CHAPTER 7
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7.0 INTRODUCTION

This chapter describes the requirements for meeting Minimum Requirement # 7, Flow Control. See Kitsap County Code Title 12.18.100, Flow Control, for applicability. Section 7.1 provides a summary of the methods and criteria for hydrologic analysis. The design criteria and analysis of detention facilities for flow control are contained in Section 7.2. Section 7.3 contains the methods for design and analysis of infiltration facilities for flow control and/or water quality treatment.

7.1 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.

7.1.1 Minimum Computational Standards

All storm water quantity control facilities shall utilize continuous simulation models per KCC 12.20.020.

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

A. For the purpose of designing most types of runoff treatment BMPs, a calibrated continuous simulation hydrologic model based on the EPA’s HSPF (Hydrologic Simulation Program-Fortran) program, or an approved equivalent model, must be used to calculate runoff and determine the water quality design flow rates and volumes.
B. For the purpose of designing wetpool treatment facilities, an approved continuous runoff model to estimate the 91st percentile, 24-hour runoff volume, must be used.

C. For the purpose of designing flow control facilities, an approved continuous runoff model to estimate the 91st percentile, 24-hour runoff volume, must be used.

Significant progress has been made in the development and availability of HSPF-based continuous runoff models for Western Washington. The Department of Ecology has coordinated the development of the Western Washington Hydrology Model (WWHM). It uses rainfall/runoff relationships developed for specific basins in the Puget Sound region to all parts of western Washington. Where field monitoring establishes basin-specific rainfall/runoff parameter calibrations, those can be entered into the model, superseding the default input parameters.
Two other HSPF-based continuous runoff models have been approved by the Department of Ecology: MGS Flood and KCRTS (King County Runoff Time Series). Though MGS Flood uses different, extended precipitation files, its features and more importantly, its runoff estimations are very similar to those predicted by WWHM. KCRTS is a pre-packaged set of runoff files developed by King County. KCRTS can be used throughout King County, but is not applicable to Kitsap County.

Where large (typically 320 acres or greater) master-planned developments are proposed, a basin-specific calibration of HSPF rather than use of the default parameters in the above-referenced models may be required.

7.1.2 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 Kitsap County Code: Minimum Requirement #7 KCC 12.18.110- Flow Control, and Minimum Requirement #8 - Wetlands Protection KCC 12.18.130. Minimum Requirement #7 specifies flow frequency and flow duration ranges for which the post-development 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.

A. 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.
B. The model uses pond discharge data to compare the predevelopment and postdevelopment durations and determines if the flow control standards have been met.
C. There are three criteria by which flow duration values are compared:

1. If the post-development 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 post-development 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 exceedances in alterations to wetland hydroperiods are provided in guidelines cited in Guide Sheet 2B of the Puget Sound Wetland Guidelines (Azous and Horner, 1997). These guidelines are contained in Appendix 1-D of the 2005 Department of Ecology Stormwater Management Manual for Western Washington.

Additional flow control requirements for closed depressions and other critical drainage areas are contained in Chapter 10.

7.2 DETENTION FACILITIES FOR FLOW CONTROL

This section presents the methods, criteria, and details for design and analysis of detention facilities. These facilities provide for the temporary storage of increased surface water runoff resulting from development pursuant to the performance standards set forth in KCC 12.18.100. There are three primary types of detention facilities described in this section: detention ponds, tanks, and vaults.

7.2.1 Detention Ponds

The design criteria in this section are for detention ponds. However, many of the criteria also apply to infiltration ponds (Section 7.3), and water quality wetponds and combined detention/wetponds (Chapter 6).

7.2.1.1 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)). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled release of the pond contents. Peak flows from dam failures are typically much

larger than the 100-year flows which these ponds are typically designed to accommodate.
The Dam Safety Office is located in the Ecology headquarters building in Lacey. Information is also available at
http://www.ecy.wa.gov/programs/wr/dams/dss.html.

7.2.1.2 General Design Criteria

Standard details for detention ponds are shown in Figure 7.1 through Figure 7.3. Control structure details are provided in Section 7.2.4

A. General

1. Ponds must be designed as flow-through systems (however, parking lot storage may be utilized through a back-up system; see Section 7.2.4.3). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.
2. Pond bottoms shall be level and be located a minimum of 0.5 foot (preferably 1 foot) below the inlet and outlet to provide sediment storage.
3. Design criteria for outflow control structures are specified in Section 7.2.4.
4. A geotechnical analysis and report are required if the pond is located within 200 feet of the top of any steep slope (greater than or equal to 30%) or other geologically hazardous area. The scope of the geotechnical report shall include the assessment of impoundment seepage on the stability of the natural slope where the facility will be located within the setback limits set forth in this section.

B. Side Slopes

1. Interior side slopes up to the emergency overflow water surface shall not be steeper than 3H:1V unless a fence is provided (see "Fencing").
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 reinforced concrete per Section 7.2.3, Material; (b) a fence is provided along the top of the wall; (c) the entire pond perimeter may be retaining walls, however, it is recommended that at least 25 percent of the pond perimeter be a vegetated soil slope not steeper than 3H:1V; and (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. If the entire pond perimeter is to

be retaining walls, ladders shall be provided on the walls for safety reasons.

C. Embankments

1. For pond berm embankments higher than 6 feet, the minimum top width shall be 6 feet and the berm must be designed by a professional engineer with geotechnical expertise.
2. For berm embankments 6 feet or less, the minimum top width shall 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 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 width unless specified otherwise by a geotechnical engineer.
5. Embankment compaction shall 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 shall 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 shall lie within 1% dry to 3% wet of the optimum moisture content.
6. The berm embankment shall 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. Note: In general, excavated glacial till is well suited for berm embankment material.
7. Anti-seepage filter-drain diaphragms must be placed on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Department of Ecology Dam Safety Guidelines, Part IV, Section 3.3.B on pages 3-27 to 3-30. An electronic version of the Dam Safety Guidelines is available in PDF format at www.ecy.wa.gov/programs/wr/dams/GuidanceDocs.html.

D. Overflow

1. In all ponds, tanks, and vaults, a primary overflow (usually a riser pipe within the control structure; see Section 7.2.4) must be provided to bypass

the 100-year developed peak flow over or around the restrictor system. This assumes the facility will be full due to plugged orifices or high inflows; the primary overflow is intended to protect against breaching of a pond embankment (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 grated opening (“jailhouse window”) in the control structure manhole functions as a weir (see Figure 7.2) when used as a secondary inlet. *Note: The maximum circumferential length of this opening must not exceed one-half the control structure circumference.*

E. 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 less than 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 7.3. The emergency overflow structure must be designed to pass the 100-year developed peak flow, with a minimum 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge 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 Chapter 4, Rock Protection at Outfalls. The spillway must be armored full width, across the berm embankment and extend to the toe of the berm, at a minimum. (see Figure 7.2).
4. Emergency overflow spillway designs must be analyzed as broad-crested trapezoidal weirs as described in Section 7.2.1.5. Either one of the weir sections shown in Figure 7.2 may be used.

F. Access

1. Maintenance access road(s) shall be provided to the control structure and other drainage structures associated with the pond (e.g., inlet or bypass structures). It is recommended that manhole and catch basin lids be in or at the edge of the access road and at least five feet from a property line.
2. An access ramp is needed for removal of sediment with a trackhoe and truck. The ramp must extend to the pond bottom if the pond bottom is greater than 1,500 square feet (measured without the ramp) and it may end at an elevation 4 feet above the pond bottom, if the pond bottom is less than 1,500 square feet (measured without the ramp).

   On large, deep ponds, truck access to the pond bottom via an access ramp is necessary so loading can be done in the pond bottom. On small deep ponds, the truck can remain on the ramp for loading. On small shallow ponds, a ramp to the bottom may not be required if the trackhoe can load a truck parked at the pond edge or on the internal berm of a wetpond or combined pond (trackhoes can negotiate interior pond side slopes).
3. The internal berm of a wetpond or combined detention and wetpond may be used for access if it is no more than 4 feet above the first wetpool cell, if the first wetpool cell is less than 1,500 square feet (measured without the ramp), and if it is designed to support a loaded truck, considering the berm is normally submerged and saturated.
4. Access ramps must meet the requirements for design and construction of access roads specified below.
5. 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.
   a) Bollards shall be constructed per WSDOT Standard Plan H-60.20-1.

G. Design of Access Roads

1. Pond Access Roads shall have a maximum steepness of 20% (12% to control structures). When the length of a pond access road exceeds 40-feet, a vehicle turn-around must be provided, designed to accommodate vehicles having a maximum length of 31-feet and having a minimum outside turning radius of 40-feet. Access roads to the pond bottom shall allow for a vehicle to approach the pond, turn, and back down the access ramp into the pond. The Director may allow an exception from the turn-around requirement if the access road slope is 8% or less, and the road has a straight alignment.
2. Fence gates shall be located only on straight sections of road.
3. Access roads shall be a minimum 15 feet in width on curves and 12 feet on straight sections.
4. A paved apron must be provided where access roads connect to paved public roadways.

H. Construction of Access Roads

1. Access roads may be constructed with an asphalt or gravel surface, or modular grid pavement.

I. 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. If the fence is constructed on a slope, a small bench shall be provided along the fence to facilitate maintenance. Note, however, that other regulations such as the International Building Code may require fencing of vertical walls. If more than 10 percent of slopes are steeper than 3H:1V, the entire pond shall be fenced.
2. 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.
3. Fences shall be 6 feet in height, and shall be constructed per WSDOT Standard Plan L-20.10-00, Type 3 chain link fence.
4. Access road gates shall be 16 feet in width consisting of two swinging sections 8 feet in width. Additional vehicular access gates may be needed to facilitate maintenance access.
5. Pedestrian access gates shall be 4 feet in width and shall be provided at the outlet to the pond to allow access to the control structure from inside the pond fence. Additional pedestrian access gates may be required.
6. 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-20.10-00, Type 3 chain link fence.
7. For metal baluster fences, International Building Code standards apply.
8. Wood fences may be used in subdivisions where the fence will be maintained by homeowners associations or adjacent lot owners as well as ponds that will not be maintained by Kitsap County.
9. Wood fences shall have pressure treated posts (ground contact rated) either set in 24-inch deep concrete footings or attached to footings by

galvanized brackets. Rails and fence boards may be cedar, pressure-treated fir, or hemlock.

10. Where only short stretches of the pond perimeter (< 10 percent) have side slopes steeper than 3:1, split rail fences (3-foot minimum height) or densely planted thorned hedges (e.g., barberry, holly, etc.) may be used in place of a standard fence.

J. Signage

Detention ponds, infiltration ponds, wetponds, and combined ponds shall have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. Sign specifications for a permanent surface water control pond are illustrated in Figure 7.4.

K. Setbacks

1. The **toe of the exterior slope** of a pond berm embankment shall comply with required grading setbacks per Chapter 11, and shall be set back a minimum of 5 feet from the tract, easement, property line and any vegetative buffer required by conditions of land use approval, KCC 19 or other applicable codes.
2. The tract, easement, or property line on a **pond cut slope** shall be set back a minimum of 10 feet from the emergency overflow water surface.
3. Stormwater facilities shall comply with Kitsap County Health District (KCHD) regulations for setbacks to onsite sewage systems, wells and other features regulated by KCHD.
4. All stormwater ponds must be a minimum of 200 feet from the top of any steep slope (greater than or equal to 30%). This distance may be reduced based on recommendation and justification by a licensed geotechnical engineer. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on a steep or otherwise sensitive slope.

L. 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).

M. Planting Requirements

Exposed earth on the pond bottom and interior side slopes shall be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract shall be planted with grass or be landscaped and mulched with a 4-inch cover of hog fuel or shredded wood mulch. Shredded wood mulch is made from shredded tree trimmings, usually from trees cleared on site. The mulch shall be free of garbage and weeds and shall not contain excessive resin, tannin, or other material detrimental to plant growth.

N. Landscaping

Landscaping is encouraged for most stormwater tract areas (see below for areas not to be landscaped). However, if provided, landscaping shall adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, "naturalistic" stormwater facilities may be placed in open space tracts. Landscaping of a stormwater tract may not be appropriate in some cases, and is subject to approval by the director. The following guidelines should be followed if landscaping is proposed for facilities.

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 should 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 7.1 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, should be planted in good topsoil. Native underlying soils 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 compost per WSDOT Standard Specifications 9-14.

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 should be planted in clumps to form "landscape islands" rather than evenly spaced.

6. The landscaped islands should be a minimum of six feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet. Where tree foliage extends low to the ground, the six feet setback should be counted from the outer drip line of the trees (estimated at maturity).

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

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. Trees be set back so that branches do not extend over the pond (to prevent leaf-drop into the water).

9. Drought tolerant species are recommended.

O. Guidelines for Naturalistic Planting.

Stormwater facilities may 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.

1. **Open Woodland.** In addition to the general landscaping guidelines above, the following are recommended.
   a) Landscaped islands (when mature) should cover a minimum of 30 percent or more of the tract, exclusive of the pond area.
   b) 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.
   c) Landscaped islands should be placed at several elevations rather than "ring" the pond, and the size of clumps shall vary from small to large to create variety.
   c) 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.*

2. **Northwest Savannah or Meadow.** In addition to the general landscape guidelines above, the following are recommended.
   a) Landscape islands (when mature) should cover 10 percent or more of the site, exclusive of the pond area.
   b) Planting groundcovers and understory shrubs is encouraged to eliminate the need for mowing under the trees when they are young.
   c) Landscape islands be placed at several elevations rather than “ring” the pond.
   d) The remaining site area be planted with an appropriate grass seed mix, which may include meadow or wildflower species. Native or dwarf grass mixes are preferred. Table 7.2 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 is required for all plantings (see BMP 5.10 in chapter 5).
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.

P. **Seed Mixes** The seed mixes listed below were developed for central Puget Sound.

7.2.1.3 Detention Volume and Outflow

The volume and outflow design for detention ponds must be in accordance with Minimum Requirements #7 in KCC12.18.100 and the hydrologic analysis and design methods in this chapter. Design criteria for restrictor orifice structures are given in Section 7.2.4.

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

7.2.1.4 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 7.3). 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 7.3 for infiltration ponds, including a soils report, testing, groundwater protection, pre-settling, and construction techniques.

7.2.1.5 Emergency Overflow Spillway Capacity

For impoundments less than 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 7.5, for example, would be:

$$Q_{100} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}\,(\operatorname{Tan}\theta)\,H^{5/2}\right] \qquad \text{(equation 7-1)}$$

Where Q_{100} = peak flow for the 100-year runoff event (cfs)
C = discharge coefficient (0.6)
g = gravity (32.2 ft/sec^2)
L = length of weir (ft)
H = height of water over weir (ft)
θ = 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, indicated by an approved continuous runoff model, multiplied by a factor of 1.6.

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

$$Q_{100} = 3.21[LH^{3/2} + 2.4\,H^{5/2}] \qquad \text{(equation 7-2)}$$

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

$$L = [Q_{100}/(3.21H^{3/2})] - 2.4\,H \quad \text{or} \quad 6 \text{ feet minimum} \qquad \text{(equation 7-3)}$$

7.2.2 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Standard detention tank details are shown in Figure 7.6 and Figure 7.7. Control structure details are shown in Section 7.2.4.

7.2.2.1 General Design Criteria

A. Tanks shall be designed as flow-through systems with manholes in line (see Figure 3.14) to promote sediment removal and facilitate maintenance. Tanks may be designed as back-up systems if preceded by water quality facilities, since little sediment shall reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank.
B. The detention tank bottom shall be located 0.5 feet below the inlet and outlet to provide dead storage for sediment.

C. The minimum pipe diameter for a detention tank is 36 inches.
D. Tanks larger than 36 inches shall be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe.
E. Details of outflow control structures are given in Section 7.2.4.

Note: Control and access manholes shall have additional ladder rungs to allow ready access to all tank access pipes when the catch basin sump is filled with water (see Figure 7.9, plan view).

F. **Materials** Galvanized metals leach zinc into the environment, especially in standing water situations. This can result in zinc concentrations that can be toxic to aquatic life. Therefore, use of galvanized materials in stormwater facilities and conveyance systems is discouraged. Where other metals, such as aluminum or stainless steel, or plastics are available, they shall be used. Pipe material, joints, and protective treatment for tanks shall be in accordance with Section 9.05 of the *WSDOT/APWA Standard Specification*.
G. **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.
H. **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.
I. **Access**
   1. The maximum depth from finished grade to tank invert shall be 20 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 CMP riser-type manholes (Figure 7.7) of the same gauge as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.
   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.

J. **Access Roads** Access roads shall be provided to all detention tank control structures and risers. The access roads shall be designed and constructed as specified for detention ponds in Section 7.2.1.

K. **Easements**. Any publicly maintained facility not located in public right-of-way shall be provided with a minimum 20-foot wide access easement to accommodate the access road to the facility.

L. **Setbacks.** Detention tanks shall be a minimum of 10 feet from any structure, property line, and any vegetative buffer required by conditions of land use approval, KCC 19 or other applicable codes.
All detention tanks must be a minimum of 50 feet from the top of any slope greater than 15 percent. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on a steep slope to support setbacks less than 50 feet.

M. **Detention Volume and Outflow.** The volume and outflow design for detention tanks must be in accordance with Minimum Requirement #7 in KCC12.18.100 and the hydrologic analysis and design methods in this chapter. Design criteria for restrictor orifice structures are given in Section 7.2.4.

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

7.2.3 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure 7.8. Control structure details are shown in Section 7.2.4.

7.2.3.1 General Design Criteria

A. Detention vaults shall be designed as flow-through systems with the bottom level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet shall be maximized (as feasible).

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

C. The invert elevation of the outlet shall be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet shall also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.
D. Details of outflow control structures are given in Section 7.2.4.
E. **Materials** Minimum 3,000 psi structural reinforced concrete shall be used for detention vaults. All construction joints must be provided with water stops.
F. **Structural Stability** All vaults must meet structural requirements for overburden support and H-20 traffic loading (See Standard Specifications for Highway Bridges, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet live load requirements per Washington State Department of Transportation Standards. Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed civil engineer with structural expertise and require a commercial building permit. 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.
G. **Access** must be provided over the inlet pipe and outlet structure. The following guidelines for access may be used.
   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 1,250 square feet of floor area, a 5' by 10' removable panel shall be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided as shown in Figure 7.8.
   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, shall 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 floor shall be 20 feet.
   7. Internal structural walls of large vaults shall be provided with openings sufficient for maintenance access between cells. The

openings shall be sized and situated to allow access to the maintenance “v” in the vault floor.

8. The minimum internal height shall be 7 feet from the highest point of the vault floor (not sump), and the minimum width shall be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. 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 include clearly marked 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) shall be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively, removable panels over the entire vault may be provided.

H. **Access Roads**

Access roads are needed to the access panel (if applicable), the control structure, and at least one access point per cell, and shall be designed and constructed as specified for detention ponds in Section 7.2.1.

I. **Easements**

Any publicly maintained facility not located in public right-of-way shall be provided with a minimum 20-foot wide access easement to accommodate the access road to the facility.

J. **Setbacks**

Setbacks to tract or easement lines shall be a minimum of 5 feet. Detention vaults shall be a minimum of 10 feet from any structure, property line, and any vegetative buffer required by conditions of land use approval, KCC 19 or other applicable codes.

All detention vaults must be a minimum of 50 feet from the top of any slope greater than 15 percent. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on a steep slope to support setbacks less than 50 feet.

K. **Detention Volume and Outflow**

The volume and outflow design for detention vaults must be in accordance with Minimum Requirement #7 in KCC12.18.100 and the hydrologic analysis and design methods in this chapter. Design criteria for restrictor orifice structures are given in Section 7.2.4

7.2.4 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 7.9 through Figure 7.11.

7.2.4.1 Design Criteria

A. **Multiple Orifice Restrictor -** In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.
   1. Minimum orifice diameter is 0.5 inches. Note: In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards.
   2. Orifices may be constructed on a tee section as shown in Figure 7.9 (WSDOT Standard Plan B-10.40.00) or on a baffle as shown in Figure 7.10 (WSDOT Standard Plan B-10.60.00).
   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 7.13).
   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.

B. Riser and Weir Restrictor
   1. Properly designed weirs may be used as flow restrictors (see Figure 7.11 and Figure 7.13 through Figure 7.15). 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 7.16 can be used to calculate the head in feet above a riser of given diameter and flow.

C. Access
   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 7.2.1.1.
   2. Manhole and catch basin lids for control structures must be solid and 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.

7.2.4.2 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.

A. Orifices

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

$$Q = C\,A\,\sqrt{2gh} \qquad \text{(equation 7-4)}$$

where Q = flow (cfs)
C = coefficient of discharge (0.62 for plate orifice)
A = area of orifice (ft^2)
h = hydraulic head (ft)
g = gravity (32.2 ft/sec^2)

Figure 7.12 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:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(equation 7-5)}$$

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

B. Rectangular Sharp-Crested Weir

The rectangular sharp-crested weir design shown in Figure 7.13 may be analyzed using standard weir equations for the fully contracted condition.

$$Q=C\,(L - 0.2H)H^{3/2} \qquad \text{(equation 7-6)}$$

where Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P are as shown above

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

D = inside riser diameter (ft)

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

*Note that **H must be equal to or less than one-half L**.*

C. V-Notch Sharp - Crested Weir

V-notch weirs as shown in Figure 7.14 may be analyzed using standard equations for the fully contracted condition.

D. 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 7.15). The weir may be symmetrical or non-symmetrical.

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

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

where a, b, x and Z are as shown in Figure 3.23. The head-discharge relationship is:

$$Q = C_d\, b \sqrt{2ga(h_1 - \frac{a}{3})} \qquad \text{(equation 7-8)}$$

Values of C_d for both symmetrical and non-symmetrical sutro weirs are summarized in Table 7.3.

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

E. **Riser Overflow**

The nomograph in Figure 7.16 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).

7.2.4.3 Other Detention Options

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

A. **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 an adverse impact to downhill properties or drainage system.
   4. Fire lanes used for emergency equipment are free of ponding water for all runoff events up to and including the 100-year event.

B. **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.

7.3 INFILTRATION FACILITIES FOR FLOW CONTROL AND FOR TREATMENT

7.3.1 Purpose

To provide infiltration capacity for stormwater runoff quantity and flow control, and/or for water quality treatment.

7.3.2 Description

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

B. 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.

C. Use of the soil for treatment purposes is also an option as long as it is preceded by a pretreatment or a basic treatment BMP. This section highlights design criteria that are applicable to infiltration facilities serving a treatment function.

7.3.3 Applications and Limitations

The requirements and guidelines presented in this chapter are for the demonstrative approach. For the prescriptive approach, see Chapter 5, On Site Stormwater Management..

A. Infiltration facilities for flow control are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Infiltration facilities for treatment purposes rely on the soil profile to provide treatment. In either case, runoff in excess of the infiltration capacity of the facilities must be managed to comply with the flow control requirement if flow control applies to the project.

B. Infiltration facilities shall not be constructed in fill materials. An exception may be made for engineered fill specifically designed for the purpose of infiltration when overexcavation is proposed to enable utilization of suitable soils beneath restrictive soils layers.

C. Infiltration facilities can help accomplish the following:
1. Ground water recharge
2. Discharge of uncontaminated or properly treated stormwater to dry-wells in compliance with Ecology’s UIC regulations (Chapter 173-218 WAC)
3. Retrofits in limited land areas: Infiltration trenches can be considered for residential lots, commercial areas, parking lots, and open space areas
4. Flood control
5. Streambank erosion control

7.3.4 Infiltration Facilities

This section presents the methods, criteria, and details for design and analysis of infiltration facilities These facilities are used where soils are suitable for soaking the increased runoff from development into the ground. Such facilities usually have a detention volume component to allow for temporary storage of runoff while it is being infiltrated. This detention volume is typically dependent on the infiltration capacity of the soils and the required facility performance.

There are five types of infiltration facilities allowed for use in complying with Minimum Requirement # 7, "Flow Control": infiltration ponds, infiltration tanks, infiltration vaults, infiltration trenches, and small infiltration basins. In general, ponds are preferred because of the ease of maintenance and the water quality treatment that surface soil and vegetation provide. Tanks and trenches are useful where site constraints prevent use of a pond, and small infiltration basins are simple to design but have limited uses. Designers are also encouraged to explore the use of distributed infiltration facilities such as bioretention filters/rain gardens and pervious pavement systems. Chapter 5 contains more details on bioretention filters/rain gardens and pervious pavement systems.

7.3.4.1 General Requirements for Infiltration Facilities

This section presents the design requirements generally applicable to all infiltration facilities. Included are the general requirements for determining acceptable soil conditions, determining infiltration rates, and providing overflow protection, spill control, presettling, groundwater protection, protection from upstream erosion, and construction.

A. Soils

The applicant must demonstrate through infiltration testing, soil logs, and the written opinion of a geotechnical engineer that sufficient permeable soil exists at the proposed facility location to allow construction of a properly functioning infiltration facility.

The basic requirement is a minimum of 3 feet of permeable soil below the bottom of the facility (bottom of pond or excavation for tank) and at least 3 feet between the bottom of the facility and the maximum wet-season water table. Test pits or borings shall extend at least 5 feet below the bottom of the infiltration facility, and at least one test hole should reach the water table. If the water table is very deep, the test hole need not extend more than one-fourth the maximum width of the pond below the bottom of a pond, or more than 5 feet below the bottom of a tank. If there is any question about the actual wet-season water table elevation, measurements shall be made during the period when the water level is expected to be at a maximum.

<u>NOTE</u>: The 3 foot limit applies to large centralized systems designed to serve greater than 10,000 square feet of impervious surface, or ¾ acre of pollution generating pervious surface or greater than 5,000 square feet of pollution generating impervious surface. See the Kitsap County LID Guidance Manual for permeable soil depth limits for distributed systems serving smaller areas of land. Any requirements associated with impacts to an ***erosion hazard area***, ***steep slope hazard area***, or ***landslide hazard area*** should also be addressed in the soil study. *The geotechnical engineer shall provide a report stating whether the location is suitable for the proposed infiltration facility, and shall recommend a design infiltration rate (see "C. Design Infiltration* Rate" *below).*

B. Measured Infiltration Rates

Infiltration rate tests are used to help estimate the maximum sub-surface vertical infiltration rate of the soil below a proposed infiltration facility (e.g., pond or tank) or a closed depression. The tests are intended to simulate the physical process that will occur when the facility is in operation; therefore, a saturation period is required to approximate the soil moisture conditions that may exist prior to the onset of a major winter runoff event.

<u>Testing Procedure</u>

1. Excavations shall be made to the bottom elevation of the proposed infiltration facility. The measured infiltration rate of the underlying soil

shall be determined using either the EPA falling head percolation test procedure (*Onsite Wastewater Treatment and Disposal Systems*, EPA, 1980; see Reference Section 6-A), the double ring infiltrometer test (ASTM D3385), a single ring at least 3 feet in diameter, or large scale Pilot Infiltration Test (PIT) as described in the 2005 Department of Ecology Stormwater Management Manual for Western Washington. Large single ring and PIT tests have been shown to more closely match actual full-scale facility performance than smaller test methods.

2. The test hole or apparatus shall be filled with water and maintained at depths above the test elevation for the saturation periods specified for the appropriate test.
3. Following the saturation period, the rate shall be determined in accordance with the specified test procedures, with a head of 6 inches of water.
4. The design engineer shall perform sufficient tests to determine a representative infiltration rate. At a minimum, three small-scale tests shall be performed for each proposed infiltration facility location, and at least 2 tests per acre (minimum of 4 tests) shall be performed for a closed depression. If large-scale tests are performed, the number of tests may be reduced at the discretion of the review engineer.
5. A minimum of two soils logs shall be obtained for each tank and for each 10,000 square feet (plan view area) of proposed infiltration surface area. Soils shall be logged for a minimum of 5 feet below the bottom of each proposed infiltration facility. The logs shall describe the SCS series of the soil, indicate the textural class of the soil horizons throughout the depth of the log, note any evidence of high groundwater level (such as mottling), and estimate the maximum groundwater elevation, if within the limits of the log.

C. Design Infiltration Rate

In the past, many infiltration facilities have been built that have not performed as the designer intended. This has resulted in flooding and substantial public expenditures to correct problems. Monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate determined by small-scale testing. Actual measured facility rates of 10% of the small-scale test rate have been seen. It is clear that great conservatism in the selection of design rates is needed, particularly where conditions are less than ideal. The design infiltration rate shall be determined using an analytical groundwater model to investigate the effects of the local hydrologic conditions on facility performance. Since this analysis may be excessively costly for small projects, the simplified method described below may be used in lieu of groundwater modeling for ***single family residential projects*** (excluding plats and short plats of 5 or more lots), and projects with less than 1 acre of disturbed area.

For other sites, the designer must either conduct groundwater modeling (mounding analysis) of the proposed infiltration facility shall be done using the design infiltration rate and the estimated maximum groundwater elevation determined for the proposed facility location or calculate the design infiltration rate per the guidelines found in chapters 3.3.5 through 3.3.9, including post construction verification, of volume III the 2005 Department of Ecology Stormwater Design Manual for Western Washington (2005 DOE). MODRET or an equivalent model must be used for the groundwater modeling unless the director approves an alternative analytical technique.

D. Simplified Method

A simplified method may be used for determining the preliminary design infiltration rate by applying correction factors to the measured infiltration rate. The correction factors account for uncertainties in testing, depth to the water table or impervious strata, infiltration receptor geometry, and long-term reductions in permeability due to biological activity and accumulation of fines. Equation 7-9 has been developed to account for these factors. This equation estimates the **maximum** design infiltration rate (I_{design}); additional reduction in rate beyond that produced by the equation may be appropriate. Note that the design infiltration rate I_{design} **must not exceed 10 inches/hour.**

$$I_{design} = I_{measured} \times F_{testing} \times F_{geometry} \times F_{plugging} \qquad 7\text{-}9$$

Correction factor $F_{testing}$ accounts for uncertainties in the testing methods. For the EPA method, $F_{testing}$ = 0.30; for the ASTM D3385 method or large-scale testing, $F_{testing}$ = 0.50

$F_{geometry}$ accounts for the influence of facility geometry and depth to the water table or impervious strata on the actual infiltration rate. A shallow water table or impervious layer will reduce the effective infiltration rate of a large pond, but this will not be reflected in a small scale test. Clearly, a large pond built over a thin pervious stratum with a shallow water table will not function as well as the same pond built over a thick pervious stratum with a deep water table. $F_{geometry}$ must be between 0.25 and 1.0 as determined by the following equation:

$$F_{geometry} = 4\,D/W + 0.05 \qquad 7\text{-}10$$

where D = depth from the bottom of the proposed facility to the maximum wet-season water table or nearest impervious layer, whichever is less

W = width of the facility

$F_{plugging}$ accounts for reductions in infiltration rates over the long term due to plugging of soils. This factor is:

- 0.7 for loams and sandy loams
- 0.8 for fine sands and loamy sands
- 0.9 for medium sands
- 1.0 for coarse sands or cobbles, or any soil type in an infiltration facility preceded by a water quality facility.

E. Performance testing

Where the design is based on the Simplified Method, or the methods described in chapters 3.3.5 through 3.3.9 of volume III of the 2005 DOE manual. The completed facility must be tested and monitored to demonstrate that the facility performs as designed. If the facility performance is not satisfactory, the facility will need to be modified or expanded as needed in order to make it function as designed. Where a groundwater mounding analysis was used in the design, small-scale infiltration testing in the bottom of the facility to demonstrate that the soils in the constructed facility are representative of the design assumptions is required.

F. 100-Year Overflow Conveyance

An overflow route shall be identified for stormwater flows that overtop the facility when infiltration capacity is exceeded or the facility becomes plugged and fails. The overflow route must be able to safely convey the 100-year developed peak flow to the downstream conveyance system or other acceptable discharge point in accordance with conveyance requirements in chapter 4.

Where the entire ***project site*** is located within a closed depression (such as some gravel pits), the requirement to identify and analyze a 100-year overflow pathway may be waived by DCD if (1) an additional correction factor of 0.5 is used in calculating the **design infiltration rate**, (2) the facility is sized to fully infiltrate the 100-year runoff event, and (3) the facility is not bermed on any side. **Intent:** to address situations where the infiltration facility may be a highly permeable onsite closed depression, such as a gravel pit, where all stormwater is currently, and will remain, fully infiltrated.

G. Spill Control device

All infiltration facilities must have a spill control device upstream of the facility to capture oil or other floatable contaminants before they enter the infiltration facility. The spill control device shall be a **tee section** per chapter 6 or an equivalent device approved by the director. If a tee section is used, the top of the riser shall be set above the 100-year overflow elevation to prevent oils from entering the infiltration facility.

H. Presettling

Presettling must be provided before stormwater enters the infiltration facility. This requirement may be met by either of the following:

1. A water quality facility from the Basic treatment menu of chapter 6. (preferred alternative)
2. A pretreatment device from chapter 6.

I. Protection from Upstream Erosion

Erosion must be controlled during construction of areas upstream of infiltration facilities since sediment-laden runoff can permanently impair the functioning of the system. Erosion control measures must be designed, installed and maintained with great care. Various strategies may be employed to protect infiltration facilities during construction, as described below.

Projects may be phased to limit clearing and minimize the time that soils are exposed. An alternative to this approach is to serve the undeveloped area with a large sediment trap on an undeveloped tract with the trap left in place until all clearing and construction is complete and all permanent landscaping is in place. See Chapter 2 for design details. At the completion of all construction, the sediment trap must be cleaned out (taking care that no sediment enters the drainage system) and filled in, and the flow routed to the permanent drainage system.

J. Facility Construction Guidelines

Excavation of infiltration facilities should be done with a backhoe working at "arms length" to **minimize disturbance and compaction of the completed infiltration surface**. If the bottom of the facility will be less than three feet below final grade, the facility area should be cordoned off so that construction traffic does not traverse the area. The exposed soil should be inspected by a soils engineer after excavation to confirm that soil conditions are suitable. Two simple **staff gages for measuring sediment depth** should be installed at opposite ends of the bottom of ponds. The gages may consist of 1-inch pipe driven at least one foot into the soil in the bottom of the pond, with 12 inches of the pipe protruding above grade.

K. Offsite Groundwater Level Impacts

Potential impacts to groundwater levels off the ***project site*** shall be considered. In general, replacing vegetation with impervious cover will increase the total annual volume of runoff generated on a ***site***. Infiltrating this runoff will tend to increase ground water recharge, which may affect groundwater levels offsite. The impacts of infiltration could include increased water to ***geologic hazard areas***, increased groundwater resources available, increased water levels in closed depressions, and higher groundwater levels. Higher groundwater levels offsite could result in increased flooding of basements, or impaired functioning of infiltration systems resulting in surface water flooding. Evidence of offsite groundwater flooding problems should be examined during the offsite analysis.

In general, groundwater level impacts will be very difficult to reduce, and there are no specific requirements that apply in many cases. The design engineer is encouraged to consider whether there are any feasible approaches to reduce groundwater flooding impacts, such as moving facilities or changing facility geometry, retaining forest cover, minimizing impervious coverage, or fixing downstream problems.

L. Groundwater Protection

The protection of groundwater quality is recognized as an issue of greater concern than in the past, and groundwater protection standards are changing rapidly. Increased safeguards are often required. The applicant shall check the critical areas ordinance (KCC Title 19) and wellhead protection areas mapped by the Washington State Department of Health, to determine if the project lies within a critical aquifer recharge area.

1. The **groundwater protection requirements** of this manual call for implementing one of the following actions when infiltrating runoff from pollution-generating surfaces:
   a. Provide water quality treatment prior to infiltration as specified in Minimum Requirement #6 Runoff Treatment.
   b. Demonstrate that the soil beneath the infiltration facility has properties that reduce the risk of groundwater contamination from typical stormwater runoff. Such properties are defined below depending on whether the project is located outside of, or within, a ***critical aquifer recharge area.***

2. Soil Properties Required for Groundwater Protection Outside of Groundwater Protection Areas

For infiltration facilities located outside of ***critical aquifer recharge area***, acceptable groundwater protection is provided by the soil if the first two feet or more of the soil beneath the infiltration facility has a *cation exchange capacity*[1] greater than 5 and an *organic content*[2] greater than 0.5%, AND meets **one of the following** criteria:

   a. The soil has a measured infiltration rate less than or equal to 9 inches per hour[3] or is logged as one of the classes from the **USDA Textural Triangle** (Figure 7.17), excluding sand and loamy sand (*Note: soil texture classes other than sand and loamy sand may be assumed to have an infiltration rate of less than or equal to 9 inches per hour without doing field testing to measure rates.*[4]), OR
   b. The soil is composed of less than 25% gravel by weight with at least 75% of the soil passing the #4 sieve. The portion passing the #4 sieve must meet one of the following gradations:
   - At least 50% must pass the #40 sieve and at least 2% must pass the #100 sieve, or;
   - At least 25% must pass the #40 sieve and at least 5% must pass the #200 sieve.

   Note: These soil properties must be met by the native soils onsite. Soil may not be imported in order to meet groundwater protection criteria without an approved technical deviation.

3. Soil Properties Required within Groundwater Protection Areas

For projects located within ***groundwater protection areas***, acceptable groundwater protection is provided by the soil if the first two feet or more of

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1 *Cation exchange capacity* shall be tested using EPA Laboratory Method 9081.

2 *Organic content* shall be measured on a dry weight basis using method ASTM D2974 for the fraction passing the #40 sieve.

3 See discussion of the measured infiltration rate

4 Criteria (a) is based on the relationship between infiltration rates and soil texture. However, there are many other factors, such as high water table, presence of impervious strata or boulders close to the surface, etc., which also affect infiltration rate. When any such condition is suspected because soils are coarser than expected from the measured infiltration rate, a sieve analysis should be done to establish soil characteristics. The judgment of a geotechnical engineer, geologist or soil scientist shall determine whether a sieve analysis is warranted. The sieve analysis must meet Criteria (c) above to be considered protective.

the soil beneath the infiltration facility has a **cation exchange capacity** greater than 5 and an **organic content** greater than 0.5%, AND meets **one of the following** criteria:

a. The soil has a **measured infiltration rate** less than or equal to **2.4 inches per hour** or is logged as one of the classes from the **USDA Textural Triangle** (Figure 7.17), excluding sand, loamy sand, and sandy loam (*Note: soil triangle texture classes other than sand, loamy sand, and sandy loam may be assumed to have an infiltration rate of less than or equal to 2.4 inches per hour without doing field testing to measure rates.*[5]), OR

b. The soil has a measured infiltration rate less than or equal to 9 inches per hour, and it must be composed of less than 25% gravel by weight with at least 75% of the soil passing the #4 sieve. The portion passing the #4 sieve must meet one of the following gradations:

- At least 50% must pass the #40 sieve and at least 2% must pass the #100 sieve, or
- At least 25% must pass the #40 sieve and at least 5% must pass the #200 sieve.

Note: The above soil properties must be met by the native soils onsite. Soil may not be imported in order to meet groundwater protection criteria without an approved technical deviation.

M. Infiltration near Water Supply Wells

The design engineer shall consider the following when designing infiltration facilities near water supply wells:

1. In no case should infiltration facilities be placed closer than 100 feet from drinking water wells and 200 feet from springs used for drinking water supplies. Where water supply wells exist nearby, it is the responsibility of the applicant's engineer to locate such wells, meet any applicable protection standards, and assess possible impacts of the proposed infiltration facility on groundwater quality. If negative impacts on an individual or community water supply are possible, additional runoff treatment must be included in the facility design, or relocation of the facility shall be considered.
2. All infiltration facilities located within the one-year capture zone of any well should be preceded by a water quality treatment facility that meets at least the basic treatment requirements of chapter 6
3. See Kitsap County Health District regulations for further guidance.

N. Infiltration near Steep Slopes and Geologically Hazardous Areas

Where slopes are steeper than 15 % and flatter than 30%, infiltration facilities (excluding individual lot systems) shall be placed no closer to the top of slope than the distance equal to the total vertical height of the slope area.

Infiltration facilities shall not be located within 200 feet of a slope steeper than or equal to 30% or a geologically hazardous area (as described in KC Code Title 19.400). This distance may be reduced if supported by a detailed geotechnical engineering evaluation and report.

[5] Concerns regarding Criteria (a) and the correspondence between the measured infiltration rate and soil textures are the same as discussed for projects outside sole-source aquifer areas.

O. Underground Injection Control Well Registration

The Department of Ecology adopted revisions to Chapter 173-218 WAC, the Underground Injection Control (UIC) program rules, on January 3, 2006. The newly adopted revisions went into effect on February 3, 2006. These rules require the registration of new injection wells that manage stormwater. Information regarding these new regulations may be found at Ecology's Underground Injection Control Program website. In general, infiltration systems that have buried pipe, tanks, or vaults would be considered injection wells, but systems managing runoff only from single-family roofs are exempt. Open ponds are not considered injection wells.

7.3.4.2 Infiltration Ponds

Infiltration ponds may be constructed by excavating or constructing berms. See Figure 7.18 for a typical detail.

A. Design Criteria

General: The following criteria for ponds are in addition to the general requirements for infiltration facilities specified in Section 7.3.4.1:

1. The proposed **pond bottom** must be at least 3 feet above the seasonal high groundwater level and have at least 3 feet of permeable soil beneath the bottom.
2. The infiltration surface **must be in native soil** (excavated at least one foot in depth).
3. **Maintenance access** shall be provided to both the presettling pond or vault (if provided) and the infiltration pond.
4. An **overflow structure** such as that shown in Figure 7-3 shall be provided. In addition, infiltration ponds shall have an emergency spillway as required for detention ponds in Section 7.2.1.5.
5. The criteria for **general design**, side slopes, embankments, planting, maintenance access, access roads, fencing, signage, and right-of-way shall be the **same as for detention ponds** (see Section 7.2.1), except as required for the infiltration design.

B. Setbacks

1. The **toe of the exterior slope** of an infiltration pond berm embankment shall be set back a minimum of 5 feet from the tract, easement, property line and any vegetative buffer required by conditions of land use approval, KCC Title19 or other applicable codes.
2. The tract, easement, or property line on a **pond cut slope** shall be set back a minimum of 10 feet from the emergency overflow water surface.
3. See Kitsap County Health District (KCHD) regulations for setbacks to on site sewage systems, wells and other features regulated by KCHD.
4. The infiltration pond design water surface shall be set back **20** feet from **tract, easement or property lines**. This may be reduced to 10 feet if the facility soils report addresses the potential impacts of the facility phreatic surface on existing or future structures located on adjacent external lots.

C. Methods of Analysis

The size of the pond shall be determined using the hydrologic analysis and routing methods described for detention ponds in Section 7.2.4. The **storage volume** in the pond is used to detain runoff prior to infiltration. The **stage/discharge curve** shall be developed from the design infiltration rate determined according to Section 7.3.4.1. At a given stage the discharge may be computed using the **area of pervious surface** through which infiltration will occur (which will vary with stage) multiplied by the recommended design infiltration rate (in appropriate units). Berms (which should be constructed of impervious soil such as till), maintenance access roads, and lined swales should not be included in the design pervious surface area.

7.3.4.3 Infiltration Tanks

Infiltration tanks consist of underground pipe that has been perforated to allow detained stormwater to be infiltrated. Figure 7.19 shows a typical infiltration tank.

A. General Design Criteria

The following criteria for tanks are in addition to the general requirements for infiltration facilities specified in Section 7.3.4.1:

1. The proposed **tank trench bottom** shall be at least 3 feet above the seasonal high groundwater level and have at least 3 feet of **permeable soil** beneath the trench bottom.
2. The infiltration surface elevation (bottom of trench) **must be in native soil** (excavated at least one foot in depth).
3. **Spacing between parallel tanks** shall be calculated using the distance from the lowest trench bottom to the maximum wet season ground water surface (D) and the design width of the trench for a single tank (W). The tank spacing $S = W^2/D$, where S is the centerline spacing between trenches (or tanks) in feet. S shall not be less than W, and S need not exceed 2W.
4. Tanks shall be **bedded and backfilled with washed drain rock** that extends at least 1 foot below the bottom of the tank, at least 2 feet but not more than 5 feet beyond the sides, and up to the top of the tank.
5. Drain rock (3 to $1^1/_2$ inches) shall be completely covered with **filter fabric** prior to backfilling.
6. The **perforations** (holes) in the tank must be one inch in diameter and located in the bottom half of the tank starting at an elevation of 6 inches above the invert of the tank. The number and spacing of the perforations should be sufficient to allow complete utilization of the available infiltration capacity of the soils with a safety factor of 2.0 without jeopardizing the structural integrity of the tank.
7. Infiltration tanks shall have an overflow structure equipped with a **solid bottom riser** (with clean-out gate) and outflow system for safely discharging overflows to the downstream conveyance system or another acceptable discharge point.

8. The criteria for **general design,** materials, structural stability, buoyancy, maintenance access, access roads, and right-of-way shall be the **same as for detention tanks** (see Section 7.2.1), except for features needed to facilitate infiltration.

B. Setbacks

1. Tank setbacks shall comply with Kitsap County Health District regulations for setbacks from **wells and onsite sewage systems.**
2. Infiltration tanks shall be set back 20 feet from **tract, easement, or property lines**. This may be reduced to 10 feet if the facility soils report addresses the potential impacts of the facility phreatic surface on existing or future structures located on adjacent external lots.

C. Methods of Analysis

The **size of the tank** shall be determined using the hydrologic analysis and routing methods described in Section 7.2.4, and the **stage/discharge curve** developed from the recommended design infiltration rate. The **storage volume** in the tank is used to detain runoff prior to infiltration with the perforations providing the outflow mechanism. At any given stage, the discharge may be computed using the **area of pervious surface** through which infiltration will occur multiplied by the recommended design infiltration rate (in appropriate units). The area of pervious surface used for determining the potential infiltration from the tank shall be computed by taking the lesser of the trench width, or two times the width of the tank, and then multiplying by the length of the tank (assuming infiltration through the bottom of the trench only).

7.3.4.4 Infiltration Vaults

Infiltration vaults consist of a bottomless concrete vault structure placed underground in native infiltrative soils. Infiltration is achieved through the native soils at the bottom of the structure.

Infiltration vaults are similar to detention vaults. A standard detention vault detail is shown in Figure 7.20.

A. General Design Criteria

The following criteria for vaults are in addition to the general requirements for infiltration facilities specified in Section 7.3.4.1:

1. The proposed **vault bottom** shall be at least 3 feet above the seasonal high groundwater level and have at least 3 feet of permeable soil beneath the bottom.
2. The vault bottom **must be in native soil** (excavated at least one foot in depth).
3. A suitable means to dissipate energy at the inlet is required to prevent scour.
4. Infiltration vaults shall have a **solid bottom riser** (with clean-out gate) and outflow system for safely discharging overflows to the downstream conveyance system or another acceptable discharge point.

B. Structural Stability

All vaults shall meet structural requirements for overburden support and H-20 vehicle loading. Vaults located under roadways must meet the live load requirements of the *Washington State Department of Transportation Standards*. Cast-in-place wall sections shall be designed as retaining walls. Structural designs for vaults must be stamped by a licensed structural engineer and require a separate building permit . Bottomless vaults shall be provided with footings placed on stable, well-consolidated native material and sized considering overburden support, traffic loading (assume maintenance traffic, if placed outside ROW), and lateral soil pressures when the vault is dry. Infiltration vaults shall not be allowed in fill slopes unless analyzed in a geotechnical report for stability. The infiltration surface at the bottom of the vault must be in native soil.

C. Access Requirements

Same as specified for detention vaults in Section 7.3.4.3.

D. Access Roads

Same as specified for detention vaults in Section 7.3.4.3.

E. Right-of-Way

Infiltration vaults to be maintained by Kitsap County but not located in County right-of-way shall be in a tract dedicated to Kitsap County, or in a tract dedicated to the Homeowners' Association with an easement conveyed to the County. Any tract not abutting public right-of-way will require a 20-foot wide extension of the tract or easement to accommodate an access road to the vault.

F. Setbacks

1. Infiltration vaults shall be set back from wells and on site sewage systems according to Kitsap County Health District regulations.
2. Infiltration vaults shall be set back 20 feet from **tract, easement, or property lines**. This may be reduced to 10 feet if the facility soils report addresses the potential impacts of the facility phreatic surface on existing or future structures located on adjacent external lots.

G. Methods of Analysis

The **size of the vault** shall be determined using the hydrologic analysis and routing methods described in Section 7.2.4 and the **stage/discharge curve** developed from the recommended design infiltration rate as described in Section 7.3.4.1. The **storage volume** in the vault is used to detain runoff prior to infiltration. At any given stage, the discharge may be computed using the **area of pervious surface** through which infiltration will occur (the exposed soil comprising the vault bottom) multiplied by the recommended design infiltration rate (in appropriate units).

7.3.4.5 Infiltration Trenches

Infiltration trenches can be a useful alternative for developments with constraints that make siting a pond difficult. Infiltration trenches may be placed beneath parking areas, along the ***site*** periphery, or in other suitable linear areas. See Figure 7.21.

A. Design Criteria

General

The following criteria for trenches are in addition to the general requirements for infiltration facilities specified in Section 7.3.4.1:

1. The proposed **trench bottom** must be at least 3 feet above the seasonal high groundwater level and 3 feet below finished grade.
2. There must be at least 3 feet of **permeable soil** beneath the trench bottom.
3. The infiltration surface elevation (bottom of trench) must be in **native soil** (excavated at least one foot in depth).
4. Trenches shall be a minimum of **2 feet wide**.
5. Trenches shall be **backfilled with $1^{1}/_{2}$ - $^{3}/_{4}$-inch washed rock**, completely surrounded by filter fabric and overlain by a minimum 1 foot of compact backfill.
6. Level 6-inch minimum diameter rigid **perforated distribution pipes** shall extend the length of the trench. Distribution pipe inverts shall be a minimum of 2 feet below finished grade. Provisions (such as clean-out wyes) shall be made for cleaning the distribution pipe. The pipe capacity shall be calculated to verify that the distribution pipe has capacity to handle the maximum design flow.
7. Alternative trench-type systems using **pre-fabricated bottomless chambers** that provide an equivalent system may be used at the discretion of DCD.
8. Two feet minimum **cover** shall be provided in areas subject to vehicle loads.
9. Trenches shall be **spaced** no closer than 10 feet, measured on center.

B. Setbacks

1. Trench systems shall be set back from wells and onsite sewage systems according to Kitsap County Health District regulations.
2. **Structures** shall be set back 20 feet from individual trenches. This may be reduced if the facility soils report addresses potential impacts of trench phreatic[6] surface on structures so located.

C. Methods of Analysis

The sections and lengths of trenches shall be determined using the hydrologic analysis and routing methods for flow control design described in Section 7.2.4. The **stage/discharge curve** shall be developed from the design infiltration rate recommended by the soils engineer, as described in Section 7.3.4.1. **Storage volume** of the trench system shall be determined considering void space of the washed rock backfill and maximum design water surface level at the crown of the distribution pipe. At any given stage, the discharge may be computed using the **area of pervious surface** through which infiltration will occur (trench bottom area only) multiplied by the recommended design infiltration rate (in appropriate units).

[6] The term **phreatic** surface is where the hydrostatic pressure of groundwater or soil moisture is atmospheric . This surface normally coincides with the water table.

7.3.4.6 Alternative Infiltration Systems
Manufacturers have developed other systems made with pre-cast plastic that have properties in common with vaults, tanks, and trenches, but that do not conform to the standards for those facility types. These systems may be approved by the director using suitable design standards adapted from the established standards for similar systems.

A. General Design Criteria

The following criteria for alternative systems are **in addition to** the general requirements for infiltration facilities:

1. The proposed infiltration surface must be at least 3 feet above the seasonal high groundwater level.
2. There must be at least 3 feet of **permeable soil** beneath the infiltration surface.
3. The infiltration surface elevation must be in **native soil** (excavated at least one foot in depth).
4. Systems shall be **backfilled with $1^1/_2$ - $^3/_4$-inch washed rock or similar material**, completely surrounded by filter fabric and overlain by a minimum 1 foot of compact backfill.
5. Two feet minimum **cover** shall be provided in areas subject to vehicle loads.
6. **Chambers** shall be spaced **no more than 10 feet apart** as measured from the adjacent edges. Inflow pipes or a manifold system shall be connected to each infiltration chamber. Inspection and maintenance access to each chamber shall be provided as deemed necessary by the County.

B. Setbacks

1. Alternative systems shall be set back from wells and on site sewage systems in accordance with Kitsap County Health District regulations.
2. **Structures** shall be set back 20 feet from infiltration systems. This may be reduced if the facility soils report addresses potential impacts of trench phreatic surface on structures so located.

C. Methods of Analysis

The sizing and layout of the system shall be determined using the hydrologic analysis and routing methods for flow control design described in this chapter. The **stage/discharge curve** shall be developed from the design infiltration rate recommended by the soils engineer, as described in Section 7.3.4.1. **Storage volume** of the system shall be determined considering void space of the washed rock backfill and the volume contained in system elements. At any given stage, the discharge may be computed using the **area of pervious surface** through which infiltration will occur multiplied by the recommended design infiltration rate (in appropriate units).

7.3.4.7 Small Infiltration Basins
Small infiltration basins consist of a bottomless, precast concrete catch basin or equivalent structure placed in an excavation filled with washed drain rock. Stormwater infiltrates through the drain rock into the surrounding soil. This

facility is intended for use with contributing surface areas of less than 5,000 square feet. Presettlement is most easily provided by a catch basin or manhole with a turned-down elbow; see figure 7.22 (below) for a generic design sketch. The Department of Ecology (DOE) regulates infiltration basins serving other than a single-family residence under the Underground Injection Control (UIC) laws. Additional requirements by DOE may apply.

A. Design Criteria

The design criteria for small infiltration basins are essentially the same as for infiltration tanks, except that only one infiltration rate test and soil log is required for each small infiltration basin. Access into the basins shall be provided for inspection and maintenance. Designs may incorporate Type II catch basins, but equivalent designs using other materials may be accepted.

APPENDIX 7-A
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 can be found here: http://www.ecy.wa.gov/programs/wq/stormwater/wwhmtraining/index.html .

A. Limitations to the WWHM

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.

In addition, the WWHM is limited in its routing capabilities. The user is allowed to input multiple stormwater control facilities and runoff is routed through them. If the proposed development site involves routing through a natural lake or wetland in addition to multiple stormwater control facilities then the user shall 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 less than an acre in size.

B. Assumptions made in creating the WWHM

1. Precipitation data
   a. 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.
   b. A total of 17 precipitation stations are used, representing the different rainfall regimes found in Western Washington.
   c. These stations represent rainfall at elevations below 1,500 feet -snowfall and snowmelt are not included in the WWHM.
   d. The primary source for precipitation data is National Weather Service stations.
   e. The base 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. Based on more frequent (15-minute) rain data collected over 25 years in Seattle, a relationship has been developed and incorporated in WWHM for converting the 60-minute water quality design flows to 15-minute flows. The 15-minute water quality design flows are more appropriate and must be used for design of water quality treatment facilities that are expected to have a hydraulic residence time of less than one hour.

2. Precipitation multiplication factors
   a. The WWHM uses precipitation multiplication factors to increase or decrease recorded precipitation data to better represent local rainfall conditions.
   b. 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.
   c. 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. By default, WWHM does not allow the precipitation multiplication factor to go below 0.8 or above 2.

3. Pan evaporation data
   a. 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.
   b. 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.
4. Soil data
   a. The WWHM uses three predominate soil type to represent the soils of western Washington: till, outwash, and saturated.
   b. 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.
   c. Additional soils will be included in the WWHM if appropriate HSPF parameter values are found to represent other major soil groups.
5. Vegetation data
   a. The WWHM will represent the vegetation of western Washington with three predominate vegetation categories: forest, pasture, and lawn (also known as grass).
   b. The predevelopment land conditions are generally assumed as forest (the default condition), however, the user has the option of specifying pasture if there is documented evidence that pasture vegetation was native to the predevelopment site.

6. Development land use data
   a. 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.
   b. Credits are given for infiltration and dispersion of roof runoff and for use of porous pavement for driveway areas. Refer to Chapter 5, Onsite Stormwater Management, LID Appendix, for further information.
   c. Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the development. ***Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances.***
   d. 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.

<u>Application of WWHM in Re-development Projects</u>

Redevelopment requirements may allow, for some portions of the redevelopment project area, the predeveloped condition to be modeled as the existing condition rather than forested or pasture condition. For instance, where the replaced impervious areas do not have to be served by updated flow control facilities because area or cost thresholds in KCC12.20.010 are not exceeded. .

C. Pervious and Impervious Land Categories (PERLND and IMPLND Parameter values)

1. In WWHM (and HSPF) pervious land categories are represented by PERLNDs; impervious land categories by IMPLNDs
2. The WWHM provides 16 unique PERLND parameters that describe various hydrologic factors that influence runoff and 4 parameters to represent IMPLND.
3. 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.
4. 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 runoff from a development if there is a reason to believe that groundwater would be surfacing (such where there is a cut in a slope). However, the default condition in WWHM assumes that no groundwater flow from small catchments reaches the surface to become runoff.

APPENDIX 7-B

Procedure for Conducting a Pilot Infiltration Test

The Pilot Infiltration Test (PIT) consists of a relatively large-scale infiltration test to better approximate infiltration rates for design of stormwater infiltration facilities. The PIT reduces some of the scale errors associated with relatively small-scale double ring infiltrometer or "stove-pipe" infiltration tests. It is not a standard test but rather a practical field procedure recommended by Ecology's Technical Advisory Committee.

A. Infiltration Test

1. The horizontal surface area of the bottom of the test pit should be approximately 100 square feet. For small drainages and where water availability is a problem smaller areas may be considered as determined by the site professional. Accurately document the size and geometry of the test pit.
2. Install a vertical measuring rod (minimum 5-ft. long) marked in half-inch increments in the center of the pit bottom.
3. Use a rigid 6-inch diameter pipe with a splash plate on the bottom to convey water to the pit and reduce side-wall erosion or excessive disturbance of the pond bottom. Excessive erosion and bottom disturbance will result in clogging of the infiltration receptor and yield lower than actual infiltration rates.
4. Add water to the pit at a rate that will maintain a water level between 3 and 4 feet above the bottom of the pit. A rotameter can be used to measure the flow rate into the pit.

Note: A water level of 3 to 4 feet provides for easier measurement and flow stabilization control. However, the depth should not exceed the proposed maximum depth of water expected in the completed facility.

6. Every 15-30 min, record the cumulative volume and instantaneous flow rate in gallons per minute necessary to maintain the water level at the same point (between 3 and 4 feet) on the measuring rod.
7. Add water to the pit until one hour after the flow rate into the pit has stabilized (constant flow rate) while maintaining the same pond water level. (usually 17 hours)
8. After the flow rate has stabilized, turn off the water and record the rate of infiltration in inches per hour from the measuring rod data, until the pit is empty.

B. Data Analysis

1. Calculate and record the infiltration rate in inches per hour in 30 minutes or one-hour increments until one hour after the flow has stabilized.

Note: Use statistical/trend analysis to obtain the hourly flow rate when the flow stabilizes. This would be the lowest hourly flow rate.

2. Apply appropriate correction factors for site heterogeneity, anticipated level of maintenance and treatment to determine the site-specific design infiltration rate (see Table 7.3).

C. Example

1. The area of the bottom of the test pit is 8.5-ft. by 11.5-ft.
2. Water flow rate was measured and recorded at intervals ranging from 15 to 30 minutes throughout the test. Between 400 minutes and 1,000 minutes the flow rate stabilized between 10 and 12.5 gallons per minute or 600 to 750 gallons per hour, or an average of (9.8 + 12.3) / 2 = 11.1 inches per hour.
3. Applying a correction factor of 5.5 for gravelly sand in table 6.3 the design long-term infiltration rate becomes 2 inches per hour, anticipating adequate maintenance and pre-treatment.

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