions.

Alluvial soils are found in valley bottoms. These are generally fine-grained and often have a high seasonal water table. There has been relatively little experience in calibrating the HSPF model to runoff from these soils, so in the absence of better information, these soils may be modeled as till soils.

Additional soils will be included in the WWHM if appropriate HSPF parameter values are found to represent other major soil groups.

The three predominate soil types are represented in the WWHM by specific HSPF parameter values that represent the hydrologic characteristics of these soils. More information on these parameter values is presented below.
5. Vegetation data.

As with soil type, vegetation types greatly influence the rate and timing of the transformation of rainfall to runoff. Vegetation intercepts precipitation, increases its ability to percolate through the soil, and evaporates and transpires large volumes of water that would otherwise become runoff.

The WWHM will represent the vegetation of western Washington with three predominate vegetation categories: forest, pasture, and lawn (also known as grass).

Forest vegetation represents the typical second growth Douglas fir found in the Puget Sound lowlands. Forest has a large interception storage capacity. This means that a large amount of precipitation is caught in the forest canopy before reaching the ground and becoming available for runoff. Precipitation intercepted in this way is later evaporated back into the atmosphere. Forest also has the ability to transpire moisture from the soil via its root system. This leaves less water available for runoff.

Pasture vegetation is typically found in rural areas where the forest has been cleared and replaced with shrub or grass lots. Some pasture areas may be used to graze livestock. The interception storage and soil evapotranspiration capacity of pasture are less than forest. Soils may have also been compressed by mechanized equipment during clearing activities. Livestock can also compact soil. Pasture areas typically produce more runoff (particularly surface runoff and interflow) than forest areas.

Lawn vegetation is representative of the suburban vegetation found in typical residential developments. Soils have been compacted by earth moving equipment, often with a layer of topsoil removed. Sod and ornamental bushes replace native vegetation. The interception storage and evapotranspiration of lawn vegetation is less than pasture. More runoff results.

Predevelopment default land conditions are forest, although the user has the option of specifying pasture if there is documented evidence that pasture vegetation was native to the predevelopment site. If this option is used, the change will be recorded in the WWHM output.

Forest vegetation is represented by specific HSPF parameter values that represent the forest hydrologic characteristics. As described above, the existing regional HSPF parameter values for forest are based on undisturbed second-growth Douglas fir forest found today in western Washington lowland watersheds.

Postdevelopment vegetation will reflect the new vegetation planned for the site. The user has the choice of forest, pasture, and landscaped vegetation. Forest and pasture are only appropriate for postdevelopment vegetation in parcels separate from standard residential or non-standard residential/commercial. Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances. The WWHM assumes the pervious land portion of developed areas the standard residential and non-standard residential/commercial is covered with lawn vegetation, as described above.
6. Development land use data.

The WWHM user must enter land use information for the pre-developed condition and the proposed development condition into the model.

There are 6 basic land use categories and 3 soil types available in the WWHM2. The land use categories are: Impervious Area (Roof), Streets/Sidewalks/Parking, Landscaped Area (this is modeled as includes lawn, garden, areas with ornamental plants, and any natural areas not legally protected from future disturbance), Forest, Pasture, and Pond. The soils types are A/B (outwash), C/D (Till), and Saturated (wetland).

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 standard residential development. **Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances.**

Impervious, as the name implies, allows no infiltration of water into the pervious soil. All runoff is surface runoff. Impervious land typically consists of paved roads, sidewalks, driveways, and parking lots. Roofs are also impervious.

For the purposes of hydrologic modeling, only effective impervious area is categorized as impervious. Effective impervious area (EIA) is the area where there is no opportunity for surface runoff from an impervious site to infiltrate into the soil before it reaches a conveyance system (pipe, ditch, stream, etc.). An example of an EIA is a shopping center parking lot where the water runs off the pavement and directly goes into a catch basin where it then flows into a pipe and eventually to a stream. In contrast, some homes with impervious roofs collect the roof runoff into roof gutters and send the water down downspouts. When the water reaches the base of the downspout it can be directed either into a pipe (which is connected to the local storm sewer), dumped onto a splash block, or dispersed into soil. Well-dispersed roof water has the opportunity to spread out into the yard and soak into the soil, so it may be considered non-effective impervious area (see below for more information).

The non-effective impervious area uses the adjacent or underlying soil and vegetation properties. Vegetation often varies by the type of land use. The assumption is made in the WWHM that the EIA equals the TIA (total impervious area). This is consistent with King County’s determination of EIA acres for new developments. Where appropriate, the TIA can be reduced through the use of runoff credits (more on that below).

In addition, WWHM2 offers the following 2 optional features:

**Standard Residential:** For housing developments where lot-specific details (e.g., size of roof and driveway) are not yet determined, the WWHM provides a set of default assumptions about the amount of impervious area per lot and its division between driveways and rooftops. Ecology has selected a standard impervious area of 4200 square feet per residential lot, with 1000 square feet of that as driveway, walkways, and patio area, and the remainder as rooftop area. The rest of the lot acres will be assumed to be landscaped area (including lawn). The user inputs the number...
of residential lots and the total acreage of the residential lots (public right-of-way acreages and non-residential lot acreages excluded). The number of residential lots and the associated number of acres will be used to compute the average number of residential lots per acre. This value together with the number of residential lots and the impervious area in the public right-of-way will be used by the model to calculate the TIA for the proposed development. The areas covered by streets, parking areas, and sidewalk areas are input separately by the user.

**Runoff Credits:**

Runoff credits can be obtained using any or all of the low impact development methods listed below. The WWHM2 has an automated procedure for taking credits for infiltrating or dispersing roof runoff - methods #1 and #2 below. Credits for using methods 4, 6, 7, and 8 must be taken by following the guidance in Appendix C. Roof areas using method #5 – rainwater harvesting systems - designed in accordance with the guidance in Appendix C need not be entered into the model. Also, if using method 9 – Full dispersion – the runoff model need not be used for the area that meets the criteria in Appendix C.

1. Infiltrate roof runoff
2. Disperse roof runoff
3. Porous pavement for driveways and walks
4. Vegetated roofs
5. Rainwater harvesting
6. Reverse slope sidewalks
7. Low impact foundations
8. Rain gardens (Bioretention Areas)
9. Full dispersion

1. Infiltrate roof runoff
Credit is given for disconnecting the roof runoff from the development’s stormwater conveyance system and infiltrating on the individual residential lots. The WWHM assumes that this infiltrated roof runoff does not contribute to the runoff flowing to the stormwater detention pond site. It disappears from the system and does not have to be mitigated. See Volume III for design requirements for downspout infiltration systems.

2. Disperse roof runoff
Credit is also given for disconnecting the roof runoff from the development’s stormwater conveyance system and dispersing it on the surface of individual lots. If the runoff is dispersed using splashblocks onto compost-amended soils or native vegetation and the runoff’s vegetative flow path is 50 feet or longer, the roof area can be entered into the model as landscaped area rather than impervious surface. This runoff is assumed to be the equivalent of runoff from lawn vegetation.

3. Porous pavement for driveways and walks
The third option for runoff credit is the use of porous pavement for private driveways, sidewalks, streets, and parking areas. The WWHM2 currently includes an option for obtaining credits for the use of porous pavements on Streets/Sidewalk/Parking. The credit
given under this option is believed to be too small. Until such time as WWHM2 is upgraded to WWHM3, the LID credit guidance in Appendix C should be followed. It will direct you to enter a certain percentage of the pervious pavement area into the lawn/landscaped area category rather than the street/sidewalk/parking lot category.

Similar procedures should be followed for vegetated roofs, reverse slope sidewalks, and low impact foundations. The LID credit guidance of Appendix C directs how these surfaces should be entered into the model. If you do not know the specific quantities of the different land cover types for your development (e.g., the individual lots will be sold to builders who will determine layout and size of home), you should start with the assumption of 4200 sq. ft. of impervious area per lot – including 1,000 sq. ft. for driveways, and begin making adjustments in those totals as allowed in the LID guidance of Appendix C.

Other Development Options and Model Features
The WWHM allows the flexibility of bypassing a portion of the development area around a flow control facility and/or having offsite inflow that is entering the development area pass through the flow control facility.

Bypass occurs when a portion of the development does not drain to a stormwater detention facility. Onsite runoff from a proposed development project may bypass the flow control facility provided that all of the following conditions are met.

1. Runoff from both the bypass area and the flow control facility converges within a quarter-mile downstream of the project site discharge point, and
2. The flow control facility is designed to compensate for the uncontrolled bypass area such that the net effect at the point of convergence downstream is the same with or without bypass, and
3. The 100-year peak discharge from the bypass area will not exceed 0.4 cfs, and
4. Runoff from the bypass area will not create a significant adverse impact to downstream drainage systems or properties, and
5. Water quality requirements applicable to the bypass area are met.

Offsite Inflow occurs when an upslope area outside the development drains to the flow control facility in the development. If the existing 100-year peak flow rate from any upstream offsite area is greater than 50% of the 100-year developed peak flow rate (undetained) for the project site, then the runoff from the offsite area must not flow to the onsite flow control facility. The bypass of offsite runoff must be designed so as to achieve the following:

1. Any existing contribution of flows to an onsite wetland must be maintained, and
2. Offsite flows that are naturally attenuated by the project site under predeveloped conditions must remain attenuated, either by natural means or by providing additional onsite detention so that peak flows do not increase.

Application of WWHM in Re-development Projects
WWHM allows only forest or pasture as the predevelopment land condition in the Design Basin screen. This screen does not allow other types of land uses such as impervious and
landscaped areas to be entered for existing condition. However, WWHM can be used for redevelopment projects by modeling the existing developed areas that are not subject to the flow control requirements of Volume I as offsite areas. For the purposes of predicting runoff from such an existing developed area, enter the existing area in the Offsite Inflow screen. This screen is designed to predict runoff from impervious and landscaped areas in addition to the forest and pasture areas. If the existing 100-year peak flow rate from the existing developed areas that are not subject to flow control is greater than 50% of the 100-year developed peak flow rate (undetained but subject to the flow control requirements of Volume I), then the runoff from the offsite area must not be allowed to flow to the onsite flow control facility.

7. PERLND and IMPLND parameter values.

In WWHM (and HSPF) pervious land categories are represented by PERLNDs; impervious land categories (EIA) by IMPLNDs. An example of a PERLND is a till soil covered with forest vegetation. This PERLND has a unique set of HSPF parameter values. For each PERLND there are 16 parameters that describe various hydrologic factors that influence runoff. These range from interception storage to infiltration to active groundwater evapotranspiration. Only four parameters are required to represent IMPLND.

The PERLND and IMPLND parameter values to be used in the WWHM are listed below. These values are based on regional parameter values developed by the U.S. Geological Survey for watersheds in western Washington (Dinicola, 1990) plus additional HSPF modeling work conducted by AQUA TERRA Consultants.

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PERLND types:  
OP = Outwash Pasture  
OL = Outwash Lawn  
SF = Saturated Forest  
SP = Saturated Pasture  
OF = Outwash Forest  
SL = Saturated Lawn  

PERLND parameters:  
LZSN = lower zone storage nominal (inches)  
INFILT = infiltration capacity (inches/hour)  
LSUR = length of surface overland flow plane (feet)  
SLSUR = slope of surface overland flow plane (feet/feet)  
KVARY = groundwater exponent variable (\text{inch}^{-1})  
AGWRC = active groundwater recession constant (\text{day}^{-1})  
INFEXP = infiltration exponent  
INFILD = ratio of maximum to mean infiltration  
BASETP = base flow evapotranspiration (fraction)  
AGWETP = active groundwater evapotranspiration (fraction)  
CEPSC = interception storage (inches)  
UZSN = upper zone storage nominal (inches)  
NSUR = roughness of surface overland flow plane (Manning’s n)  
INTFW = interflow index  
IRC = interflow recession constant (\text{day}^{-1})  
LZETP = lower zone evapotranspiration (fraction)

A more complete description of these PERLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).

PERLND parameter values for other additional soil/vegetation categories will be investigated and added to the WWHM, as appropriate.

**IMPLND Parameters**

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**IMPLND parameters:**  
LSUR = length of surface overland flow plane (feet)  
SLSUR = slope of surface overland flow plane (feet/feet)  
NSUR = roughness of surface overland flow plane (Manning’s n)  
RETSC = retention storage (inches)
A more complete description of these IMPLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).

The PERLND and IMPLND parameter values will be transparent to the general user. The advanced user will have the ability to change the value of a particular parameter for that specific site. However, such changes will be recorded in the WWHM output.

Surface runoff and interflow will be computed based on the PERLND and IMPLND parameter values. Where groundwater flow from small catchments reaches the surface and becomes runoff, the groundwater flow can be computed and added to give the total runoff (i.e., surface runoff, interflow, and groundwater.


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. Guidance is provided on the standards that must be met to comply with the Ecology Stormwater Management Manual.

There are two flow control standards stated in the Ecology Manual: Minimum Requirement #7 - Flow Control and Minimum Requirement #8 - Wetlands Protection (See Volume I). Minimum Requirement #7 specifies flow frequency and flow duration ranges for which the postdevelopment runoff cannot exceed predevelopment runoff. Minimum Requirement #8 specifies that discharges to wetlands must maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated beneficial uses.

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% of the 2-year peak flow up to the full 50-year peak flow. In general, matching discharge durations between 50% of the 2-year and 50-year will result in matching the peak discharge rates in this range.

The WWHM uses the predevelopment peak flow value for each water year to compute the predevelopment 2- through 100-year flow frequency values. The postdevelopment runoff 2- through 100-year flow frequency values are computed from the outlet of the proposed stormwater facility. The user must enter the stage-surface area-storage-discharge table (HSPF FTABLE) for the stormwater facility. The model then routes the postdevelopment runoff through the stormwater facility. As with the predevelopment peak flow values, the maximum developed flow value for each water year will be selected by the model to compute the developed 2- through 100-year flow frequency.

The actual flow frequency calculations are made using the federal standard Log Pearson Type III distribution described in Bulletin 17B (United States Water Resources Council, 1981). This standard flow frequency distribution is provided in U.S. Geological Survey program J407,
Minimum Requirement #7 is based on flow duration. The WWHM will use the entire predevelopment and postdevelopment runoff record to compute flow duration. The standard requires that postdevelopment runoff flows must not exceed the flow duration values of the predevelopment runoff between the predevelopment flow values of 50 percent of the 2-year flow and 100 percent of the 50-year flow.

Flow duration is computed by counting the number of flow values that exceed a specified flow level. The specified flow levels used by WWHM in the flow duration analysis are listed below.

1. 50% of the 2-year predevelopment peak flow.
2. 100% of the 2-year predevelopment peak flow.
3. 100% of the 50-year predevelopment peak flow.

In addition, flow durations are computed for 97 other incremental flow values between 50 percent of the 2-year predevelopment peak flow and 100 percent of the 50-year predevelopment peak flow.

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% and 100% of the 2-year 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% of the 2-year and 100% of the 50-year 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.

The results are provided in the WWHM report.

Minimum Requirement #8 specifies that discharges to wetlands must maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated beneficial uses. Criteria for determining maximum allowed exceedences in alterations to wetland hydroperiods are provided in guidelines cited in Guide Sheet 2B of the Puget Sound Wetland Guidelines (Azous and Horner, 1997).

Because wetland hydroperiod computations are relatively complex and are site specific, they have not yet been included in the WWHM2. HSPF is required for wetland hydroperiod analysis. Ecology intends to include the ability to perform hydroperiod computations in WWHM3.
**WWHM Computation Steps:** For sizing a detention pond. Follow steps under Quick Start in WWHM2 under Help/Contents. These are also reproduced below:

**Quick Start**

Here is a brief set of steps to demonstrate pond sizing using the WWHM2.

1. On the map screen (the first screen that shows up) click somewhere within the county boundaries.

   ![Tool bar](image)

2. On the Tool bar (above the map screen) click the second button to switch to the Scenario Editor.

   ![Schematic](image)

3. Drag and drop the Basin Icon somewhere towards the top of the Schematic. You should then have a basin in your schematic flowing to the Point of Compliance (POC). The POC represents outflow or the sum of all flow from your project.
4. Left click on the basin you just added. This will open a window on the right where you can enter land use for this basin.

5. Enter 10 acres in the field for Till Forest, and then click the Update button. You have now set your pre-developed conditions to 10 acres of Till Forest.
6. Now press the Developed Unmitigated button just below the schematic. Now you can enter basins and land use for your Developed unmitigated Scenario.

Now drag and drop a basin as you did in step 3. Click on it to enter land use as in step 4. This time instead of 10 acres of till forest, enter:

- 5 acres of Streets/Sidewalks/Parking.
- 3 acres of Landscaped Area.
- 1 acre of Impervious Area (Roof).
- 1 acre of Pond.

Be sure it’s all in the middle column indicating it’s on till soils as in the pre-developed Scenario. The screen should look like this:

![Developed Land Use](image)

Then click the update button.

![Developed Land Use](image)
7. Now click the Developed Mitigated button below the schematic. This brings you to the final Scenario where your detention facility will be placed. Notice that your Developed basin is already there. Now drag and drop a pond into the space just below the basin. The schematic should look like this:

Drag and drop a pond

8. Click on the pond to open the pond-editing window. You can edit any aspect of the pond from here, but for now, just click the Auto Pond button at the bottom. This will open up the Pond Wizard window.

First choose an outlet structure from the drop-down list in the middle of the Pond Wizard form. Select the first option (1 Orifice & Rectangular Notch).

Next, press the Create Pond button. You will see a progress bar pop up to indicate that HSPF is running the model and the pond wizard is creating a pond according to the results.
9. The Pond Wizard will then automatically bring you to the **Run Model** screen.

![Run Model Screen](image)

You can view the results in graphs or tables. For yearly peaks, select a scenario to view (upper left) and click the yearly peaks button. Flow frequency and durations always show pre-developed vs. developed mitigated.

If you wish to change the pond and re-run the model, take the following steps:

Go back to the Scenario editor (2nd Tool bar button).
Chose the Developed Mitigated Scenario.
Click on your pond.
Change one or more pond values and click Update.
Go back to the Run Model screen (3rd Tool bar button).
Chose the developed mitigated Scenario.
Check the Run HSPF and Duration Analysis check boxes.
Click Run Analysis.
References for Western Washington Hydrology Model


King County. 1998. Surface Water Design Manual. Department of Natural Resources. Seattle, WA.

Appendix III-C

This guidance suggests how to represent various LID techniques within continuous simulation models, so that their benefit in reducing surface runoff can be estimated. The lower runoff estimates should translate into smaller stormwater treatment and flow control facilities. In certain cases, use of various techniques can result in the elimination of those facilities.

The flow control credits presented in this chapter were developed by an LID credit committee comprised of stormwater managers from various local jurisdictions, WSU and Ecology.

This section identifies seven categories of LID techniques. For each category, the guidance lists basic design criteria that Ecology considers necessary in order to justify use of the suggested runoff “credit” or “runoff model representation.” More detailed design guidance is available in the Low Impact Development Technical Guidance Manual for Puget Sound (LID Manual), published by the Puget Sound Water Quality Action Team and the Washington State University Cooperative Extension, Pierce County. It may be found at http://www.psat.wa.gov/Programs/LID.htm.

As Puget Sound gains more experience with and knowledge of LID techniques, the design criteria will evolve. Also, our ability to model their performance will change as our modeling techniques improve. Therefore, we anticipate this guidance will be updated periodically to reflect the new knowledge and modeling approaches. Meanwhile, we encourage all to use the guidance, and to give us feedback on its usefulness and accuracy. Comments can be sent to Ed O’Brien of the Washington State Department of Ecology at eobr461@ecy.wa.gov.

Note that the terminology for grass has changed in the WWHM. The term grass has been replaced with landscaped area.

7.1 Permeable Pavements

7.1.1 Credits

7.1.1.1 Porous Asphalt or Concrete

Description of Public Road or Public Parking lot

Model Surface as

1. Base material laid above surrounding grade:

a) Without underlying perforated drain pipes to collect stormwater

Grass over underlying soil type (till or outwash)
b) With underlying perforated drain pipes for stormwater collection:

- at or below bottom of base layer
  - Impervious surface

- elevated within the base course
  - Impervious surface

2. Base material laid partially or completely below surrounding grade:

a) Without underlying perforated drain pipes

- Option 1: Grass over underlying soil type
- Option 2: Impervious surface routed to an infiltration basin

b) With underlying perforated drain pipes:

- at or below bottom of base layer
  - Impervious surface

- elevated within the base course
  - Model as impervious surface routed to an infiltration basin

Description of Private Facilities (driveways, parking lots, walks, patios)

1. Base material below grade without underlying perforated drain pipes
   - 50% grass on underlying soil; 50% impervious

2. Base material below grade with underlying perforated drain pipes
   - Impervious surface

7.1.1.2 Grid/lattice systems (non-concrete) and Paving Blocks

Description of Public Road or Public Parking lot

Model Surface as

1. Base material laid above surrounding grade

a) Without underlying perforated drain pipes

- Grid/lattice systems: grass on underlying soil (till or outwash).
- Paving Blocks: 50% grass on underlying soil; 50% impervious.

---

1 See section 7.8 for detailed instructions concerning how to represent the base material below grade as an infiltration basin in the Western Washington Hydrology Model.

2 If the perforated pipes function is to distribute runoff directly below the wearing surface, and the pipes are above the surrounding grade, follow the directions for 2a above.
b) With underlying perforated drain pipes

2. Base material laid partially or completely below surrounding grade

a) Without underlying perforated drain pipes

Option 1:
- Grid/lattice as grass on underlying soil.
- Paving blocks as 50% grass; 50% impervious.

Option 2:
- Impervious surface routed to an infiltration basin.\(^1\)

b) With underlying perforated drain pipes

at or below bottom of base layer

Impervious surface

elevated within the base course\(^2\)

Model as impervious surface routed to an infiltration basin.\(^1\)

Description of Private Facilities (driveways, parking lots, walks, patios)

Base material laid partially or completely below surrounding grade

a) Without underlying perforated drain pipes

50% grass; 50% impervious

b) With underlying drain pipes

Impervious surface

7.1.2 Design Criteria for Permeable Pavements

Subgrade

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

Geotextile

- Use geotextile between the subgrade and base material/separation layer to keep soil out of base materials.
- The geotextile should pass water at a greater rate than the subgrade soils.

Separation or Bottom Filter Layer (recommended but optional)

- A layer of sand or crushed stone (0.5 inch or smaller) graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect underlying
soil from compaction, and serve as a transition between the base course and the underlying geotextile material.

**Base material**
- Many design combinations are possible. The material must be free draining. For more detailed specifications for different types of permeable pavement, see section 6.2: Permeable Paving.
  - Driveways (recommendation):
    - > 4" layer of free-draining crushed rock, screened gravel, or washed sand.
    - < 5% fines (material passing thru #200 sieve) based on fraction passing #4 sieve.
  - Roads: The standard materials and quantities used for asphalt roads should be followed. For example:
    - Pierce Co. cites larger rock on bottom, smaller on top (e.g., 2" down to 5/8"); compacted; minimal fines; 8 inches total of asphaltic concrete and base material.
    - WSDOT lists coarse crushed stone aggregate (AASHTO Grading No. 57: 1.5 inch and lower); stabilized or unstabilized with modest compaction; meets fracture requirements.
    - FHWA suggests three layers between the porous pavement and geotextile. Typical layers would be:
      - Filter course: 13 mm diameter gravel, 25 to 50 mm thick.
      - Stone reservoir: 40-75 mm diameter stone.
      - Filter course: 13 mm diameter gravel, 50 mm thick.

**Wearing layer**
- For all surface types, a minimum initial infiltration rate of 10 inches per hour is necessary. To improve the probability of long-term performance, significantly higher infiltration rates are desirable.
- **Porous Asphalt:** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 12 – 20% is common.
- **Porous Concrete:** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 15 – 21% is common.
- **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. It should be underlain with 6 inches or more of sand or gravel to provide an adequate base. The fill material should be at or slightly below the top elevation of the grid/lattice structure. Modular-grid openings must be at least 40% of the total surface area of the modular grid pavement. Provisions for removal of oil and grease contaminated soils should be included in the maintenance plan.
- **Paving blocks:** 6 inches of sand or aggregate materials should fill spaces between blocks and must be free draining. Do not use sand for the leveling layer or filling spaces with EcoStone.
- The block system should provide a minimum of 12% free draining surface area.
- Provisions for removal of oil and grease contaminated soils should be included in the maintenance plan.

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

Acceptance test
• Driveways can be tested by simply throwing a bucket of water on the surface. If anything other than a scant amount puddles or runs off the surface, additional testing is necessary prior to accepting the construction.
• Roads may be initially tested with the bucket test. In addition, test the initial infiltration with a 6-inch ring, sealed at the base to the road surface, or with a sprinkler infiltrometer. Wet the road surface continuously for 10 minutes. Begin test to determine compliance with 10 inches per hour minimum rate.

Limitations
• No run-on from pervious surfaces is preferred. If runoff comes from minor or incidental pervious areas, those areas must be fully stabilized.
• Slope impervious runoff away from the permeable pavement to the maximum extent practicable. Sheet flow from up-gradient impervious areas is not recommended, but permissible if porous surface flow path > impervious surface flow path. (Note: Impermeable surface that drains to a permeable pavement can also be modeled as noted above as long as the flow path restriction is met.
• Do not use at “high-use” sites, auto commercial services (gas stations, mini-marts, commercial fueling stations, auto body and auto repair shops, auto wash), commercial truck parking areas, areas with heavy industrial activity (as defined by USEPA regulations), or areas with high pesticide use.
• Soils must not be tracked onto the wear layer or the base course during construction.
• Slopes:
  o Asphalt: Works best on level slopes and up to 2%. Do not use on slopes > 5%.
  o Concrete: Maximum recommended slope of 6%.
  o Interlocking pavers: Maximum recommended slope of 10%.
  o Grid/lattice systems: Maximum generally in 5-6% range.
• Do not use in areas subject to heavy, routine sanding for traction during snow and ice accumulation.
• Comply with local building codes for separation distances from buildings and wells. Inquire with the local jurisdiction concerning applicable setbacks.

Maintenance
• Inspect project upon completion to correct accumulation of fine material. Conduct periodic visual inspections to determine if surfaces are clogged with vegetation or fine soils. Clogged surfaces should be corrected immediately.
• Surfaces should be swept with a high-efficiency or vacuum sweeper twice per year; preferably, once in the autumn after leaf fall, and again in early spring. For porous asphalt and concrete surfaces, high pressure hosing should follow sweeping once per year.
7.2 Dispersion

7.2.1 Full Dispersion for the Entire Development Site (fulfills treatment and flow control requirements)
Developments that preserve 65% of a site (or a threshold discharge area of a site) in a forested or native condition can disperse runoff from the developed portion of the site into the native vegetation area as long as the developed areas draining to the native vegetation do not have impervious areas that exceed 10% of the entire site. Runoff must be dispersed into the native area in accordance with the BMPs cited in BMP T5.30 of Volume V - Chapter 5. Additional impervious areas are allowed, but should not drain to the native vegetation area and are subject to the thresholds, treatment and flow control requirements of this stormwater manual.

7.2.2 Full Dispersion for All or Part of the Development Site
Developments that maintain ratios of:
≥ 65% forested or native condition; and
≤ 10% effective impervious surface of the area draining into the native vegetation area may disperse runoff into the native area in accordance with the BMPs cited in BMP T5.30 of Volume V - Chapter 5. Examples of such ratios are:

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<th>% Effective Impervious (max. allowed)</th>
<th>% Lawn/Landscape (max. allowed)</th>
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<tr>
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<td>65*</td>
</tr>
</tbody>
</table>

* Where these lawn/landscape areas are established on till soils, and exceed 50% of the total site, they should be developed using guidelines in BMP T5.13 of Volume V – Chapter 5, or a locally approved alternative soil quality and depth specification.

Within the context of this dispersion option, the only impervious surfaces that are ineffective are those that are routed into an appropriately sized dry well or into an infiltration basin that meets the flow control standard and does not overflow into the forested or native vegetation area.

Note: For options in 7.2.1 and 7.2.2, native vegetation areas must be protected from future development. Protection must be provided through legal documents on record with the local government. Examples of adequate documentation include: a conservation easement, conservation parcel or tract area, or deed restriction.

7.2.3 Partial Dispersion on residential lots and commercial buildings

If roof runoff is dispersed on single-family lots and the vegetative flow path is 20 feet or larger through undisturbed native landscape or lawn/landscape area that meets the guidelines in BMP T5.13 (compost-amended soil), the roof area may be modeled as
landscaped area. This is done by clicking on the "Credits" button in the WWHM and entering the percent of roof area that is being dispersed.

The vegetated flow path is measured from the downspout or dispersion system discharge point to the downstream property line, stream, wetland, or other impervious surface.

Where BMP T5.11 (concentrated flow dispersion) or BMP T5.12 (sheet flow dispersion) of Volume V – Chapter 5 is used to disperse runoff into a native vegetation area or an area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the impervious area may be modeled as landscaped area. This can be done by entering the impervious area as landscaped area rather than entering it as impervious area.

7.2.4 Road Projects

1) Uncollected or natural dispersion into adjacent vegetated areas (i.e., sheet flow into the dispersion area).

Full dispersion credit (i.e. no other treatment or flow control required) for sites that meet the following criteria:

a) Outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated infiltration rate of 4 inches per hour or greater. The infiltration rate must be based on one of the following: (1) A D_{10} size (10% passing the size listed) greater than 0.06 mm (based on the estimated infiltration rate indicated by the upper-bound line in Figure 3.26a of Ecology Manual Volume III – Chapter 3 for the finest soil within a three foot depth; (2) field results using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V.

- 20 feet of impervious flow path needs 10 feet of dispersion area width.
- Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.

b) Other soils: (Types C and D and some Type B not meeting the criterion in 1a above)

- Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.

c) Criteria applicable to all soil types:

- Depth to the average annual maximum groundwater elevation should be at least 3 feet.
- Impervious surface flow path must be ≤ 75 ft. Pervious flow path must be ≤ 150 ft. Pervious flow paths are runoff contributions to the dispersion area from pervious surfaces, and include up-gradient road side slopes that run onto the road and down-gradient road side slopes that precede the dispersion area.
- Lateral slope of impervious drainage area should be ≤ 8%. Road side slopes must be ≤ 25%. Road side slopes do not count as part of the dispersion area unless native vegetation is re-established and slopes are less than 15%. Road shoulders that are paved or graveled to withstand occasional vehicle loading count as impervious surface.
- Longitudinal slope of road should be ≤ 5%.
• Length of dispersion area should be equivalent to length of road.
• Average longitudinal (parallel to road) slope of dispersion area should be ≤ 15%.
• Average lateral slope of dispersion area should be ≤ 15%.

2) Channelized (collected and re-dispersed) stormwater into areas with (a) native vegetation or (b) cleared land in areas outside of Urban Growth Areas that do not have a natural or man-made drainage system.

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

a) Outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated infiltration rate of 4 inches per hour or greater. The infiltration rate must be based on one of the following: (1) A $D_{10}$ size (10% passing the size listed) greater than 0.06 mm (based on the estimated infiltration rate indicated by the upper-bound line in Figure 3.26a of Ecology Manual Volume III – Chapter 3 for the finest soil within a three foot depth; 2 field results using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V.

• Dispersion area should be at least ½ of the impervious drainage area.

b) Other soils: (Types C and D and some Type B not meeting the criterion in 2a above)

• Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.

c) Other criteria applicable to all soil types:

• Depth to the average annual maximum groundwater elevation should be at least three feet.
• Channelized flow must be redispersed to produce longest possible flow path.
• Flows must be evenly dispersed across the dispersion area.
• Flows must be dispersed using rock pads and dispersion techniques as specified in BMP T5.30, of Ecology Manual Volume V – Chapter 5.
• Approved energy dissipation techniques may be used.
• Limited to onsite (associated with the road) flows.
• Length of dispersion area should be equivalent to length of the road.
• Average longitudinal and lateral slopes of the dispersion area should be ≤ 8%.

3) Engineered dispersion of stormwater runoff into an area with engineered soils

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

• Stormwater can be dispersed via sheet flow or via collection and re-dispersion in accordance with the techniques specified in BMP T5.30 in Ecology Manual Volume V – Chapter 5.
• Depth to the average annual maximum groundwater elevation should be at least three feet.
Type C and D soils must be compost-amended following guidelines in BMP T5.13 of Volume V – Chapter 5. The guidance document Guidelines and Resources for Implementing Soil Depth & Quality BMP T5.13 in WDOE Western Washington Stormwater Manual, 2003 can be used, or an approved equivalent soil quality and depth specification approved by the Department of Ecology.
  
  - Dispersion area must meet the 6.5 to 1 ratio for full dispersion credit.
  
Type A and B soils that meet the 4 inches per hour initial saturated infiltration rate minimum (See Section 2.D.1. above) must be compost amended in accordance with guidelines in BMP T5.13 of Volume V – Chapter 5. Compost may be incorporated into the soil in accordance with the guidance document cited above, or can be placed on top of the native soil.
  
  - 20 feet of impervious flow path needs 10 feet of dispersion area width.
  - Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.
  
- Average longitudinal (parallel to road) slope of dispersion area should be ≤ 15%.
- Average lateral slope of dispersion area should be ≤ 15%.
- The dispersion area should be planted with native trees and shrubs.

4) Other Characteristics for Dispersal areas

- Dispersal areas must be outside of the urban growth area; or if inside the urban growth area, in legally protected areas (easements, conservation tracts, public parks).
- If outside urban growth areas, legal agreements that run with the land are necessary with property owners of dispersal areas subject to stormwater that has been collected and is being re-dispersed.
- An agreement with the property owner is advised for uncollected, natural dispersion via sheet flow that represents a continuation of past practice. If not a continuation of past practice, an agreement must be obtained with the property owner.

7.3 Vegetated Roofs

7.3.1 Option 1 Design Criteria
- 3 inches to 8 inches of soil/growing media

Runoff Model Representation
- till landscaped area

7.3.2 Option 2 Design Criteria
- ≥ 8 inches of soil/media

Runoff Model Representation
- till pasture

7.3.3 Other Necessary Design Criteria
- Soil or growth media that has a high field capacity, and a saturated hydraulic conductivity that is ≥ 1 inch/hour (i.e., equivalent to a sandy loam or soil with a higher hydraulic conductivity).
- Drainage layer that allows free drainage under the soil/media.
• Vegetative cover that is both drought and wet tolerant.
• Waterproof membrane between the drain layer and the structural roof support.
• Maximum slope of 20%.

7.4 Rainwater Harvesting

7.4.1 Design Criteria
• 100% reuse of the annual average runoff volume (use continuous runoff model to get annual average for drainage area).
• System designs involving interior uses must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually.

Runoff Model Representation:
• Do not enter drainage area into the runoff model.

7.4.2 Other Criteria
• Restrict use to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.

7.5 Reverse Slope Sidewalks

Reverse slope sidewalks are sloped to drain away from the road and onto adjacent vegetated areas.

7.5.1 Design Criteria:
• > 10 feet of vegetated surface downslope that is not directly connected into the storm drainage system.
• Vegetated area receiving flow from sidewalk must be native soil or meet guidelines in BMP T5.13 of Volume V – Chapter 5.

7.5.2 Runoff Model Representation:
• Enter sidewalk area as landscaped area.

7.6 Minimal Excavation Foundations

Low impact foundations are defined as those techniques that only minimally disturb the natural soil profile within the footprint of the structure. This preserves most of the hydrologic properties of the native soil. Pin foundations are an example of a minimal excavation foundation.

7.6.1 Runoff Model Representation
• Where residential roof runoff is dispersed on the up gradient side of a structure in accordance with the design criteria and guidelines in BMP T5.10 of Volume V – Chapter 5, the tributary roof area may be modeled as pasture on the native soil.
• Where “step forming” is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. In “step forming,” the
building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. The following equation (suggested by Rick Gagliano of Pin Foundations, Inc.) can be used to reduce the roof area that can be modeled as pasture.

\[
A_1 = \frac{dC(0.5) \times A_1}{dP} = A_2
\]

- \( A_1 \) = roof area draining to up gradient side of structure
- \( dC \) = depth of cuts into the soil profile
- \( dP \) = permeable depth of soil (The A horizon plus an additional few inches of the B horizon where roots permeate into ample pore space of soil).
- \( A_2 \) = roof area that can be modeled as pasture on the native soil

- If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in BMP T5.10 of Volume V – Chapter 5, AND there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the tributary roof areas may be modeled as landscaped area.

7.6.2 Limitations
- To minimize soil compaction, heavy equipment cannot be used within or immediately surrounding the building. Terracing of the foundation area may be accomplished by tracked, blading equipment not exceeding 650 psf.

7.7 Bioretention areas (rain gardens)

The design criteria provided below outline basic guidance on bioretention design specifications, procedures for determining infiltration rates, and flow control guidance. For details on design specifications see section 6.1: Bioretention Areas of the Low Impact Development Technical Guidance Manual for Puget Sound (LID Manual). Also contact the local permitting authority, which may have design specifications that would supersede the design criteria.

7.7.1 Design Criteria

Soils
- The soils surrounding bioretention facilities are a principal design element for determining infiltration capacity, sizing and rain garden type. The planting soil mix placed in the cell or swale is a highly permeable soil mixed thoroughly with compost amendment, and a surface mulch layer.
- Soil depth should be a minimum of 18 inches to provide acceptable minimum pollutant attenuation and good growing conditions for selected plants.
- The texture for the soil component of the bioretention soil mix should be a loamy sand (USDA Soil Textural Classification). Clay content for the final soil mix should be less than 5 percent. The final soil mix (including compost and soil) should have a minimum short-term hydraulic conductivity of 1.0 inches/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 80 percent compaction per ASTM Designation D 1557.
• The final soil mixture should have a minimum organic content of approximately 10 percent by dry weight.
• The pH for the soil mix should be between 5.5 and 7.0.

Mulch layer
• Bioretention areas can be designed with or without a mulch layer.

Compost
• pH between 5.5 and 7.0.
• Carbon nitrogen ratio between 20:1 and 35:1 (35:1 CN ratio recommended for native plants)
• Organic matter content should be between 40% and 50%.

Installation
• Minimize compaction of the base and sidewalls of the bioretention area. Excavation should not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the bioretention facility and no heavy equipment with narrow tracks, narrow tires or large lugged, high pressure tires should be allowed on the bottom of the bioretention facility.
• On-site soil mixing or placement should not be performed if soil is saturated. The bioretention soil mixture should be placed and graded by excavators and/or backhoes operating adjacent to the bioretention facility.

Plant materials
• Plants should be tolerant of ponding fluctuations and saturated soil conditions for the length of time anticipated by the facility design, and drought during the summer months.
• In general, the predominant plant material utilized in bioretention areas are facultative species adapted to stresses associated with wet and dry conditions.

Maximum ponding depth
• A maximum ponding depth of 12 inches is recommended.
• A maximum surface pool drawdown time of 24 hours is recommended.
• Ponding depth and system drawdown should be specified so that soils dry out periodically in order to:
  o Restore hydraulic capacity to receive flows from subsequent storms.
  o Maintain infiltration rates.
  o Maintain adequate soil oxygen levels for healthy soil biota and vegetation.
  o Provide proper soil conditions for biodegradation and retention of pollutants.

7.7.2 Limitations

• A minimum of 3 feet of clearance is necessary between the lowest elevation of the bioretention soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the rain garden meets or exceeds any of the following limitations:
  o 5,000 square feet of pollution-generating impervious surface; or
  o 10,000 square feet of impervious area; or
  o ¾ acres of lawn and landscape.
• If the tributary area to an individual rain garden does not exceed the areal limitations above, a minimum of 1 foot of clearance is adequate between the lowest elevation of the bioretention soil (or any underlying gravel layer) and the seasonal high groundwater elevation or other impermeable layer.

7.7.3 Runoff Model Representation

Pothole design (bioretention cells)
The rain garden is represented as a pond with a steady-state infiltration rate. Proper infiltration rate selection is described below. The pond volume is a combination of the above ground volume available for water storage and the volume available for storage within the imported soil. The latter volume is determined by multiplying the volume occupied by the imported soil by the soil’s percent porosity. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual. That volume is presumed to be added directly below the surface soil profile of the rain garden. The theoretical pond dimensions are represented in the Pond Information/Design screen. The Effective Depth is the distance from the bottom of the theoretical pond to the height of the overflow. This depth is less than the actual depth because of the volume occupied by the soil. Approximate side slopes can be individually entered. On the Pond Information/Design screen, there is a button, which asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button if the rain garden has sidewalls steeper than 2 horizontal to 1 vertical.

Rain gardens with underlying perforated drain pipes that discharge to the surface can also be modeled as ponds with steady-state infiltration rates. However, the only volume available for storage (and modeled as storage as explained herein) is the void space within the imported material (usually sand or gravel) below the invert of the drain pipe.

Linear Design: (bioretention swale or slopes)
Swales
Where a swale design has a roadside slope and a back slope between which water can pond, and an overflow/drainage pipe at the lower end of the swale, the swale may be modeled as a pond with a steady state infiltration rate. This method does not apply to swales that are underlain by a drainage pipe.

If the long-term infiltration rate through the imported bioretention soil is lower than the infiltration rate of the underlying soil, the surface dimensions and slopes of the swale should be entered into the WWHM as the pond dimensions and slopes. The effective depth is the distance from the soil surface at the bottom of the swale to the invert of the overflow/drainage pipe. If the infiltration rate through the underlying soil is lower than the estimated long-term infiltration rate through the imported bioretention soil, the pond dimensions entered into the WWHM should be adjusted to account for the storage volume in the void space of the bioretention soil. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual. For instance, if the soil is 40% voids, and the depth of the imported soils is 2 feet throughout the swale, the depth of the pond is increased by 0.8 feet. If the depth of imported soils varies within the side slopes of the swale, the theoretical side slopes of the pond can be adjusted.
This procedure to estimate storage space should only be used on bioretention swales with a 1% slope or less. Swales with higher slopes should more accurately compute the storage volume in the swale below the drainage pipe invert.

**Slopes**
Where a bioretention design involves only a sloped surface such as the slope below the shoulder of an elevated road, the design can also be modeled as a pond with a steady state infiltration rate. This procedure only applies in instances where the infiltration rate through the underlying soil is less than the estimated long-term infiltration rate of the bioretention imported soil. In this case, the length of the bioretention slope should correspond to the maximum wetted cross-sectional area of the theoretical pond. The effective depth of the theoretical pond is the void depth of the bioretention soil as estimated by multiplying the measured porosity times the depth of the bioretention soils. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual.

**7.7.4 Infiltration Rate Determinations**

The assumed infiltration rate for the pond must be the lower of the estimated long-term rate of the imported soil or the initial (a.k.a. short-term or measured) infiltration rate of the underlying soil profile. Using one of the procedures explained below, the initial infiltration rates of the two soils must be determined. Then after applying an appropriate correction factor to the imported soil of the rain garden, the designer can compare and determine the lower of the long-term infiltration rate of the imported soil, and the initial infiltration rate of the underlying native soil. The underlying native soil does not need a correction factor because the overlying imported soil protects it. Below are explanations for how to determine infiltration rates for the imported and underlying soils, and how to use them with the WWHM.

**7.7.4.1 Imported Soil for the rain garden**

1. Method for imported soil in a rain garden with a tributary area of or exceeding any of the following limitations: 5,000 square feet of pollution-generating impervious surface; or 10,000 square feet of impervious surface; or ¾ acres of lawn and landscape:
   - Use 4 as the infiltration reduction correction factor.
   - Compare this rate to the infiltration rate of the underlying soil (as determined using one of the methods below). If the long-term infiltration rate of the imported soil is lower, enter that infiltration rate and the correction factor into the corresponding boxes on the pond information/design screen of the WWHM.

2. Method for imported soil in a rain garden with a tributary area less than 5,000 square feet of pollution-generating impervious surface; and less than 10,000 square feet of impervious surface; and less than ¾ acres of lawn and landscape:
   - Use 2 as the infiltration reduction correction factor.
Compare this rate to the infiltration rate of the underlying soil (as determined using one of the methods below). If the long-term infiltration rate of the imported soil is lower, enter that infiltration rate and the correction factor into the corresponding boxes on the pond information/design screen of the WWHM.

7.7.4.2 Underlying Soil:

- Method 1: Use Table 3.7 of Ecology Manual Volume III – Chapter 3 to determine the short-term infiltration rate of the underlying soil. Soils not listed in the table cannot use this approach. Compare this short-term rate to the long-term rate determined above for the bioretention imported soil. If the short-term rate for the underlying soil is lower, enter it into the measured infiltration rate box on the pond information/design screen in the WWHM. Enter 1 as the infiltration reduction factor.
- Method 2: Determine the D_{10} size of the underlying soil. Use the “upperbound line” in Figure 4-17 in WSDOT’s *Highway Runoff Manual March 2004* to determine the corresponding infiltration rate. If this infiltration rate is lower than the long-term infiltration rate determined for the imported bioretention soil, enter the rate for the underlying soil into the measured infiltration rate box on the pond/information design screen. Enter 1 as the infiltration reduction factor.
- Method 3: Measure the in situ infiltration rate of the underlying soil using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V. If this rate is lower than the long-term infiltration rate determined for the imported bioretention soil, enter the underlying soil infiltration rate into the corresponding box on the pond information/design screen of the WWHM. Enter 1 as the infiltration reduction factor.

7.7.5 WWHM Routing and Runoff File Evaluation

In WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage be exceeded. So in the Riser/Weir screen, for the Riser head enter a value slightly smaller than the effective depth of the pond (say 0.1 ft below the Effective Depth); and for the Riser diameter enter a large number (say 10,000 inches) to ensure that there is ample capacity for overflows.

Within the model, route the runoff into the pond by grabbing the pond icon and placing it below the tributary “basin” area. Be sure to include the surface area of the bioretention area in the tributary “basin” area. Run the model to produce the effluent runoff file from the theoretical pond. For projects subject to the flow control standard, compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. A conveyance system should be designed to route all overflows from the bioretention areas to centralized treatment facilities, and to flow control facilities if flow control applies to the project.

7.7.6 Modeling of Multiple Rain Gardens

Where multiple rain gardens are scattered throughout a development, it may be possible to represent those as one rain garden (a “pond” in the WWHM) serving the cumulative area tributary to those rain gardens. For this to be a reasonable representation, the design of each rain garden should be similar (e.g., same depth of soil, same depth of surface ponded water, roughly the same ratio of impervious area to rain garden volume).
7.7.7 Other Rain Garden Designs

Guidance for modeling other bioretention designs is not yet available. However, where compost-amended soils are used along roadsides the guidance in section 7.2: Dispersion can be applied.

7.8 WWHM Instructions for Estimating Runoff Losses in Road Base Material Volumes that are Below Surrounding Grade

Prerequisite

Before using this guidance to estimate infiltration losses, the designer should have sufficient information to know whether adequate depth to a seasonal high groundwater table, or other infiltration barrier (such as bedrock) is available. The minimum depth necessary is 3 feet as measured from the bottom of the base materials.

7.8.1 Instructions for Roads on Zero to 2% Grade

For road projects whose base materials extend below the surrounding grade, a portion of the below grade volume of base materials may be modeled in the WWHM as a pond with a set infiltration rate.

First, place a “basin” icon in the “Schematic” grid on the left side of the “Scenario Editor” screen. Left clicking on the basin icon will create a “basin information” screen on the right in which you enter the appropriate pre-developed and post-developed descriptions of your project site (or threshold discharge area of the project site). By placing a pond icon below the basin icon in the Schematic grid, we are routing the runoff from the road and any other tributary area into the below grade volume that is represented by the pond.

The dimensions of the infiltration basin/pond to be entered in the Pond Information/Design screen are: the length of the base materials that are below grade (parallel to the road); the width of the below grade material volume; and the Effective Depth. Note that the storage/void volume of the below grade base has to be estimated to account for the percent porosity of the gravel. This can be done by multiplying the below grade depth of base materials by the fractional porosity (e.g., a project with a gravel base of 32% porosity would multiply the below grade base material depth by 0.32). This is the Effective Depth. If the below grade base course has perforated drainage pipes elevated above the bottom of the base course, but below the elevation of the surrounding ground surface, the Effective Depth is the distance from the invert of the lowest pipe to the bottom of the base course multiplied by the fractional porosity.

Also in WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So in the Riser/Weir screen, for the Riser head enter a value slightly smaller than the effective depth of the base materials (say 0.1 ft below the Effective Depth); and for the Riser diameter enter a large value (say 10,000 inches) to ensure that there is ample capacity should overflows from the trench occur.
On the Pond Information/Design screen, there is a button that asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. **Do not push the button.**

Using the procedures outlined above, estimate the long-term infiltration rate of the native soils beneath the base materials. If using Method 1, enter the appropriate “short-term infiltration rate” from Table 3.7 into the “measured infiltration rate” box on the “Pond Information Design” screen of WWHM. Enter the correction factor from that table as the “Infiltration Reduction Factor.” If using Method 2, enter the appropriate long-term infiltration rate from Table 3.8 into the “measured infiltration rate” box. Enter “1” as the correction factor. If using Method 3, enter the measured in-situ infiltration rate as the “Measured Infiltration Rate” in the Pond Information/Design Screen. Also enter the appropriate cumulative correction factor.

Run the model to produce the overflow runoff file from the base materials infiltration basin. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.

7.8.2 Instructions for Roads on Grades above 2%

Road base material volumes that are below the surrounding grade and that are on a slope, can be modeled as a pond with an infiltration rate and a nominal depth. Represent the below grade volume as a pond. Grab the pond icon and place it below the “basin” icon so that the computer model routes all of the runoff into the infiltration basin/pond

The dimensions of the infiltration basin/pond to be entered in the Pond Information/Design screen 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 Depth of 1 inch. In WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So in the Riser/Weir screen, enter 0.04 ft (½ inch) for the Riser head and a large Riser diameter (say 1000 inches) to ensure that there is no head build up.

Note: 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.

Estimate the infiltration rate of the native soils beneath the base materials. See the previous section (Instructions for Roads on Zero to 2% Grade) for estimating infiltration rates and for how to enter infiltration rates and infiltration reduction factors into the “Pond Information/ Design” Screen of WWHM. Enter the appropriate information for the theoretical pond of ½-inch maximum depth.

On the Pond Information/Design screen, there is a button that asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. **Do not push the button.**
Run the model to produce the effluent runoff file from the base materials. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.

7.8.3 Instructions for Roads on a Slope with Internal Dams within the Base Materials that are Below Grade

In this option, a series of infiltration basins is created by placing relatively impermeable barriers across the below grade base materials at intervals. The barriers inhibit the free flow of water down the grade of the base materials. The barriers must not extend to the elevation of the surrounding ground. Provide a space sufficient to pass water from upgradient to lower gradient basins without causing flows to surface out the sides of the base materials that are above grade.

Each stretch of trench (cell) that is separated by barriers can be modeled as an infiltration basin. This is done by placing pond icons in series in the WWHM. For each cell, determine the average depth of water within the cell (Average Cell Depth) at which the barrier at the lower end will be overtopped.

Specify the dimensions of each cell of the below-grade base materials in WWHM on the screen, which asks for pond dimensions. The dimensions of the infiltration cell to be entered in the Pond Information/Design screen are: the length of the cell (parallel to the road); the width; and the Effective Depth (In this case, it is OK to use the total depth of the base materials that are below grade).

Also in WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. For each trench cell, the available storage is the void space within the Average Cell Depth. So, the storage/void volume of the trench cell has to be estimated to account for the percent porosity of the base materials. For instance, if the base materials have a porosity of 32%, the void volume can be represented by reducing the Average Cell Depth by 68% (1-32%). This depth is entered in the Riser/Weir screen as the Riser head. The gross adjustment works because WWHM2 (as of March 2004) does not adjust infiltration rate as a function of water head. If the model is amended such that the infiltration rate becomes a function of water head, this gross adjustment will introduce error and therefore other adjustments should be made.) For the Riser diameter in the Riser/Weir screen,, enter a large number (say 10,000 inches) to ensure that there is ample capacity should overflows from the below-grade trench occur.

Each cell should have its own tributary drainage area that includes the road above it, any project site pervious areas whose runoff drains onto and through the road, and any offsite areas. Each drainage area is represented with a “basin” icon.

Up to four pond icons can be placed in a series to represent the below grade trench of base materials. The computer graphic representation of this appears as follows:
It is possible to represent a series of cells as one infiltration basin (using a single pond icon) if the cells all have similar length and width dimensions, slope, and Average Cell Depth. A single “basin” icon is also used to represent all of the drainage area into the series of cells.

On the Pond Information/Design screen (see screen below), there is a button, which asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button if the below-grade base material trench has sidewalls steeper than 2 horizontal to 1 vertical.
Using the procedures explained above for roads on zero grade, estimate the infiltration rate of the native soils beneath the trench. Also as explained above, enter the appropriate values into the “Measured Infiltration Rate” and “Infiltration Reduction Factor” boxes of the “Pond Information/Design” screen.

Run the model to produce the effluent runoff file from the below grade trench of base materials. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.

7.9 Compost-amended soils

Compost-amended soils improve infiltration and moisture-holding capacities, and reduce the need for chemical and irrigation inputs. Landscaped areas that receive compost-amended soils in accordance with BMP T5.13 can be modeled (in WWHM) as till or outwash pasture (depending on underlying soil), instead of till or outwash grass/landscaped area.
SOIL EVALUATION REPORT
FORM 1: GENERAL SITE INFORMATION

<table>
<thead>
<tr>
<th>PROJECT TITLE:</th>
<th>SHEET OF</th>
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<td>PROJECT NO.:</td>
<td>DATE:</td>
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<tr>
<td>PREPARED BY:</td>
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</tbody>
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1. SITE ADDRESS OR LEGAL DESCRIPTION:

2. PROJECT DESCRIPTION:

3. SITE DESCRIPTION:

4. SUMMARY OF SOILS WORK PERFORMED:

5. ADDITIONAL SOILS WORK RECOMMENDED:

6. FINDINGS (Including pre-development site percolation rate):

7. RECOMMENDATIONS:

I hereby certify that I prepared this report, and conducted or supervised the performance of related work. I certify that I am qualified to do this work. I represent my work to be complete and accurate within the bounds of uncertainty inherent to the practice of soil science, and to be suitable for its intended use.

SIGNED: ________________________________

DATE: ________________________________
Form 1 is the “cover page” for all projects that require a soil evaluation report. One copy of Form 1 must accompany all soil evaluation reports. Certain information may be omitted for soil evaluations completed for small projects (e.g., single-family residences, duplexes). The following instructions should give you the guidance needed to complete the form:

1. Provide project name and address or legal description. Attach a legible map on 8 ½” by 11” paper showing site and major landmarks (e.g., roadways and surface waters) within approximately one-quarter mile radius around site.

2. Provide acreage, parcel dimensions, type of development proposed, and approximate proposed coverage of impervious surfaces.

3. Describe site topography, geomorphology, terrain, and natural cover. Distinguish among areas of the site with significantly different characteristics.

4. Provide description and purpose of soils work done. List methods used to expose, sample, and test soils. Give number of test holes logged. Describe field and lab tests performed. Attach a scaled map of good accuracy on 8 ½” by 11” paper showing locations of soil logs. Except small projects, using soil log results, divide map area into sub-areas according to hydrologic group (A through D).

5. Describe soils work still needed. For example, more work may be needed to obtain accurate percolation or infiltration rates for stormwater facilities not yet constructed.

6. Describe results of soil logs and tests and compare with expected soils from SCS Soils maps. As appropriate for the project, give your best estimate of the (a) overall predeveloped site infiltration rate, (b) the saturated infiltration rate for the above-ground stormwater facility, or (c) the saturated percolation rate for the below-ground stormwater trench or drywell. Discuss soils factors related to erosion control, infiltration, percolation, and placement of buildings, as these vary on the site.

7. Describe the recommended general approach for managing stormwater on the site. For example, if stormwater can be infiltrated or percolated, indicate where and at what depth. If erosion, soil stability, or high ground water are problems, can these problems be avoided or mitigated?

Sign the form and affix any relevant professional seal (e.g., P.E., ARCPACS). The form becomes the cover page to one or more copies of Form 2, which has soil logs for each test hole evaluated.
SOIL EVALUATION REPORT
FORM 2: SOIL LOG INFORMATION

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<td>PREPARED BY:</td>
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SOIL LOG:
LOCATION:

1. TYPES OF TESTS DONE:

2. SCS SOIL SERIES (mapped and observed):

3. HYDROLOGIC SOIL GROUP

4. DEPTH TO SEASONAL HW:

5. CURRENT WATER DEPTH

6. DEPTH TO IMPERV LAYER:

7. MISC:

8. POTENTIAL FOR:
   - EROSION
   - RUNOFF
   - PONDING

9. SOIL STRATA DESCRIPTION:

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10. FINDINGS AND RECOMMENDATIONS:
Form 2 is the detailed record of soil information obtained on the development site. One copy of Form 2 must be completed for each soil location where testing has been done. For tests other than soil logs for which the scientist wants to submit numerical results, please attach a separate sheet and briefly describe the results under “Findings and Recommendations.” The summary information that heads the sheet should be self-explanatory. Regarding location, reference the location to features that are permanent and static, such as roads or property lines.

1. State briefly tests that were done. Indicate whether tests were field, laboratory, or other.

2. Determine the soil series from the maps provided in the Soil Conservation Service (SCS) Soil Survey of Thurston County. Then, indicate what soil series was observed as a result of the soil testing done.

3. Indicate SCS hydrologic soil group (e.g., letter designation A through D).

4. Indicate seasonal high water table depth based upon the presence of mottling, gleying, or other evidence. Indicate how you determined this value under “Findings…” section. If information available is inadequate, state value to be “greater than” bottom of hole depth.

5. Indicate current water table depth based upon observation. If saturated conditions are not observed, state value to be “greater than” bottom of hole depth.

6. Indicate depth to effectively impermeable layer (e.g., basal till). If information is inadequate, state value to be “greater than” bottom of hole depth.

7. Space for other miscellaneous observations regarding setting of site (e.g., concave, convex, swale, hillslope).

8. Indicate susceptibility of area to erosion, runoff, and ponding problems. The susceptibility should be rated based upon relevant physical characteristics and development operations planned for the area, such as shape of the area (e.g., concave, convex, flat) removal or addition of fill, time of year, existing and planned vegetative cover, degree of soil compaction, etc. For erosion, the K-factor for the soils series in question might help in assessing relative credibility.

9. The profile description provides the minimum information on the physical attributes of the soil. Additional factors may be assessed at the option of the scientist, but data on these factors should be tabulated separately and summarized briefly in the “Findings and recommendations” section.
TABLE 3.1 (CONTINUED)

All information provided for the profile shall utilize standard SCS nomenclature and abbreviations. The following are the factors to be addressed, with brief examples of acceptable responses. Further information on most of these is provided in the SCS Soil Survey of Thurston County.

a. Hor(izon): A layer of soil with distinct characteristics, labeled A, AB, B, C, Cc, etc.
b. Depth: Starting at 0” (surface), depth, and interval of horizon.
c. Color: Munsell code for hue, value, and chroma, such as 10YR ¾. Indicate whether color is wet or dry.
d. Textur(al class): Class that best describes relative percentages of sand, silt, and clay in horizon, such as sandy loam (SL).
e. %Cl(ay): Clay percentage is very useful as a guide to determining the drainage capability of a soil.
f. %Org(anic)M(atter): Organic matter percentage by volume is related to the infiltration as well as pollutant removal capability of soils.
g. %C(oarse)F(ragments): Coarse fragment percentage is relevant to drainage and other site management factors.
h. Str(ucture): Describes the size and shape of soil “clods.”
i. Mot(tling): Where present, describe using three-letter abbreviation to indicate abundance, size, and contrast, such as CFD (common, fine, distinct).
j. Roo(ts): Where present, describe using two-letter abbreviation to indicate abundance and size, such as CF (common, fine).
k. Generalized range of infiltration rates from SCS Soil Survey <X>.
l. F(ield) S(aturated) P(ercollation rate): Using all available information, estimate the field saturated percolation rate. This rate should be a single number, and may vary from that range (see previous column) published in the SCS Soil Survey to horizon-specific factors.

10. Discuss results of tests done on soil. Indicate features of soil that most affect stormwater management at this location. Provide recommendations to the Project Engineer on soil-related factors such as problems and controls, and for additional work needed (if necessary).