Volume III – Flow Control and Treatment BMPs

Figures

Tables

Chapter 1 - Introduction

This volume of the City's stormwater manual focuses on controlling stormwater with designed and constructed facilities. It gives structural BMPs to address the volume and timing of stormwater flows as well as for the treatment of stormwater flows to remove sediment and other pollutants at developed sites. BMPs for preventing pollution of stormwater runoff (source control BMPs) are presented in Volume IV.

This volume details the City's policies regarding the quantity and quality control of runoff from developed or artificially altered sites. The scope of this chapter includes design criteria and specifications for the construction of runoff quantity and quality control facilities

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

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

- The Washington State Department of Ecology (Ecology) Stormwater Management Manual For Western Washington
- Any Ecology-approved stormwater management manual
- "Applied Handbook of Hydrology," by Chow
- "Handbook of Hydraulics," by E.G. Brater and H.W. King
- "Hydraulics Manual," published by Washington State Department of Transportation (WSDOT)
- "Soil Survey of Snohomish County Area, Washington," published by the Soil Conservation Service, U.S. Department of Agriculture (USDA)
- "Standard Plans for Road, Bridge and Municipal Construction," published by the WSDOT
- The City's Design and Construction Standards and Specifications
- Other information sources acceptable to the City and based on general use by the professional engineering community

The most current edition of all publications shall be used.

Chapter 2 - General Design Criteria for Flow Control and Treatment BMPs

2.1 Introduction

This chapter provides general design requirements that are common to more than one stormwater flow control or treatment BMP. The criteria in this chapter apply in addition to any BMP-specific criteria presented in subsequent chapters of this volume. These requirements relate to:

- Access
- Basins and Ponds
- Berms and Embankments
- Easements
- Fencing
- Landscaping
- Liners
- Maintenance
- Overflows
- Projects with public maintenance of the stormwater facilities (residential plat and short plats)
- Setbacks
- Sites Containing or Adjacent to Critical Areas
- Top Soil
- Underground Facilities

2.2 Access Requirements

Adequate access for maintenance and operation activities must be provided for all stormwater facilities constructed in the City.

2.2.1 General

1. An access road is required to all stormwater facility inlet pipes, control structures, risers and at least one point of each cell or compartment of a stormwater facility.
2. Access roads shall have a minimum width of 15 feet, a maximum slope of 15 percent, and a minimum inside road radius of at least 40 feet.
3. Access roads shall have an all-weather surface of crushed rock or better.
4. A paved apron must be provided where access roads connect to paved public roadways.
5. Manhole and catch basin lids must be in or at the edge of the access road and at least 5 feet from a property line.
6. When the length of an access road exceeds 75 feet, a vehicle turn-around must be provided, and designed to accommodate vehicles having a maximum length of 31 feet and having an inside

wheel path radius of 40 feet. The vehicle turn around requirement may be waived if a completely paved perimeter road is provided and can be used in a continuous drive back to the entrance with no turnarounds.

7. Stormwater facility access roads shall be located in the same tract as facilities, when the facilities themselves are in tracts. When facilities are located in designated open space areas, access roads may be located in the designated open space also, provided that they are constructed so as to be aesthetically compatible with the open space use.

2.2.2 Access to open-air facilities (ponds and basins)

Access Roads

1. Vehicle access to open-air facilities shall be limited to maintenance and operation personnel.
2. Access roads shall be provided to the bottom of **all** cells or compartments of open-air facilities unless all of the following conditions apply:
   a. cell or compartment bottoms are accessible or reachable by track hoes from an access road along the side of the facility; and
   b. a truck can be loaded without the truck accessing the bottom of the cell or compartment (i.e., the cell depth, as measured from the bottom of the cell to the access road surface is less than); and (need number from M&O)
   c. no point in the bottom of the cell or compartment is more than 20 feet from the center of the access road.
3. A perimeter access road may be required by the City for large open-air stormwater facilities in order to provide complete vehicular access to all points of the facility requiring regular maintenance.
4. Perimeter roads may be 12 feet in width where the road is not accessing a structure or being used for a circular loop road in lieu of turn around.

Access Gates or Bollards

1. A minimum of one locking access road gate shall be provided to fenced open-air facilities. Gates must meet WSDOT State Standard Plan L30.10 and may be 14, 16, 18, or 20 feet in width.
2. Access to unfenced open-air facilities shall be limited by removable bollards. Bollards shall consist of two fixed bollards on the outside of the access road and two removable bollards equally spaced between the fixed bollards (or all four removable if placed in the traveled way).
3. Access gates and bollards must be set 20 feet back from the property line when the access road is connecting to a road that is posted at 35 mph or greater.

2.2.3 Access to underground facilities (vaults and tanks)

General access requirements

1. Access roads shall be provided to all underground facilities (other than catch basins with solid locking lids located downstream of detention facilities).
2. Access openings shall be provided over all inlet pipes and outlet structures. Pipe inlets and outlet structures shall be visible from the rim of the access opening.
3. Access openings shall be positioned a maximum of 50 feet from any location within a tank or a vault. Additional access points may be needed on large tanks or vaults.

4. The maximum depth from finished grade to vault bottom or tank invert shall be 20 feet.
5. Ladders and hand-holds shall be provided at the outlet structure and inlet pipes and as needed to meet OSHA confined space requirements.
6. All access openings, except those covered by removable panels/access doors, shall have round, solid locking lids per City standards, or 3-foot square, locking diamond plate covers.
7. Rim elevations must match the finished grade.

Ventilation requirements

1. Ventilation pipes (minimum 12-inch diameter or equivalent) must be provided in all four corners of vaults and at each end of tanks to allow for artificial ventilation prior to entry of maintenance personnel into the vault.
2. Vaults and tanks providing manhole access at 12-foot spacing need not provide corner/end ventilation pipes as specified above.
3. Vaults and tanks must comply with the Occupational Safety and Health Administration (OSHA) confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid

Access criteria specific to vaults:

1. If more than one "V" is provided in the vault floor, access to each end of each "V" must be provided.
2. For vaults with greater than 1,250 square feet of floor area, a 5 x 10-foot 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.
3. Internal structural walls of large detention 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.
4. The minimum internal height of vaults must be 7 feet from the highest point of the vault floor (not sump), and the minimum width must be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. Also the minimum internal height requirement may not be needed for any areas covered by removable panels.

Access criteria specific to tanks

1. A 36-inch minimum diameter CMP riser-type manhole of the same gage as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.

2.3 Berm and Embankment Requirements

2.3.1 General

Stormwater facility berms and embankments shall satisfy the following criteria:

1. Pond berm embankments shall be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report), which is free of loose surface soil materials, roots and other organic debris.

2. Pond berm embankments shall be constructed by excavating a “key” equal to 50 percent of the berm embankment cross-sectional height and width (except on till soils where the “key” minimum depth can be reduced to 1 foot of excavation into the till).
3. Pond berm embankment cores shall be constructed of compacted soil (a minimum of 95 percent of the maximum dry density, standard proctor method per American Society for Testing and Materials [ASTM] D1557) placed in 6-inch lifts, with the following soil characteristics per the USDA’s textural triangle: a minimum of 30 percent clay, a maximum of 60 percent sand, a maximum of 60 percent silt, with nominal gravel and cobble content or as recommended by a geotechnical engineer. The core shall be adequate to make the embankment impervious.
4. Exposed earth on the pond side slopes and berms shall be sodded or seeded with appropriate seed mixture (see Volume II, Erosion and Sedimentation Control BMPs). Establishment of protective vegetative cover shall be ensured with appropriate surface protection BMPs and reseeded as necessary.
5. Where maintenance access is provided along the top of the berm, the minimum width of the top of the berm shall be 15 feet.
6. Pond berm embankments greater than 6 feet in height shall require a design by a qualified professional engineer licensed in the State of Washington. Berm embankment width shall vary as recommended by the professional engineer.
7. Embankments less than 6 feet in height shall have a minimum 6-foot top width unless otherwise recommended by a qualified professional engineer licensed in the State of Washington.
8. Embankments adjacent to a stream or other body of water shall be sufficiently protected with riprap or bioengineering methods to prevent erosion of the pond embankment. Other control measures may be necessary to protect the embankment.
9. Anti-seepage filter-drain diaphragms must be placed on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Dam Safety Guidelines, Part IV, Section 3.3.B 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/dss.html>.

2.3.2 Side Slopes

1. Interior earthen side slopes up to the emergency overflow water surface shall not be steeper than 3H:1V.
2. Exterior side slopes for grassed embankments shall be at least 3:1 to facilitate mowing.
3. Exterior side slopes shall not be steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.
4. Pond walls may be vertical retaining walls provided the following:
    a. the walls are designed by a geotechnical engineer or licensed civil engineer with structural expertise;
    b. a fence is provided along the top of the wall;
    c. an access ramp to the bottom of the pond is provided.

2.3.3 Dam Safety

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

In addition to the hydrologic and hydraulic issues related to precipitation and runoff, other dam safety requirements include geotechnical issues, construction inspection and documentation, dam breach analysis, inundation mapping, emergency action planning, and periodic inspections by project owners and by dam safety engineers.

It is recommended that Ecology's Dam Safety Section be contacted early in the facilities planning process. Electronic versions of the guidance documents in PDF format are available on Ecology's Web site at: <http://www.ecy.wa.gov/programs/wr/dams/dss.html>.

2.4 Easement Requirements

1. A drainage easement with a minimum width of 15 feet shall be provided for publicly maintained open channels, closed drainage systems, and from established city streets to a stormwater facility.
2. Storm drain pipes installed in public easements shall be constructed in the center of the easement, as nearly as possible, but in no case shall the pipe be within five feet of any structure or property line.
3. No structures shall be erected within any public drainage easement. Construction of a fence across a public easement is allowed provided a 15-foot wide access gate is provided.
4. All public easements, except for special circumstances, shall be located to run within single lots rather than being split by a lot line.
5. All man-made drainage facilities and conveyances and all natural channels (on the project site) used for conveyance of altered flows due to development shall be located within easements or dedicated tracts as required by the City. Easements shall contain the natural features and facilities and shall allow City access for purposes of inspection, maintenance, repair or replacement, flood control, water quality monitoring, and other activities permitted by law.
6. All drainage facilities such as detention or retention ponds or infiltration systems to be maintained by the City shall be located in separate tracts dedicated to the City. Conveyance systems can be in easements.
7. Drainage facilities that are designed to function as multi-use recreational facilities shall be located in separate tracts or in designated open space and shall be privately maintained and owned, unless dedicated to and accepted by the City.
8. All publicly and privately maintained conveyance systems shall be located in dedicated tracts, drainage easements, or public rights-of-way in accordance with this manual. Exceptions are roof downspout, minor yard, and footing drains unless they serve other adjacent properties.
9. Any new conveyance system located on private property designed to convey drainage from other private properties must be located in a private drainage easement granted to the contributors of stormwater to the systems to convey surface and stormwater and to permit access for maintenance or replacement in the case of failure.
10. All drainage tracts and easements, public and private, must have a minimum width of 15 feet.
11. All pipes and channels must be located within the easement so that each pipe face or top edge of channel is no closer than 5 feet from its adjacent easement boundary.

12. Pipes greater than 5 feet in diameter and channels with top widths greater than 5 feet shall be placed in easements adjusted accordingly so as to meet the required dimensions from the easement boundaries.

2.5 Fencing Requirements

1. Surface ponds and infiltration basins with a maximum depth of three feet or less do not require fencing provided the maximum associated interior side slope of the pond does not exceed 3H:1V (including baffle side slopes).
2. All ponds and basins with a maximum design depth of water greater than three feet will require a six foot high perimeter fence unless one of the following conditions is met:
    a. The facility is designed and constructed with a 10 foot wide safety bench for every three feet of depth, and no more than 10% of the interior side slopes are greater than 3H:1V (including baffle side slopes); or
    b. The facility is designed and constructed so that the maximum water depth of the facility does not exceed three feet during a 2 year recurrence interval event, nor exceed three feet during a 25 year recurrence interval event, and no more than 10% of the interior side slopes exceed 3H:1V (including baffle side slopes); or
    c. The City Council reviews a proposed facility designed and approved by a licensed engineer or architect which meets neither the requirements of a or b herein and exercising its discretion makes a policy determination that either no fencing will be required or fencing less than six feet in height will be required. Issues considered by the Council when making this determination include but are not limited to: (1) reasons why the proponent does not want to construct a fence six feet in height; (2) purpose(s) the facility is to serve; (3) design considerations of the facility; (4) safety considerations of the facility without the fencing or with fencing reduced in height; and (5) such additional issues as the Council feels are appropriate.
3. When fencing is required around a facility to be dedicated to and/or maintained by the City, the fence shall be a chain link fence. The chain link fabric shall be galvanized steel core wire and, when the facility is in a visible location, shall be coated with bonded polyvinyl. The polyvinyl coating shall not be subject to fading, cracking, peeling, or shrinkage and shall be brown, black, or some shade of natural green (such as pine, forest, or olive). The fence manufacturer shall provide a 10 year (minimum) warranty on polyvinyl coating. All posts, cross bars, rails, fasteners, and gates shall be powder-coated the same color as the chain link fence fabric.
4. Fencing slats will be allowed, subject to the same color restrictions as the polyvinyl coating, if the slats proposed are non-brittle, crack-resistant, "locked in place" in a bottom retaining channel, and non-fading.
5. The chain link fence shall meet all other applicable specifications for Type I or Type 3 chain link fence as set forth in the most current edition of the Standard Specifications for Road, Bridge, and Municipal Construction (Washington State Department of Transportation, American Public Works Association), except that line posts for Type 3 fence shall be set in concrete.
6. Fencing of tracts within the clear zone of roads with design speeds of 35 mph or higher shall use WSDOT Type 3 chain link fence.
7. Other regulations such as the International Building Code (IBC) may require fencing of vertical walls.
8. For metal baluster fences, IBC standards apply.

2.6 Landscaping/Planting Requirements

Planting Requirements

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

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.

The following guidelines shall 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, shall be avoided within 50 feet of pipes or manmade structures.
2. No trees may be planted 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

   Note: The internal berm in a wet pond is not subject to this planting restriction since the failure of an internal berm would be unlikely to create a safety problem.
3. All landscape material, including grass, shall 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. Refer to Chapter 12 of this volume for more information.
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 be evenly spaced.
6. Any landscaped islands shall be a minimum of 6 feet apart, and if set back from fences or other barriers, the setback distance shall also be a minimum of 6 feet. Where tree foliage extends low to the ground, the 6-foot setback shall be counted from the outer drip line of the trees (estimated at maturity). This setback allows a 6-foot wide mower to pass around and between clumps.
7. Tree clumps should be under planted with shade-tolerant shrubs and groundcover plants. The goal is to provide a dense understory that need not be weeded or mowed.
8. Deciduous trees must be set back so that branches do not extend over the pond (to prevent leaf-drop into the water).
9. Native, drought tolerant species are recommended.
10. The remaining site area shall be planted with an appropriate grass seed mix, which may include meadow or wildflower species. Native or dwarf grass mixes are preferred. Table 2.1 below gives an example of a dwarf grass mix developed for central Puget Sound. Grass seed should be applied at 2.5 to 3 pounds per 1,000 square feet. See also Volume II, Chapter 3.2.7.

Table 2.1 Stormwater Tract "Low Grow" Seed Mix.

Seed Name	% by Weight
Dwarf tall fescue	45%
Dwarf perennial rye "Barclay"*	30%
Red fescue	20%
Colonial bentgrass	5%

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

2.7 Liner Requirements

Liners are intended to reduce the likelihood that pollutants in stormwater will reach groundwater when runoff treatment facilities are constructed. In addition to groundwater protection considerations, some facility types require permanent water for proper functioning. An example is the first cell of a wet pond.

Treatment liners amend the soil with materials that treat stormwater before it reaches more freely draining soils. They have slow rates of infiltration, generally less than 2.4 inches per hour (1.7×10^{-3} centimeters squared), but not as slow as low permeability liners. Treatment liners may use in-place native soils or imported soils.

Low permeability liners reduce infiltration to a very slow rate, generally less than 0.02 inches per hour (1.4×10^{-5} centimeters squared). These types of liners are used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff, or where infiltration is not recommended due to site limitations. Low permeability liners may be fashioned from compacted till, clay, geomembrane, or concrete.

2.7.1 General Design Criteria for Liners

1. Table 2.2 shows the type of liner required for use with various runoff treatment facilities. Other liner configurations may be used with prior approval from the City.
2. Liners shall be evenly placed over the bottom and/or sides of the treatment area of the facility as indicated in Table 2.2. Areas above the treatment volumes that are required to pass flows greater than the water quality treatment flow (or volume) need not be lined. However, the lining must be extended to the top of the interior side slope and anchored if it cannot be permanently secured by other means.
3. For low permeability liners, the following criteria apply:
    a. Where the seasonal high groundwater elevation is likely to contact a low permeability liner, liner buoyancy may be a concern. In these instances, the use of a low permeability liner shall be evaluated and recommended by a geotechnical engineer.
    b. Where grass must be planted over a low permeability liner per the facility design, a minimum of 6 inches of good topsoil or compost-amended native soil (2 inches compost tilled into 6 inches of native till soil) must be placed over the liner in the area to be planted. Twelve inches of cover is preferred.
4. If a treatment liner will be below the seasonal high water level, the pollutant removal performance of the liner and facility must be evaluated by a geotechnical or groundwater specialist and found to be as protective as if the liner and facility were above the level of the groundwater.

Table 2.2 Lining Types Required for Runoff Treatment Facilities.

Water Quality Facility	Area to be Lined	Type of Liner Required
Presettling basin	Bottom and sides	Low permeability liner or Treatment liner (If the basin will intercept the seasonal high groundwater table, a treatment liner may be recommended.)
Wet pond	First cell: bottom and sides to water quality design water surface --- Second cell: bottom and sides to water quality design water surface	Low permeability liner or Treatment liner --- Treatment liner
Combined detention/water quality facility	First cell: bottom and sides to water quality design water surface --- Second cell: bottom and sides to water quality design water surface	Low permeability liner or Treatment liner --- Treatment liner
Stormwater wetland	Bottom and sides, both cells	Low permeability liner
Sand filtration basin	Basin sides only	Treatment liner
Sand filter vault	Not applicable	No liner needed
Linear sand filter	Not applicable if in vault Bottom and sides of presettling cell if not in vault	No liner needed Low permeability or treatment liner
Media filter (in vault)	Not applicable	No liner needed
Wet vault	Not applicable	No liner needed

2.7.2 Design Criteria for Treatment Liners

1. A 2-foot thick layer of soil with a minimum organic content of 5 percent AND a minimum cation exchange capacity (CEC) of 5 milliequivalents/100 grams can be used as a treatment layer beneath a water quality or detention facility.
2. To demonstrate that in-place soils meet the above criteria, one sample per 1,000 square feet of facility area shall be tested. Each sample shall be a composite of sub samples taken throughout the depth of the treatment layer (usually 2 to 6-feet below the expected facility invert).
3. Typically, side wall seepage is not a concern if the seepage flows through the same stratum as the bottom of the treatment BMP. However, if the treatment soil is an engineered soil or has very low permeability, the potential to bypass the treatment soil through the side walls may be significant. In those cases, the treatment BMP side walls shall be lined with at least 18 inches of treatment soil, as described above, to prevent untreated seepage. This lesser soil thickness is based on unsaturated flow as a result of alternating wet-dry periods.
4. Organic content shall be measured on a dry weight basis using American Society for Testing and Materials (ASTM) D2974.
5. CEC shall be tested using U.S. Environmental Protection Agency (U.S. EPA) laboratory method 9081.

6. A soils testing laboratory must certify that imported soil meets the organic content and CEC criteria above and certification shall be provided to the City.
7. Animal manures used in treatment soil layers must be sterilized because of potential for bacterial contamination of the groundwater.

2.7.3 Design Criteria for Low Permeability Liners

This section presents the design criteria for each of the following four low permeability liner options: compacted till liners, clay liners, geomembrane liners, and concrete liners.

Compacted Till Liners

1. Liner thickness shall be 18 inches after compaction.
2. Soil shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
3. A different depth and density sufficient to retard the infiltration rate to 2.4 x 10^{-5} inches per minute (1 x 10^{-6} centimeters squared) may also be used instead of Criteria 1 and 2.
4. Soil shall be placed in 6-inch lifts.
5. Soils shall be used that meet the gradation in Table 2.3 below:

Table 2.3 Compacted Till Liners.

Sieve Size	Percent Passing
6-inch	100
4-inch	90
#4	70 - 100
#200	20

Clay Liners

1. Liner thickness shall be a minimum of 12 inches.
2. Clay shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
3. A different depth and density sufficient to retard the infiltration rate to 2.4 x 10^{-5} inches per minute (1 x 10^{-6} centimeters squared) may also be used instead of the above criteria.
4. Plasticity index shall not be less than 15 percent (ASTM D-423, D-424).
5. Liquid limit of clay shall not be less than 30 percent (ASTM D-2216).
6. Clay particles passing shall not be less than 30 percent (ASTM D-422).
7. The slope of clay liners must be restricted to 3H:1V for all areas requiring soil cover; otherwise, the soil layer must be stabilized by another method so that soil slippage into the facility does not occur. Any alternative soil stabilization method must take maintenance access into consideration.
8. Where clay liners form the sides of ponds, the interior side slope shall not be steeper than 3H:1V, irrespective of fencing.

Table 2.4 Clay Liner Specifications.

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	1×10^{-6} max.
Plasticity Index of Clay	ASTM D-423 and D-424	percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	percent	Not less than 30
Clay Particles Passing	ASTM D-422	percent	Not less than 30
Clay Compaction	ASTM D-2216	percent	95 percent of Standard Proctor Density

Source: City of Austin, 1988

Geomembrane Liners

1. Geomembrane liners shall be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils shall be used in areas of maintenance access or where heavy machinery must be operated over the membrane.
2. The geomembrane fabric shall be protected from puncture, tearing, and abrasion by installing geotextile fabric, determined to have a high survivability per the WSDOT standard specifications as amended, specifically Section 9-33 Construction Geotextile (2006 or the latest version as amended),on the top and bottom of the geomembrane. Equivalent methods for protection of the geomembrane liner will be considered. Equivalency will be judged on the basis of ability to protect the geomembrane from puncture, tearing, and abrasion.
3. Geomembranes shall be bedded according to the manufacturer's recommendations.
4. Liners must be covered with 12 inches of top dressing forming the bottom and sides of the water quality facility, except for linear sand filters. Top dressing shall consist of 6 inches of crushed rock covered with 6 inches of native soil. The rock layer is to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, 12 inches of native soil may be used if orange plastic “safety fencing” or another highly visible, continuous marker is embedded 6 inches above the membrane.
5. If possible, liners should be of a contrasting color so that maintenance workers are aware of any areas where a liner may have become exposed when maintaining the facility.
6. Geomembrane liners shall not be used on slopes steeper than 5H:1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

Table 2.5 Geotextile Properties for Impermeable Liner Protection

Geotextile Property	Test Method	Geotextile Property Requirements[1]
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	250 lbs min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	>50 percent

Geotextile Property	Test Method	Geotextile Property Requirements[1]
Seam Breaking Strength (if seams are present)	ASTM D4632 and ASTM D4884 (adapted for grab test)	220 lbs min.
Puncture Resistance	ASTM D4833	125 lbs min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	90 lbs min.
Ultraviolet (UV) Radiation	ASTM D4355	50 percent strength stability retained min., after 500 hrs. in weatherometer
AOS	ASTM D4751	0.43 mm max. (#40 sieve)
Water Permittivity	ASTM D4491	0.5 sec -1 min.

[1] All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

Concrete Liners

1. Concrete liners may also be used for sedimentation chambers and for sedimentation and filtration basins less than 1,000 square feet in area. Concrete shall be 5-inch thick Class 3000 or better and shall be reinforced by steel wire mesh. The steel wire mesh shall be six (6) gage wire or larger and 6 inch by 6 inch mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete shall have a minimum 6 inch compacted aggregate base consisting of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch. Where visible, the concrete shall be inspected annually and all cracks shall be sealed.
2. Portland cement liners are allowed irrespective of facility size, and shotcrete may be used on slopes. However, specifications must be developed by a professional engineer who certifies the liner against cracking or losing water retention ability under expected conditions of operation, including facility maintenance operations. Weight of maintenance equipment can be up to 80,000 pounds when fully loaded.
3. Asphalt concrete may not be used for liners due to its permeability to many organic pollutants.
4. If grass is to be grown over a concrete liner, slopes must be no steeper than 5H: 1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

2.8 Maintenance Requirements

1. Adequate provisions to facilitate maintenance operations must be included in the design of all stormwater facilities. Provisions must be made for regular and perpetual maintenance of the facility, including replacement and/or reconstruction of any media that are relied upon for treatment purposes. The maintenance checklists in Appendix F shall be used to identify required maintenance for specific BMPs.
2. Any standing water removed during maintenance operations must be disposed of to an approved discharge location. Discharge to a sanitary sewer at an approved discharge location may be an option. The City of Everett must be contacted prior to any discharge. Residuals must be

disposed of in accordance with state and local solid waste regulations (see Minimum Functional Standards for Solid Waste Handling, Chapter 173-304 WAC).

3. The maintenance of drainage facilities associated with commercial, industrial, planned residential development, and multi-family development is the responsibility of the owner(s) of the development.

4. The City generally assumes the operation and maintenance of drainage facilities constructed in connection with residential subdivision of land in the City, after the expiration of a two-year operation and maintenance period, if the following conditions have been met:

   a. All of the requirements of Section 14.28.090 of the Everett Municipal Code have been fully complied with; and

   b. The facilities have been inspected and accepted by the utility division of the Public Works department after two years of operation and maintenance in accordance with City maintenance standards; and

   c. All deeds conveying drainage tracts and necessary easements entitling the City to properly maintain the facilities have been conveyed to the City and recorded with the Snohomish County auditor; and

   d. The warranty bond required in subsection D of Section 14.28.090 of the Everett Municipal Code has been extended for one year, covering the City's first year of operation and maintenance; and

   e. The developer has supplied to the City an accounting of capital construction, operation and maintenance expenses, or other items, for the drainage facilities to the end of the two-year period.

2.9 Overflow Requirements

1. A minimum of 1 foot of freeboard is required when establishing the design ponded water depth. Freeboard is measured from the rim of the facility to the maximum ponding level or from the rim down to the overflow point if an overflow or a spillway is included.

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

3. 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 when used as a secondary inlet. *Note: The maximum circumferential length of this opening must not exceed one-half the control structure circumference.* A “birdcage” overflow structure may also be used as a secondary inlet.

100-year Overflow Conveyance

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

Emergency Overflow Spillway Requirements

1. For impoundments less than 10 acre-feet, ponds must have an emergency overflow spillway that is sized to pass the 100-year recurrence interval developed peak flow in the event of total control structure failure (e.g., blockage of the control structure outlet pipe) or extreme inflows. Emergency overflow spillways are intended to control the location of pond overtopping and direct overflows back into the downstream conveyance system or other acceptable discharge point.
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". The emergency overflow structure must be designed to pass the 100-year recurrence interval developed peak flow, with a minimum 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point.
3. The emergency overflow spillway must be armored with riprap in conformance with Chapter 6.6 of Volume I. The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system.

Emergency Overflow Spillway Capacity.

Emergency overflow spillway designs must be analyzed as broad-crested trapezoidal weirs in accordance with the following equations.

The **broad-crested weir equation** for the spillway section would be:

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

where:

Q_{100} = peak flow for the 100-year recurrence interval runoff event (cubic feet per second)

C = discharge coefficient (0.6)

G = gravity (32.2 ft/sec^2)

L = length of weir (ft)

H = height of water over weir (ft)

θ = angle of side slopes

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

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

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

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

Minimum length shall be 6 feet.

2.10 Projects with public maintenance of the stormwater facilities

Storm facilities in rights-of-way, public easements, and those associated with residential subdivisions or any other development where the City will undertake maintenance of the facility, may have special restrictions regarding materials used and/or design criteria for open-air systems. Specific restrictions/criteria applying to this type of development include, but may not be limited to, the following:

1. Corrugated metal pipe may not be used in storm drainage systems, including detention pipes and wet tanks, unless otherwise approved by the City Engineer.
2. All stormwater detention and deep dead storage (deeper than 2.5 feet) shall be provided in underground, covered systems unless otherwise approved by the City Engineer. Only shallow vegetated storage, infiltration basins, and sand filter basins shall generally be allowed as open-air systems. Retaining walls associated with these open-air facilities shall not exceed three feet in height and side slopes shall not exceed 3:1 (H:V).
3. Open-air stormwater facilities (such as wetponds, infiltration basins, and sand filter basins) providing runoff control for residential subdivisions or any other development where the City will undertake maintenance of the facilities shall be dedicated in a separate tract to the City of Everett. The tract dedicated shall include, at a minimum, all area within the high water mark, and may be required to include any required access roads or paths associated with the facilities.
4. The City may require an area 10 feet wide, as measured from the high water mark, to be provided around the perimeter of an open-air runoff control facility and included in a tract held in common ownership, with an easement granted to the City. The City strongly encourages landscaping of this area by the developer to provide screening for the pond and an aesthetically pleasing appearance. Maintenance and irrigation of the landscaping shall be provided as necessary to ensure successful plant establishment.
5. At a minimum, an area five feet wide must be available to the City for maintenance of any fencing associated with stormwater management facilities. This area must be provided around the perimeter of the fence, on both sides. If this area is not contained within the dedicated drainage tract, then an easement must be granted to the City.
6. The developer shall establish appropriate vegetation in the entire dedicated right-of-way.

2.11 Setbacks

1. All wet pool, detention and infiltrating facilities shall maintain minimum setback distances as follows. All setbacks shall be horizontal unless otherwise specified:
    a. 1 foot positive vertical clearance from any open water maximum surface elevation to structures within 25 feet.
    b. 10 feet from the open water maximum surface elevation or edge of the stormwater facility to property lines and on-site structures.
    c. 50 feet from top of slopes greater than 20 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.
    d. 10 feet from open water maximum surface elevation or edge of stormwater facility to a sanitary sewer main or service.
    e. 50 feet from any septic tank, holding tank, containment vessel, pump chamber, and distribution box.

2. Infiltrating facilities shall maintain the following additional setbacks:
    a. 100 feet from the edge of a septic tank, drain field and drain field reserve area.
    b. 100 feet from drinking water wells and springs used for public drinking water supplies. Infiltration facilities up-gradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Health Department requirements (Washington Wellhead Protection Program, DOH, 12/93).
3. All underground stormwater facilities shall be setback from any structure or property line a distance equal to the depth of the ground disturbed in setting the structure.
4. A geotechnical analysis and report must be prepared for work located within 300 feet of the top of landslide or erosion hazard areas (as defined in Title 19, Chapter 37 of the Everett Municipal Code). The scope of the geotechnical report shall include an assessment of impoundment seepage on the stability of the hazard area.

2.12 Sites Containing or Adjacent to Critical Areas

Environmentally sensitive areas shall be protected and impacts mitigated in accordance with the City's Zoning Code requirements, this manual, and the conditions of final SEPA approval.

2.13 Topsoil

Topsoil used in constructing runoff control facilities shall be free from materials toxic to plant growth, noxious weeds, rhizomes, roots, subsoil, stones, and other debris and shall generally consist of a sandy clay loam, sandy loam, loam, clay loam, silty clay loam, or silt loam soil or mix. The mix may not be more than 50% sand or 20% clay. Total organic matter shall be 1% to 10%. A maximum of 20% of the mix volume may be retained on a 1/4 inch sieve and 100% of the topsoil shall pass through a 1/2 inch sieve.

2.14 Underground structures

1. Tanks and vaults must meet structural requirements for overburden support and vactor truck loading.
2. Tanks and vaults must be placed on stable, well consolidated native material with suitable bedding. Tanks and vaults must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.
3. 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.
4. Tank end plates must be designed for structural stability at maximum hydrostatic loading conditions.

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.

Materials.

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

Chapter 3 - Detention Facilities

3.1 Introduction

This chapter presents design criteria specific to detention facilities. These facilities provide for the temporary storage of stormwater runoff pursuant to the performance standards set forth in Minimum Requirement #7 for flow control (Volume I).

Design guidelines for outflow control structures are specified in Volume I, Chapter 6 .

There are three primary types of detention facilities described in this chapter: detention ponds, tanks, and vaults. Standard details for detention facilities and key detention facility structures are provided in the 400 series of the City's Design and Construction Standards and Specifications (DCSS).

***NOTE:* The specific requirements and design criteria given in this chapter are in addition to applicable BMP requirements from Chapter 2. Chapter 2 addresses requirements that are common to more than one BMP, such as access, maintenance, berms and embankments, etc.**

3.2 Detention BMPs

3.2.1 Detention Pond Design

General Design Criteria

1. Ponds must be designed as flow-through systems. 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 must be level and be located a minimum of 0.5 foot (preferably 1 foot) below the inlet and outlet to provide sediment storage.
3. Drainage facilities should be made attractive features of the urban environment. To this end, engineers are encouraged to be creative in shaping and landscaping facilities and to consider aesthetics when choosing alternatives for parking lot paving, conveyance systems, detention facilities, weirs, structures, etc.

3.2.2 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Detention tanks may not be perforated to provide infiltration of stormwater.

General Design Criteria

1. Tanks may be designed as flow-through systems with manholes in line to promote sediment removal and to facilitate maintenance. Tanks may also be designed as back-up systems if preceded by runoff treatment facilities, since little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank.
2. The detention tank bottom must be located 0.5 feet below the inlet and out elevations to provide dead storage for sediment, without compromising the ability to remove sediment from the facility.
3. The minimum pipe diameter for a detention tank is 36 inches.
4. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe.

5. Tanks shall not be located under the travel way in public rights of way. For single-family plats and planned urban developments (PUDs), planned residential developments, or planning and development districts, detention tanks shall be located in separate tracts.

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

Pipe material, joints, and protective treatment for tanks shall be in accordance with the City's Design and Construction Standards and Specifications.

3.2.3 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. Detention vaults may not be perforated to provide infiltration of stormwater.

General Design Criteria

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

Chapter 4 - Presettling Facilities

4.1 Introduction

This chapter presents the methods that may be used to provide presettling of solids prior to sediment sensitive BMPs. Presettlement must be provided in the following applications:

- For infiltration and for sand and media filtration BMPs, in order to protect them from excessive siltation and debris
- Where the basic treatment facility or the receiving water may be adversely affected by non-targeted pollutants (e.g., oil), or may by overwhelmed by a heavy load of targeted pollutants (e.g., suspended solids).

4.2 Presettling BMPs

The requirement for presettling may be met by any of the following:

- A runoff treatment facility from the Basic Treatment Menu (see Table 4.4 of Volume I).
- A detention system designed to meet the flow control requirements
- An Ecology approved and City accepted pretreatment technology (see Chapter 13)
- A presettling facility, which may be integrated as the first cell of the filtration facility and is described below.

4.2.1 BMP 4.10 Presettling Basins, Vaults, or Tanks

A presettling facility provides pretreatment of runoff in order to remove suspended solids, which can impact other runoff treatment BMPs. Acceptable presettling facilities in the City include presettling basins, tanks, and vaults.

Runoff treated by a presettling facility may not be discharged directly to a receiving water or to groundwater; it must be further treated by a basic or enhanced runoff treatment BMP.

General Design criteria for presettling basins, vaults or tanks

Presettling facilities shall meet the applicable wetpool facility requirement (e.g., wet pond, wet vault, or wet tank) except as modified by the following:

1. A wetpool volume of at least 30 percent of the total water quality treatment design volume shall be provided.
2. If the runoff in the presettling facility will be in direct contact with the soil, the presettling facility shall be lined with an impermeable liner meeting the requirement in Chapter 2.7.
3. The length-to-width ratio shall be at least 3:1. Berms or baffles may be used to lengthen the flowpath.
4. The minimum depth shall be 4 feet, including one foot of sediment storage
5. The maximum depth shall be 6 feet.
6. Inlets and outlets shall be designed to minimize velocity and reduce turbulence.
7. Inlet and outlet structures shall be located to maximize particle-settling opportunities.

Chapter 5 - Sand Filtration Treatment Facilities

5.1 Introduction

This chapter presents criteria for the design and construction of runoff treatment sand filters including basin, vault, and linear filters.

Three BMPs are discussed in this chapter:

- BMP 5.10 Sand Filter Basin
- BMP 5.20 Sand Filter Vault
- BMP 5.30 Linear Sand Filter.

5.2 General Requirements for Sand Filters

Sand filters shall be sized using an approved continuous simulation hydrologic model (see Volume I, Chapter 5). Basic sand filters must capture and treat 91 percent of the total runoff volume; large sand filters must capture and treat 95 percent of the total runoff volume. Only 9 percent of the total runoff volume may bypass or overflow from a basic sand filter facility; 5% for large sand filters. The sand filter design rate shall be that flow rate which results in the above percentages of total runoff volume being treated.

Inlet bypass and flow spreading structures (e.g., flow spreaders, weirs or multiple orifice openings) shall be designed to capture the applicable design flow rate, minimize turbulence, and to spread the flow uniformly across the surface of the sand filter. Stone riprap or other energy dissipation devices shall be installed to prevent gouging of the sand medium and to promote uniform flow.

Overflow requirements must be met (see Chapter 2.9).

In an off-line system, a diversion structure shall be installed to divert the design flow rate into the sediment chamber and bypass the remaining flow to detention/retention (if necessary to meet Minimum Requirement #7), or to surface water.

Design Assumptions

A hydraulic conductivity of 1 inch per hour shall be used in the sand filter design. The depth of the sand bed shall be 18 inches.

Pretreatment Requirements

Filtration facilities are particularly susceptible to clogging. Therefore, presettling must be provided before stormwater enters a filtration facility. See Chapter 4 for presettling facilities.

Floatable trash and debris must be removed before flows reach the sand bed. This requirement may be met by providing a catch basin with a capped riser on the inlet to the sand filter.

For high-use sites, sand filters must be preceded by oil control.

Sequencing with detention systems

Sequencing requirements of sand filters and detention facilities are as follows:

- ***On-line*** sand filters must NOT be placed ***upstream*** of a detention facility. This requirement helps to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants.

- ***On-line*** sand filters placed ***downstream*** of a detention facility must be sized to filter the design water quality volume.
- ***Off-line*** sand filters placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the sand filter design flow rate to the sand filter. The sand filter shall be sized to filter all the runoff sent to it (no overflows from the treatment facility shall occur). Note that WWHM allows any bypasses and the runoff filtered through the sand to be directed to the downstream detention facility.
- ***Off-line*** sand filters placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 2-year recurrence interval flow from the detention facility to the treatment facility. The treatment facility shall be sized to filter all the runoff sent to it (no overflows from the treatment facility shall occur).

Inlet Systems

1. Inlet flow distribution shall be optimized and shall create minimal sand bed disturbance. Any flow distribution system must retain any pretreatment dead storage volume provided in a presettling cell, minimize turbulence within the sand filtration cell, and be readily maintainable.
2. If an inlet pipe and manifold system is used, the minimum pipe size shall be 8 inches. Multiple inlets are recommended to minimize turbulence and reduce local flow velocities.
3. Erosion protection must be provided along the first foot of the sand bed adjacent to a flow spreader. Geotextile fabric secured on the surface of the sand bed, or equivalent method, may be used.

Underdrain systems

1. An underdrain system is required for sand filters. Acceptable underdrain systems include a central longitudinal collector pipe (for installations less than 30 feet wide), a central longitudinal collector pipe with lateral feeder pipes, and longitudinal feeder pipes, with a lateral collector pipe at the outlet end.
2. The maximum distance between feeder pipes or the edge of the facility shall be 15 feet. Geotextile drains may be used in place of feeder pipes.
3. All collector pipes shall have a minimum slope of 0.5 percent, with an invert outlet above the seasonal high groundwater level.
4. Cleanouts with water-tight caps and valve boxes (for access) shall be provided at each end of the main collector pipe and shall extend to the surface of the filter.
5. At least 8 inches of drain rock shall be maintained over, and 6 inches on each side of, all underdrain piping to prevent damage by heavy equipment during maintenance.
6. A geotextile fabric shall be used between the sand layer and the drain rock and shall be placed so that one inch of drain rock is above the fabric.
7. If the sand filter is located upstream of detention, then underdrain piping shall be sized to handle double the two-year return frequency flow.
8. If the sand filter is located downstream of detention, then the underdrain piping shall be sized for the two-year return frequency flow.
9. A minimum of one (1) foot of hydraulic head shall be provided above the invert of the upstream end of the collector pipe.

Material Specifications

1. Drain rock shall be ***clean*** 0.75-1.5 inch rock or gravel backfill, washed and free of any clay or organic material.
2. The sand in a filter must consist of a medium sand meeting the size gradation (by weight) given in Table 5.1. The contractor must obtain a grain size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met. (*Note: Standard backfill for sand drains, Wa. Std. Spec. 9-03.13, does **not** meet this specification and must not be used for sand filters*).
3. Underdrain pipes shall be perforated PVC, SDR 35 (or approved equal), with a minimum diameter of 6 inches. The pipe shall have two rows of ½-inch holes, with the rows spaced 120 degrees apart. Holes shall be spaced a maximum of 6 inches apart longitudinally. The pipe shall be laid with the holes located downward
4. Geotextile with the properties in Table 5.2 shall be used in sand filter design, between the sand filter bed and the drain rock.

Table 5.1 Sand Media Specification.

U.S. Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Source: King County Surface Water Design Manual, January 2009

Table 5.2 Geotextile Property Requirements for Sand Filter Design[1]

Geotextile Property	Test Method	Value
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	250 lbs/160 lbs min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	<50 percent/>50 percent
Seam Breaking Strength (if seams are present)	ASTM D4632	220 lbs/140 lbs min.
Puncture Resistance	ASTM D4833	80 lbs/50 lbs min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	80 lbs/50 lbs min.
Ultraviolet (UV) Radiation stability	ASTM D4355	50 percent strength retained min., after 500 hrs. in weatherometer
AOS	ASTM D4751	0.18 mm max. (#80 sieve)
Water Permittivity	ASTM D4491	0.3 sec -1 min.

[1] All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

5.3 Construction Criteria

1. Sand filtration systems may not be operated and no surface runoff shall be permitted to enter the system until all project improvements are completed which produce surface runoff and all exposed ground surfaces are stabilized by revegetation or by landscaping.
2. Construction runoff may be routed to a presettling facility, but the discharge shall by-pass downstream sand filters
3. Careful level placement of the sand is necessary to avoid formation of voids within the sand that could lead to short-circuiting (particularly around penetrations for underdrain cleanouts), and to prevent damage to the underlying geomembranes and underdrain system.
4. Over-compaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 psig or less). After the sand layer is placed, water settling is recommended by flooding the sand with 10 to 15 gallons of water per cubic foot of sand.

5.4 Sand Filtration BMPs

5.4.1 BMP 5.10 Sand Filter Basin

Sand filter basins are open impoundments.

Criteria specific to basic and large sand filter basins.

1. Impermeable liners are generally required for soluble pollutants such as metals and toxic organics and where the underflow could cause problems with structures. Impermeable liners may be clay, concrete or geomembrane. See Chapter 2.7 for impermeable liner specifications.
2. An access ramp with a slope not to exceed 7:1, or equivalent, shall be included for maintenance purposes at the inlet and the outlet of a surface filter. An access port for inspection and maintenance shall be provided where feasible.

5.4.2 BMP 5.20 Sand Filter Vault

A sand filter vault is similar to an open sand filter except that the sand layer and underdrains are installed below grade in a vault.

Criteria specific to sand filter vaults:

1. Vaults may be designed as off-line systems or as on-line systems for small drainages.
2. Pretreatment may occur in a properly designed pretreatment cell within the sand filter vault, or in a separate upstream pretreatment system.
3. If a retaining baffle is used to retain floatable materials in a presettling cell, it must extend at least one foot above to one foot below the design flow water level. Provision for the passage of flows in the event of plugging must be provided. An access opening and ladder must be provided on both sides of the baffle.
4. To help prevent anoxic conditions within the sand bed, a minimum of 24 square feet of ventilation grate shall be provided for each 250 square feet of sand bed surface area. For sufficient distribution of airflow across the sand bed, grates may be located in one area if the sand filter is small, but placement at each end is preferred. Small grates may also be dispersed over the entire sand bed area.

5. A sand filter inlet shutoff/bypass valve shall be provided for maintenance.

5.4.3 BMP 5.30 Linear Sand Filter

Linear sand filters are typically long, shallow, two-celled rectangular vaults. The first cell is designed for settling coarse particles, and the second cell contains the sand bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader. See Figure 5.1 for an illustration of a linear sand filter.

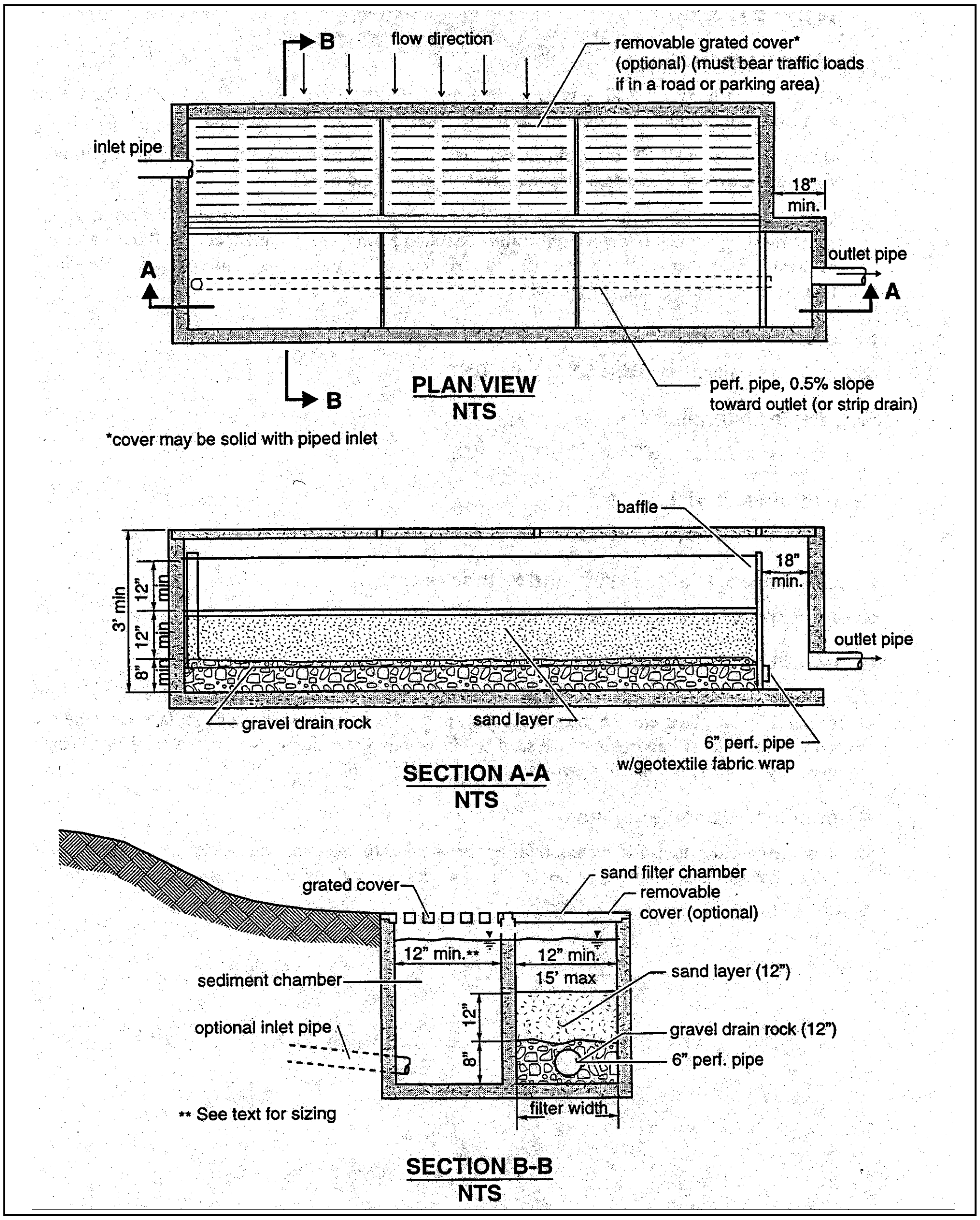


Figure 5.1 Linear Sand Filter

Application and Limitations

Linear sand filters are applicable in the following situations:

- For oil control treatment from high use sites
- In long narrow spaces such as the perimeter of a paved surface
- As a part of a treatment train, upstream or downstream of a filter strip.

Additional Design Criteria for Linear Sand Filters

1. The two cells shall be divided by a divider wall that is level and extends a minimum of 6 inches above the sand bed.
2. Stormwater may enter the sediment cell by sheet flow or a piped inlet.
3. The width of the sand cell must be 1 foot minimum to 15 feet maximum.
4. The sand filter bed must be a minimum of 12 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.
5. The drainpipe must be 6-inch diameter minimum and be wrapped in geotextile and sloped a minimum of 0.5 percent.
6. The maximum sand bed ponding depth shall be 1 foot.
7. The filter must be vented as for sand filter vaults
8. The sediment cell width shall be set as follows:

Sand filter width, (w) inches	12-24	24-48	48-72	72+
Sediment cell width, inches	12	18	24	w/3

Chapter 6 - Filter Strips

6.1 Introduction

Filter strips are vegetated treatment systems (typically grass) that remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are designed to remove low concentrations and quantities of total suspended solids, heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater.

This chapter presents the following treatment BMPs:

- BMP 6.10 Basic Filter Strip
- BMP 6.20 Compost-Amended Filter Strip
- BMP 6.30 Narrow Area Filter Strip.

In cases where high concentrations of hydrocarbons, total suspended solids, or debris would be present in the runoff, such as runoff from high-use sites, a pretreatment system for those pollutants may be necessary. If possible, an off-line configuration is preferred to prevent damage from high flows.

PLEASE NOTE: Biofiltration swales are not an acceptable treatment facility type in the City of Everett. Therefore, no guidance for their design has been provided in this manual.

6.2 Filter Strip BMPs

6.2.1 BMP 6.10 Basic Filter Strip

A basic filter strip is essentially flat with no side slopes – see Figure 6.1. Stormwater runoff is distributed as sheet flow across the inlet width of the filter strip.

Applications/Limitations

The basic filter strip is typically used on-line and adjacent and parallel to a paved area such as parking lots, driveways, and roadways.

Design Criteria for Filter Strips

1. Use the design criteria in Table 6.1.
2. Filter strips shall only receive well distributed sheet flow at the head of the strip.
3. To determine the required length of filter:

   Calculate the design flow depth using the following equation:

   $$y = [KQn/1.49Ts^{0.5}]^{0.6}$$

   where:

   Q = Water quality design flow rate

   K = 1.5 if Q is determined using continuous flow modeling;

   = 1.0 if Q is determined using SBUH methodology (see Volume I, Chapter 5)

   n = Manning's roughness coefficient

   s = Longitudinal slope of filter strip parallel to direction of flow

   T = Width of filter strip perpendicular to the direction of flow, ft.

Note – maximum allowable y = 1 inch

Calculate the design flow velocity V, ft./sec., through the filter strip:

$$V = KQ/Ty$$

Note – maximum allowable V = 0.5 feet per second

Calculate the required length of the filter strip (in feet) at the minimum hydraulic residence time, t, of 9 minutes:

$$L = tV = 540V$$

Table 6.1 Filter Strip Design Criteria

Design parameter	BMP T 8.40-Filter Strip
Longitudinal Slope	0.01 - 0.15
Maximum velocity	0.5 feet/sec
Maximum water depth	1-inch
Manning coefficient	0.35 (0.45 if compost-amended, and mowed to maintain grass height ≤ 4”)
Design Flow	Water Quality Design Flow Rate
Minimum hydraulic residence time	9 minutes
Transition detail	Inlet edge ≥ 3” lower than contributing paved area
Max. tributary drainage flowpath	150 ft
Max. longitudinal slope of contributing area	0.05 (steeper than 0.05 needs upslope flow spreading and energy dissipation)
Max. lateral slope of contributing area	0.02 (at the edge of the strip inlet)

6.2.2 BMP 6.20 Compost Amended Filter Strip

A compost amended filter strip shall meet all the requirements above, with the following additional criteria:

- the filter strip area shall be compost-amended to a minimum of 10 percent organic content in accordance with BMP T5.13; and
- grass shall be maintained at 95 percent density and a 4-inch length by mowing and periodic re-seeding.

6.2.3 BMP 6.30 Narrow Area Filter Strip

This section describes a filter strip design for impervious areas with flowpaths of 30 feet or less that can drain along their widest dimension to grassy areas.

Applications/Limitations

A narrow area filter strip could be used at roadways with limited right-of-way, or for narrow parking strips. If space is available to use the basic filter strip design, that design should be used in preference to the narrow filter strip.

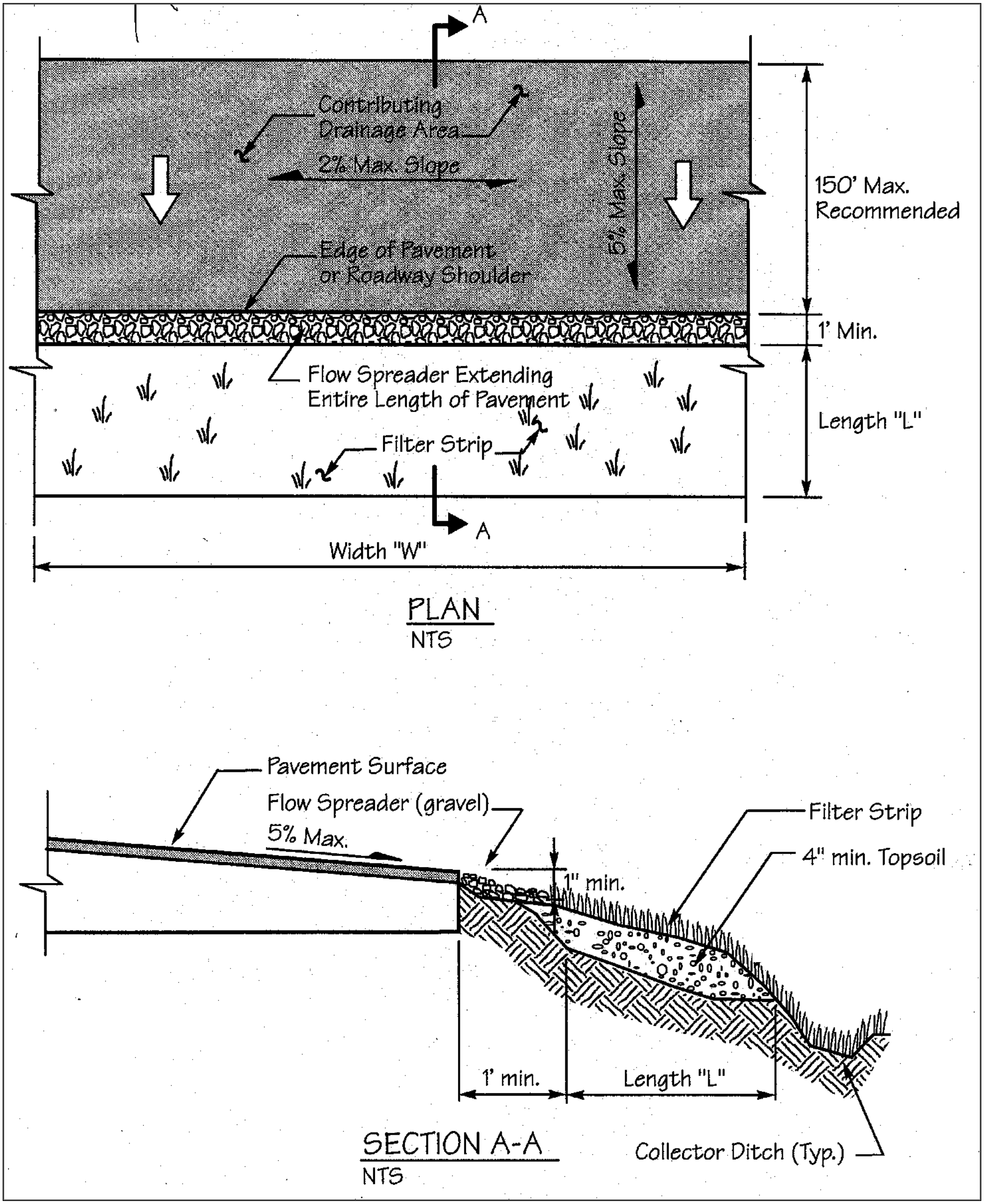


Figure 6.1 Typical Filter Strip

Design Criteria

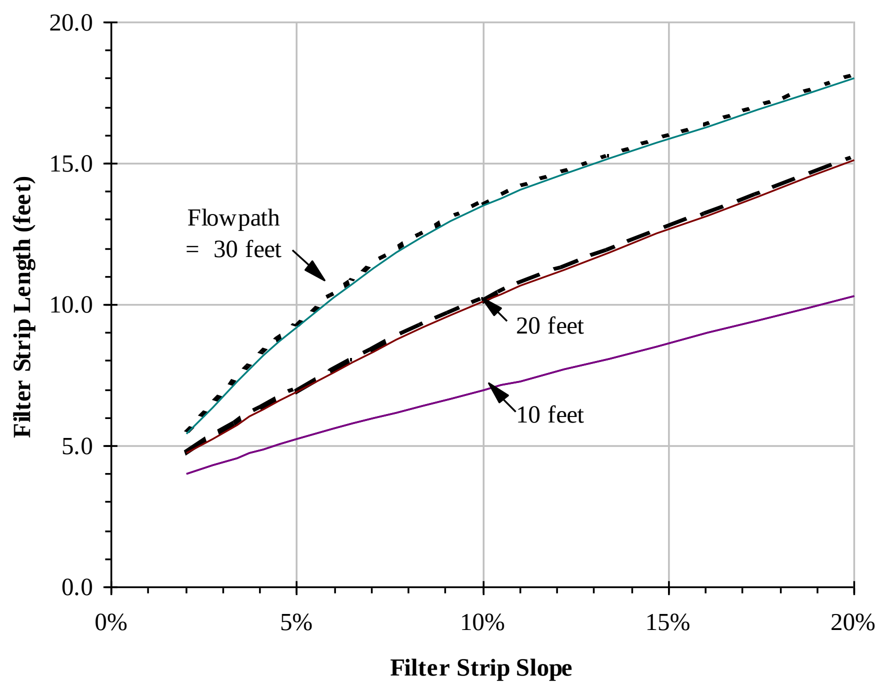
Design criteria for narrow area filter strips are the *same as specified for basic filter strips*. However, the sizing of a narrow area filter strip is based on the length of flowpath draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to the flowpath).

Step 1: Determine the length of the flowpath from the upstream to the downstream edge of the impervious area draining sheet flow to the strip. Normally this is the same as the width of the paved area, but if the site is sloped, the flow path may be longer than the width of the impervious area.

Step 2: Calculate the longitudinal slope of the filter strip (along the direction of unconcentrated flow), averaged over the total width of the filter strip. The minimum sizing slope is 2 percent. If the slope is less than 2 percent, use 2 percent for sizing purposes. The maximum allowable filter strip slope is 20 percent. If the slope exceeds 20 percent, the filter strip must be stepped down the slope so that the treatment areas between drop sections do not have a longitudinal slope greater than 20 percent. Drop sections must be provided with erosion protection at the base and flow spreaders to re-spread flows. Vertical drops along the slope must not exceed 12 inches in height. If this is not possible, a different treatment facility must be selected.

Step 3: Select the appropriate filter strip length for the flowpath length and filter strip longitudinal slope (Steps 1 and 2 above) from the graph in Figure 4.4. The filter strip must be designed to provide this minimum length *L* along the entire stretch of pavement draining into it.

To use the graph: Find the length of the flowpath on one of the curves (interpolate between curves as necessary). Move along the curve to the point where the design longitudinal slope of the filter strip (x-axis) is directly below. Read the filter strip length on the y-axis which corresponds to the intersection point.



Note: minimum allowable filter strip length is 4 feet

Figure 6.2 Filter Strip Lengths for Narrow Right-of-Way.

Chapter 7 - Wet Pool Facilities

7.1 Introduction

This chapter presents the methods, criteria, and details for analysis and design of wet ponds, wet vaults, and stormwater wetlands. These facilities have as a common element a permanent pool of water - the wet pool. Each of the wet pool facilities can be combined with a detention or flow control pond in a combined facility. Included are the following specific facility designs:

- BMP 7.10 Wet ponds - Basic and Large
- BMP 7.20 Wet vaults
- BMP 7.30 Stormwater Wetlands
- BMP 7.40 Combined Detention and Wet Pool Facilities.

7.2 General Design Criteria for All Wetpool Facilities

1. The basic wet pool volume shall be the water quality design volume. The water quality design volume is the volume of runoff predicted from a 24-hour storm with a 6-month return frequency (6-month, 24-hour storm). Alternatively, the 91st percentile, 24-hour runoff volume indicated by an approved continuous simulation runoff model may be used. See Chapter 5 of Volume I for more information.
2. The following design features shall be used to encourage plug flow and to avoid dead zones within wetpools:
   a. Energy dissipation at the inlet.
   b. A large effective length-to-width ratio (3:1 length to width, minimum) .
   c. Maximizing the flowpath between inlet and outlet, including the vertical path, also enhances treatment by increasing residence time.
3. Wet pool facilities may be single-purpose facilities, providing only runoff treatment, or they may be combined with detention to also provide flow control. If combined, the wet pool volume can be provided below the outlet elevation of the combined facility, with the live storage provided above. See BMP 7.40 for a description of combined detention and wet pool facilities.
4. The inlet to the wet pool shall be submerged with the inlet pipe invert a minimum of 3 feet from the wetpool bottom (including sediment storage).
5. The top of the inlet pipe shall be submerged at least 1 foot, if possible. Wet Pool BMPs

7.2.1 BMP 7.10 Wet Ponds – Basic and Large

A wet pond is a constructed stormwater pond that retains a permanent pool of water ("wet pool"), at least during the wet season.

The following design criteria cover two wet pond applications - the basic wet pond and the large wet pond. Large wet ponds are designed for higher levels of pollutant removal. As with other similar BMPs, wet ponds may be used as sedimentation ponds during construction. However, any sediment that has accumulated in the pond must be removed after construction is complete and before the pond is permanently placed on-line.

Applications and Limitations

Wet ponds are designed to maintain a standing pool of water (at the design treatment elevation) through much of the wet season. The wet pool storage of wet ponds may be provided below the groundwater level. However, if combined with a detention function, the live storage must be above the seasonal high groundwater level.

Sizing Criteria

For a basic wet pond, the wet pool volume provided shall be the water quality design volume. For a large wet pond, the wetpool volume provided shall be 1.5 times the water quality design volume.

Wet Pond Design Criteria

1. The wet pool shall be divided into two cells separated by a vertical divider, such as a berm, which ties into the wetpond side slopes at each end. The volume of the vertical divider shall not count as part of the total wet pool volume.
2. The interior vertical divider may be a retaining wall provided that the design is prepared and stamped by a licensed civil engineer.
3. Sediment storage shall be provided in the first cell with a minimum sediment storage depth of 1 foot. The first cell shall have a level bottom.
4. The first cell of the wet pond (the presettling cell) shall contain 30 percent of the total wet pool volume. The presettling volume may also be provided in an underground wet vault instead of an open pond cell.
5. The depth of the first cell shall be 4 – 6 feet, excluding the sediment storage depth.
6. The maximum depth of the second cell shall be 6 feet.
7. A minimum of 15% of the total wet pool volume shall be provided in the second cell at depths of 0 – 2.5 feet, with a maximum average depth of 2.0 feet (the emergent treatment area).
8. Inlets and outlets shall be placed to maximize the flow path through the facility with a length to width from the inlet to the outlet of at least 3:1.

   Note: The ***flow path length*** is defined as the distance from the inlet to the outlet, as measured at mid-depth in each cell. The ***width*** at mid-depth can be found as follows: width = (average top width + average bottom width)/2.
9. All inlets shall enter the first cell. If there are multiple inlets, the length-to-width ratio shall be based on the average flow path length for all inlets.
10. The wet pool cells shall be lined in accordance with the low permeability liner requirements outlined in Chapter 2.7.
11. Erosion control measures shall be used to prevent erosion of the berm back-slope when the pond is initially filled.

Inlet and Outlet

1. An outlet structure shall be provided. Either a Type 2 catch basin with a grated opening (jail house window) or a manhole with a cone grate (birdcage) may be used.
2. A floatable material separator (DSCC Drawings #410 and #411) is required on the outlet pipe from the outlet structure.
3. The pond outlet pipe shall be sized, at a minimum, to pass the on-line water quality flow rate and shall be placed on a reverse grade from the pond's wet pool to the outlet structure.

4. The primary overflow elevation is determined by using the charts in Figures 7.1, 7.2, and 7.3 (see the end of this chapter). Use these figures to select a pond outlet pipe size and overflow stage. The charts provide the overflow stage by assuming the on-line water quality design flow, Q_{wq}, is the flow rate that occurs at the critical depth. The primary overflow elevation is the outlet invert elevation plus the overflow stage.
5. The overflow criteria for single-purpose (treatment only, not combined with flow control) wet ponds are as follows:
    a. The requirement for primary overflow is satisfied by either the grated inlet to the outlet structure or by a birdcage above the pond outlet structure.
    b. The bottom of the grate opening in the outlet structure shall be set at or above the height needed to pass the water quality design flow through the pond outlet pipe.
    c. The primary overflow shall be sized to pass the 100-year recurrence interval design flow.
6. The City may require a bypass/ shutoff valve for off-line ponds to enable the pond to be isolated from the upstream conveyance system for maintenance purposes.

Sizing Procedure

Procedures for determining a wet pond's dimensions and volume are outlined below.

Step 1: Determine the required wet pool volume in accordance with Chapter 5 in Volume I.

Step 2: Design the pond outlet pipe and determine the primary overflow water surface elevation.

Step 3: Determine the wet pool dimensions satisfying the Wet Pond Design Criteria. A simple way to check the volume of each wet pool cell is to use the following equation:

$$V = \frac{h(A_1 + A_2)}{2}$$

where

V = wet pool volume (cf)

h = wet pool average depth (ft)

A_1 = water quality design surface area of wet pool (sf)

A_2 = bottom area of wet pool (sf)

Planting Requirements

1. The emergent treatment area shall be planted with emergent wetland vegetation. See Table 4.8 for recommended emergent wetland plant species for wet pools.
2. Cattails (Typha latifolia) are not recommended because they tend to crowd out other species and will typically establish themselves anyway.

Table 7.1 Emergent Wetland Plant Species Recommended for Wet Pools

Species	Common Name	Notes	Maximum Depth
INUNDATION 1 TO 2 FT			
Agrostis exarata (1)	Spike bent grass	Prairie to coast	
Alisma plantago-aquatica	Water plantain		
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	
Juncus effusus	Soft rush	Wet meadows, pastures, wetland margins	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sparganium emmersum	Bur reed	Shallow standing water, saturated soils	
INUNDATION 1 TO 3 FT			
Carex obnupta	Slough sedge	Wet ground or standing water	1.5 to 3 ft
Beckmania syzigachne (1)	Western sloughgrass	Wet prairie to pond margins	
Scirpus acutus (2)	Hardstem bulrush	Single tall stems, not clumping	to 3 ft
Scirpus validus (2)	Softstem bulrush		
INUNDATION GREATER THAN 3 FT			
Nuphar polysepalum	Spatterdock	Deep water	3 to 7.5 ft
Nymphaea odorata (1)	White waterlily	Shallow to deep ponds	to 6 ft

Notes:
(1) Non-native species. Beckmania syzigachne is native to Oregon. Native species are preferred.
(2) Scirpus tubers must be planted shallower for establishment, and protected from foraging waterfowl until established. Emerging aerial stems should project above water surface to allow oxygen transport to the roots.
Primary sources: Municipality of Metropolitan Seattle, Water Pollution Control Aspects of Aquatic Plants, 1990. Hortus Northwest, Wetland Plants for Western Oregon, Issue 2, 1991. Hitchcock and Cronquist, Flora of the Pacific Northwest, 1973.

7.2.2 BMP 7.20 Wet Vaults

A wet vault is an underground structure similar in appearance to a detention vault, except that a wet vault has a wet pool which dissipates energy and improves the settling of particulate pollutants.

Applications and Limitations

Wet vaults are generally not allowed for the primary treatment of runoff in the City - the only exception is single family residential subdivisions creating less than 10,000 square feet of effective impervious area. However, wet vaults may be used for sediment removal upstream of sediment sensitive treatment facilities, or as the first/presettling cell of a wet pond design.

Combined detention and wet vaults are allowed; see BMP 7.40.

If a wet vault/tank is designed to provide runoff treatment but not runoff quantity control, it should generally be located off-line from the primary conveyance/detention system. Flows above the peak flow for the water quality design storm should bypass the facility in a separate conveyance to the point of discharge. A mechanism should also be provided at the bypass point to isolate the facility for maintenance purposes.

Wetpool Geometry

Same as specified for wet ponds (see BMP T9.10) except for the following two modifications:

- The sediment storage depth in the first cell shall be an average of 1-foot.
- Wet vaults shall be a minimum of 3 feet deep, excluding sediment storage depth.

Vault Structure Criteria

1. Vaults with more than 2,000 cubic feet of dead storage volume and a length-to-width ratio of less than 5:1 must be separated into two cells by a wall or a removable baffle.
2. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells.
3. Baffles shall extend from a minimum of 1 foot above the runoff treatment design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.
4. The lowest point of a separating baffle shall be a minimum of 2 feet from the bottom of the vault..
5. The two cells of a wet vault should not be divided into additional subcells by internal walls. If internal structural support is needed, it is preferred that post and pier construction be used to support the vault lid rather than walls. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flowpath.
6. The bottom of the first cell shall be sloped toward the access opening. Slope should be between 0.5 percent (minimum) and 2 percent (maximum).
7. The second cell may be level (longitudinally) or sloped toward the outlet, with a high point between the first and second cells. The intent of sloping the bottom is to direct the sediment accumulation to the closest access point for maintenance purposes.
8. The vault bottom shall slope laterally a minimum of 5 percent from each side towards the center, forming a broad “V” to facilitate sediment removal. More than one “V” may be used on wide vaults to minimize vault depth.

   Exception: The City may allow the vault bottom to be flat if removable panels are provided over the entire vault. Removable panels should be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
9. The highest point of a vault bottom must be at least 6 inches below the outlet elevation to provide for sediment storage over the entire bottom.
10. Where pipes enter and leave the vault below the water quality design water surface, they shall be sealed using a non-porous, non-shrinking grout.

Inlet and Outlet

1. The inlet to the wet vault shall be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom. The top of the inlet pipe shall be submerged at least 1 foot.
2. Conveyance modeling for the stormwater system leading to the vault must be shown to include consideration of the backwater effects of the submerged vault inlet. Additional information on backwater analyses is provided in Volume I, Chapter 4.
3. A floatable material separator (DSCC Drawing #4) shall be placed on the outlet pipe.
4. The City may require a bypass/shutoff valve to enable the vault to be isolated for maintenance.

7.2.3 BMP 7.30 Stormwater Treatment Wetlands

Stormwater treatment wetlands are shallow man-made ponds that are designed to treat stormwater through the biological processes associated with emergent aquatic vegetation. Mitigation wetlands may not also be used as stormwater treatment facilities.

Applications and Limitations

This stormwater wetland design occupies about the same surface area as wet ponds, but has the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. Since water depths are shallower than in wet ponds, water loss by evaporation is an important concern. Stormwater wetlands are a good runoff treatment facility choice in areas with high winter groundwater levels.

Design Criteria

When used for stormwater treatment, stormwater wetlands employ some of the same design features as wet ponds. However, instead of gravity settling being the dominant treatment process, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus when designing wetlands, water volume is not the dominant design criteria. Rather, factors which affect plant vigor and biomass are the primary concerns.

Sizing Procedure

Step 1: Calculate the total required surface area of the stormwater wetland by dividing the water quality design volume by a theoretical average depth of 3 feet. (Note: this theoretical average depth bears no relationship to the actual depths in the stormwater wetland – it merely decreases the overall surface area of the stormwater wetland to be comparable to a basic wetpond.)

Step 2: Determine the actual surface area of the first cell of the stormwater wetland. Use the volume determined from Criterion 2 under “Wetland Geometry”, and the actual depth of the first cell.

Step 3: Determine the surface area of the wetland cell by subtracting the surface area of the first cell (Step 3) from the total surface area (Step 2).

Step 4: Determine the water depth distribution in the second cell. Decide if the top of the dividing berm will be at the surface or submerged (designer's choice). Adjust the distribution of water depths in the second cell according to Criterion 8 under “Wetland Geometry” below. Note: This will result in a facility that holds less volume than the water quality design volume. This is acceptable.

Step 5: Choose plants. See Table 4.8 for a list of plants recommended for wet pond water depth zones, or consult a wetland scientist.

Wetland Geometry

1. Stormwater wetlands shall consist of two cells, a presettling cell and a wetland cell.
2. The presettling cell shall contain approximately 33 percent of the wet pool volume calculated in Step 1 above.
3. The depth of the presettling cell shall be between 4 feet and 6 feet, excluding sediment storage.
4. One foot of sediment storage shall be provided in the presettling cell.
5. The top of the berm shall be at the water quality design water surface or submerged 1 foot below the water quality design water surface.

6. A distribution of depths shall be provided in the wetland cell depending on whether the dividing berm is at the water surface or submerged (see Table 7.2 below). The maximum depth is 2.5 feet in either configuration, and the average water depth shall be 1.5 feet (plus or minus 3 inches).. Other configurations within the wetland geometry constraints listed above may be approved by the City.

Table 7.2 Distribution of Depths in Wetland Cell

Dividing Berm at Design Water Surface		Dividing Berm Submerged 1 Foot	
Depth Range (ft)	**Percent of wetland cell surface area**	**Depth Range (ft)**	**Percent of wetland cell surface area**
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

7. A low permeability liner is required for both cells of the stormwater wetland.
8. A minimum of 18 inches of native soil amended with topsoil must be placed over the low permeability liner. For geomembrane liners, a soil depth of 3 feet is recommended to prevent damage to the liner during planting.

Inlet and Outlet

Inlets and outlets shall be configured per the requirements of wet ponds, see BMP 7.10.

Planting Requirements

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Table 4.8, or the recommendations of a wetland specialist.

Construction Criteria

1. Construction and maintenance considerations are the same as for wet ponds.

7.2.4 BMP 7.40 Combined Detention and Wet Pool Facilities

Combined detention and water quality wet pool facilities have the appearance of a detention facility but contain a permanent pool of water as well. The following design procedures, requirements, and recommendations cover differences in the design of the stand-alone runoff treatment facility when combined with detention storage. The following combined facilities are addressed:

- Detention/wet pond (basic and large)
- Detention/wet vault
- Detention/stormwater wetland.

Applications and Limitations

Combined detention and runoff treatment facilities are very efficient for sites that also have detention requirements. The runoff treatment facility wetpool may often be provided “beneath” the detention facility’s live storage without greatly increasing the facility’s surface area.

The detention portion of the combined facility is designed to meet flow control requirements per Chapter 5 of Volume I. The wet pool volume for a combined facility shall be equal to or greater than the water quality design volume.

Unlike the wet pool volume, the live storage component of the facility must be provided above the seasonal high water table.

The wet pool and any required sediment storage volumes shall not be included in the required detention volume.

Unless specifically noted, the design criteria of the following combined facilities shall be equal to the corresponding wet pool or detention BMP. A sump must be provided in the outlet structure of combined facilities.

Combined Detention and Wet Pond (Basic and Large)

The "Wet Pool Geometry" criteria for wet ponds (see BMP 7.10) shall apply with the following modifications/clarifications:

- Criterion 1: The permanent pool may be made shallower to take up most of the pond bottom, or deeper and positioned to take up only a limited portion of the bottom at the inlet location. However, wet pond criteria governing water depth must still be met.
- Criterion 2: The minimum sediment storage depth in the first cell is 1 foot. The 6 inches of sediment storage required for detention ponds does not need to be added to this depth, but 6 inches of sediment storage must be added to the second cell to comply with the detention sediment storage requirement.

Combined Detention and Wet Vault

Six inches of sediment storage depth shall be added to the second cell. In addition, the oil retaining baffle shall extend a minimum of 2 feet below the water quality design water surface. The greater depth of the baffle in relation to the runoff treatment design water surface compensates for the greater water level fluctuations experienced in the combined vault.

Combined Detention and Stormwater Wetland

Water Level Fluctuation Restrictions: The difference between the water quality design water surface and the maximum water surface associated with the 2-year recurrence interval runoff shall not be greater than 3 feet. If this restriction cannot be met, the size of the stormwater wetland must be increased. The additional area may be placed in the first cell, second cell, or both. If placed in the second cell, the additional area need not be planted with wetland vegetation or counted in calculating the average depth.

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

- *Scirpus acutus* (hardstem bulrush) 2 - 6' depth
- *Scirpus microcarpus* (small-fruited bulrush) 1 - 2.5' depth
- *Sparganium emersum* (burreed) 1 - 2' depth
- *Sparganium eurycarpum* (burreed) 1 - 2' depth
- *Veronica* sp. (marsh speedwell) 0 - 1' depth

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

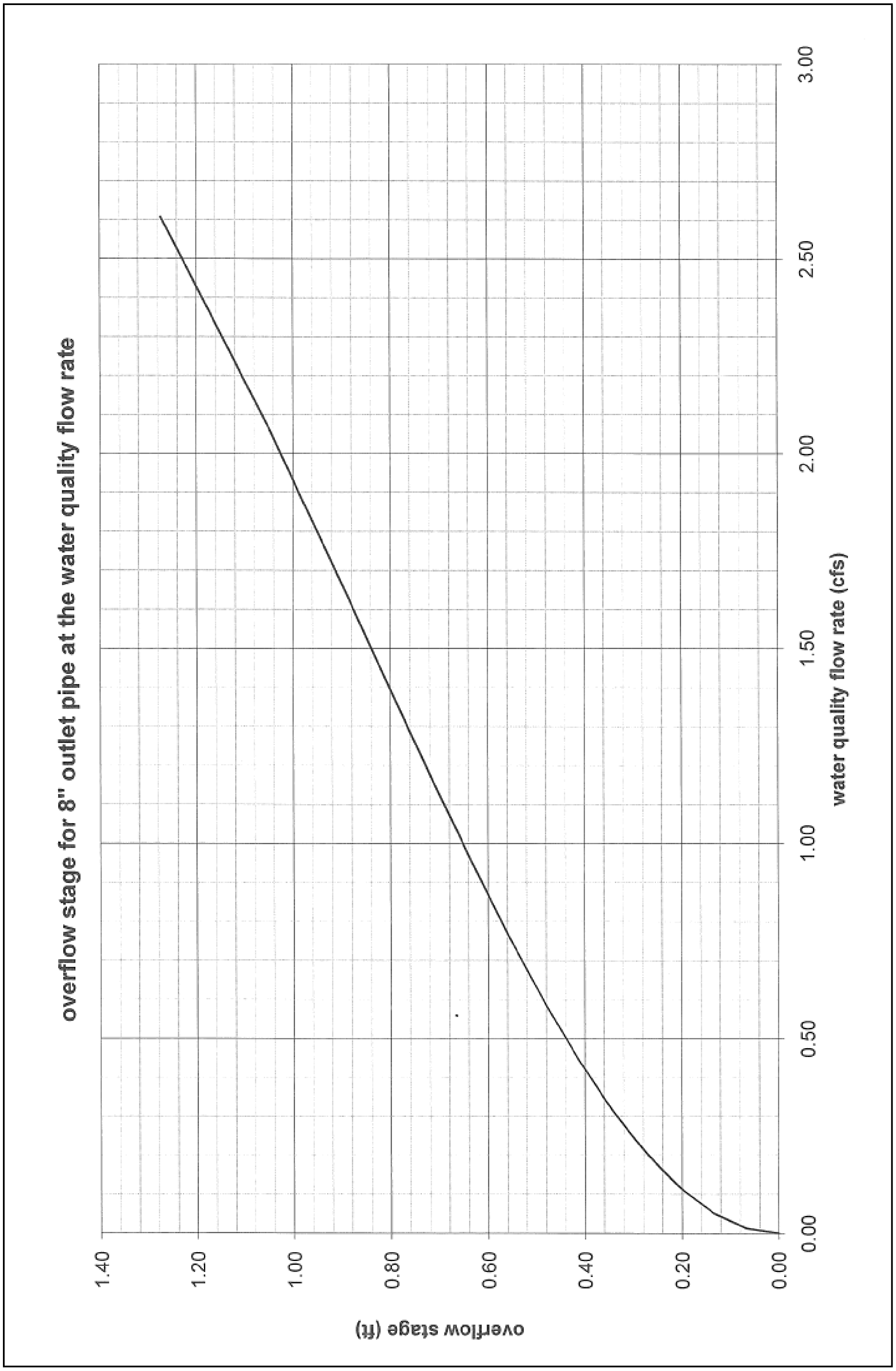


Figure 7.1 8-inch Outlet Pipe Overflow Stage

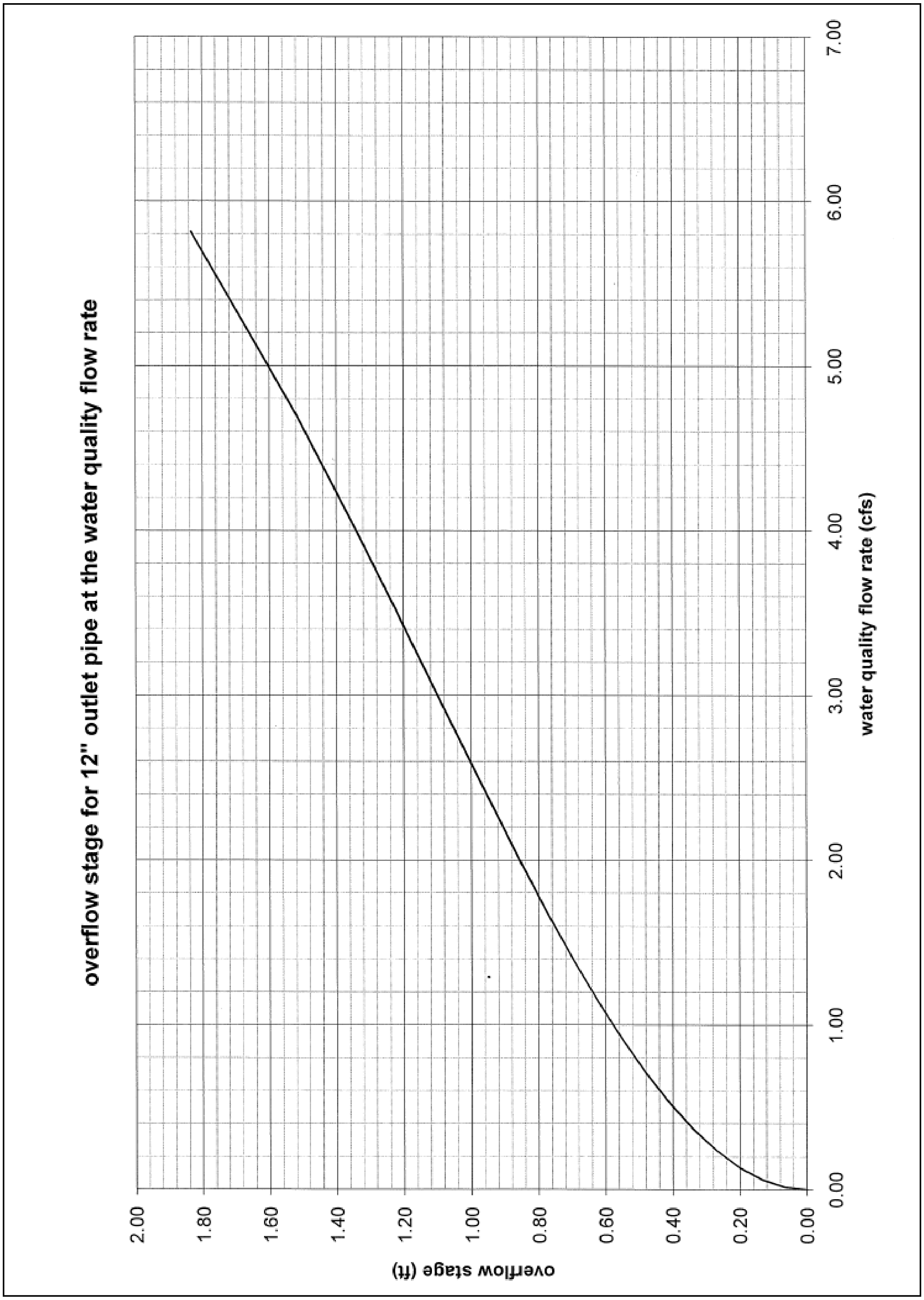


Figure 7.2 12-inch Outlet Pipe Overflow Stage

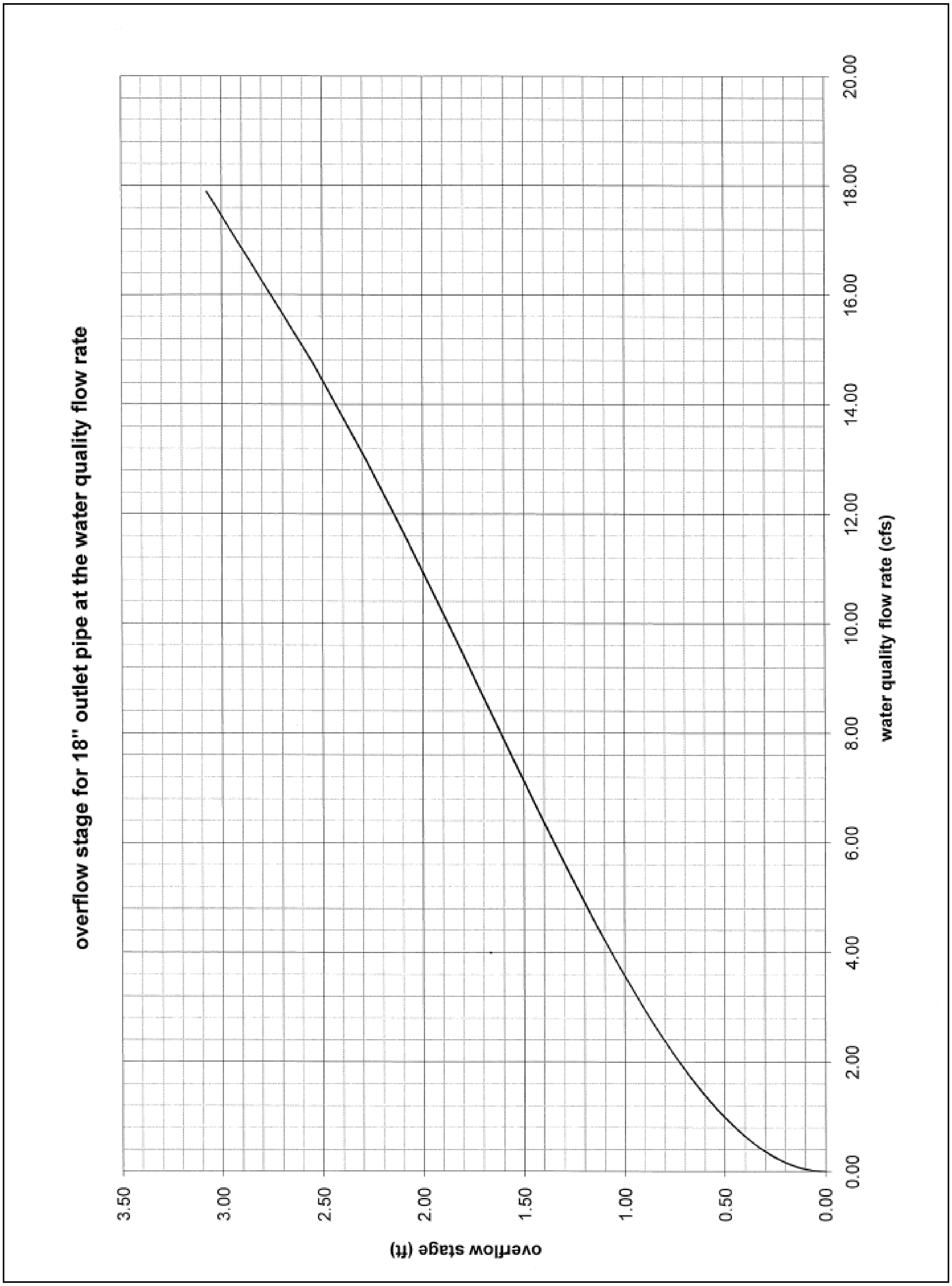


Figure 7.3 18-inch Outlet Pipe Overflow Stage

Chapter 8 - Oil Water Separators

8.1 Introduction

This chapter provides a discussion of oil and water separators, including their application and design criteria. BMPs are described for baffle type and coalescing plate separators. These facilities are intended to remove oil (and other water-insoluble hydrocarbons) from stormwater runoff.

The following BMPs are described in this chapter:

- BMP 8.10 Baffle type separators
- BMP 8.20 Coalescing plate separators.

In addition to the oil and water separators outlined in this volume, The City will also permit the use oil control booms for oil control when designed in accordance with the requirements outlined in the 2006 WSDOT Highway Runoff Manual, Chapter 5, BMP RT.22 (or subsequent updates as approved by Ecology and the City).

Oil and water separators are typically the API (American Petroleum Institute, 1990), also called baffle type, or the coalescing plate (CP) type. Both use a gravity mechanism for separation. Oil removal separators typically consist of three bays; a forebay, a separator section, and an afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates.

Oil and water separators should be designed to remove oil and TPH down to 15 mg/L at any time and 10 mg/L on a 24-hour average, and produce a discharge that does not cause an ongoing or recurring visible sheen in the stormwater discharge or in the receiving water.

Without intense maintenance, oil/water separators may not be sufficiently effective in achieving oil and TPH removal down to required levels. See Volume I, Minimum Requirement #10, and Appendix F for additional information on maintenance requirements.

8.2 General Design Criteria

The following are design criteria applicable to API and CP oil/water separators:

1. The separator should be located off-line and the incremental portion of flows that exceed the separator design flow should be bypassed.
2. The separator design flow shall be the peak rate of runoff from the 6 month, 24-hr storm using SBUH hydrograph methodology (see Chapter 5 of Volume I). If the site is being modeled using an approved continuous simulation, the water quality flow rate can be converted to the equivalent 6 month, 24-hr rate by multiplying the continuous simulation water quality flow rate by 2.75 (for an off-line design) or 1.58 (for an on-line design).
3. Use only impervious conveyances for oil contaminated stormwater.
4. Add pretreatment for total suspended solids that could cause clogging of the CP separator, or otherwise impair the long-term effectiveness of the separator.
5. Include roughing screens for the forebay or upstream of the separator to remove debris. Screen openings should be about three-fourths inch.

8.2.1 Criteria for Separator Bays

1. To collect floatables and settleable solids, design the surface area of the forebay at ≥ 20 ft² per 10,000 ft² of area draining to the separator [(6)]. The length of the forebay should be one-third to one-half of the length of the entire separator.
2. Include a submerged inlet pipe with a turn-down elbow in the first bay at least 2 feet from the bottom. The outlet pipe should be a Tee, sized to pass the design peak flow and placed at least 12 inches below the water surface.
3. Include a shutoff valve at the separator outlet pipe.

8.2.2 Criteria for Baffles

1. Oil retaining baffles (top baffles) should be located at least at one-fourth of the total separator length from the outlet and should extend down at least 50 percent of the water depth and at least 1 foot from the separator bottom.
2. Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

8.3 Oil Water Separator BMPs

8.3.1 API (Baffle type) Separator

Note: API separators may ***only*** be designed in the City for use on large sites greater than 2 acres.

Ecology's 2005 Stormwater Management Manual for Western Washington (Ecology 2005) presents a design modification for using API separators in drainage areas smaller than 2 acres (e.g., fueling stations, commercial parking lots, etc.). However, Ecology also requires each developer to perform detailed performance verification during at least one wet season when using the modified design. Given this requirement, the City has elected not to allow the use of API separators on sites smaller than 2 acres.

Design Criteria

The API design criteria is based on the horizontal velocity of the bulk fluid (V_h), the oil rise rate (V_t), the residence time (t_m), width, depth, and length considerations.

The following is the API sizing procedure:

1. Determine the oil rise rate, V_t, in centimeters per second, using Stokes' Law (Water Pollution Control Federation, 1985) or empirical determination.

   The Stokes Law equation for rise rate, V_t (ft/min) is:

   $$V_t = 1.97g(\sigma_w - \sigma_o)D^2 / 18\eta_w)$$

   where:

   1.97 = conversion factor (centimeters per second/ft per minute)

   g = gravitational constant (981 centimeters per second squared)

   D = diameter of the target oil particle (centimeters) = 60 microns (0.006 centimeters).

   η_w = dynamic viscosity of water = 0.017921 poise (gm/cm-sec). at water temperature of 32°F, (see API publication 421, February, 1990)

   σ_w = water density = 0.999 grams per cubic centimeter (gm/cc) at 32°F

σ_o = oil density,

Select a conservatively high oil density. For example, if diesel oil @ σ_o=0.85 gm/cc and motor oil @ σ_o = 0.90 gm/cc may be present then use σ_o=0.90 gm/cc

2. Determine Q in cubic feet per minute. (see section 8.2 of this chapter for information on the design flow rate).
3. Calculate horizontal velocity of the bulk fluid, V_h (in ft/min), and depth (d), ft.

   $V_h = 15V_t$

   $d = (Q/2Vh)^{1/2}$, with

   Separator water depth, $3 \leq d \leq 8$ feet (to minimize turbulence). If the calculated depth is less than 3 feet, an API separator is not appropriate for the site. If the calculated depth exceeds 8 feet, consider using two separators (American Petroleum Institute, 1990; U.S. Army Corps of Engineers, 1994).

4. Calculate the minimum residence time (t_m), in minutes, of the separator at depth d:

   $t_m = d/V_t$

5. Calculate the minimum length of the separator section, l(s), using:

   F = 1.65

   Depth/width (d/w) of 0.5 (American Petroleum Institute, 1990),

   $l(s) = FQt_m/wd = F(V_h/V_t)d$

   For other dimensions, including the length of the forebay, the length of the afterbay, and the overall length, L; refer to Figure 10.1.

6. Calculate $V = l(s)wd = FQt_m$, and $A_h = wl(s)$

   V = minimum hydraulic design volume, in cubic feet.

   Ah = minimum horizontal area of the separator, in square feet.

8.3.2 Coalescing Plate (CP) Separator

Design Criteria

1. Calculate the projected (horizontal) surface area of plates needed using the following equation:

   $A_p = Q/V_t = Q/0.00386(\sigma_w\text{-}\sigma_o/\eta_w)$

   $A_p = A_a(\text{cosine } b)$

   where:

   Q = the design flow rate, ft^3/min

   V_t = rise rate of 0.033 ft/min, or empirical determination, or Stokes Law based

   A_p = projected surface area of the plate in ft^2; .00386 is unit conversion constant

   σ_w=density of water at 32ºF

   σ_o= density of oil at 32ºF

   A_a = actual plate area in ft^2 (one side only)

   b = angle of the plates with the horizontal in degrees (usually varies from 45-60 degrees).

η_w=viscosity of water at 32ºF

2. Plate spacing should be a minimum of three-fourths of an inch of perpendicular distance between plates (WEF and ASCE, 1998; U.S. Army Corps of Engineers, 1994; US Air Force, 1991; Jaisinghani, R., 1979).
3. Select a plate angle between 45° to 60° from the horizontal.
4. Locate plate pack at least 6 inches from the bottom of the separator for sediment storage.
5. Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.
6. Design inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay should be less than 500 (laminar flow).
7. Include forebay for floatables and afterbay for collection of effluent (WEF and ASCE, 1998).
8. The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 inches.
9. Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

Chapter 9 - Infiltration Facilities

9.1 Introduction

Infiltration facilities are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Depending upon the nature of the site's soils, infiltration facilities can be used for treatment purposes and/or for partial or complete flow control. In either case, runoff in excess of the infiltration capacity of the facilities must be managed to comply with the treatment and flow control requirement in Volume I.

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil.

Infiltration basins and trenches with small contributing areas may be designed in accordance with the on-site stormwater management BMP criteria given in Chapter 12 of this volume. If the contributing area has the following characteristics, the pre-engineered, simplified design in Chapter 12 may be used:

1. has a contributing impervious area, x, less than 2,000 square feet; and
2. has a contributing pervious area, y, less than 13,000 square feet; and
3. has a combination of impervious and pervious surfaces such that the "equivalent impervious area", as defined by the following equation, is less than 2,000 square feet:

   $$\text{equivalent impervious area} = x + (y \div 6.5)$$

   where

   x = the square feet of impervious area in the contributing basin

   y = the square feet of pervious area in the contributing basin

<u>NOTE:</u> The specific requirements and design criteria given in this chapter are <u>in addition</u> to applicable BMP requirements from Chapter 1. Chapter 1 addresses requirements that are common to more than one BMP, such as access, maintenance, berms and embankments, etc.

9.2 Soil Requirements for Infiltration Treatment Facilities

Infiltration treatment (i.e., an infiltration basin or trench) meets the requirements for *basic*, *phosphorus*, and *enhanced* treatment if the water quality design volume is successfully infiltrated within a maximum time period of 48 hours. The drawdown time can be calculated using a horizontal projection of the infiltration basin mid-depth dimensions and the estimated long-term infiltration rate.

The following soil suitability criteria #1 and #2 must be met for infiltration treatment facilities:

Soil suitability criteria #1

The short-term soil infiltration rate (field measured, before safety factors) must be 2.4 inches per hour, or less, to a depth of 2.5 times the maximum design pond water depth, or a minimum of 6 feet below the base of the infiltration facility. Long-term (design) infiltration rates up to 2.0 inches/hour can be used with approval by the City, if in the judgment of the site professional, the treatment soil has characteristics comparable to those specified in soil suitability criteria #2 to adequately control the target pollutants.

Soil suitability criteria #2

The soil shall have a cation exchange capacity (CEC) greater than or equal to 5 milliequivalents per 100 milligrams of dry soil and an organic content of at least 1 percent (using ASTM D-2974) to a minimum depth of 18 inches (measured from the bottom of the facility).

9.3 Procedures

The following steps shall be followed when considering and designing an infiltration facility.

9.3.1 Step 1: Conduct a general surface characterization

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

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

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

9.3.2 Step 2: Determine if minimum requirements for infiltration facilities are met.

*Infiltration facilities are not permissible unless **all** of the following criteria are met. Note: not all sites that meet the following criteria will be suitable for infiltration – these are **minimum** requirements only. Additional setbacks listed in Chapter 2.11 also apply.*

The base of all infiltration basins or trench systems must be a minimum of 3 feet above the seasonal high groundwater levels, bedrock (or hardpan), or other low permeability layer.

Ponds and infiltration basins may not be constructed within a floodplain area.

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

Infiltration facilities are prohibited within 300 feet of a landslide or erosion hazard area (as defined by Title 19.37.080 of the Everett Municipal Code) unless the slope stability impacts of such facilities have been analyzed and mitigated by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.

The maximum depth of an infiltration facility shall be 20 feet below the surrounding finished (developed) ground elevation, in order to provide for long-term maintenance access to the facility.

If the depth of the infiltration facility being considered is greater than the largest surface dimension, it is considered an injection well and is subject to the requirements of the UIC Program, Chapter 173-218 WAC. See also Chapter 9.6.

9.3.3 Step 3: Determine the method of analysis required

The City encourages consideration of infiltration facilities for sites where conditions are appropriate. However, some sites may not be appropriate for infiltration due to soil characteristics, groundwater levels, steep slopes, or other constraints. All proposed infiltration projects are required, at a minimum, to perform the simple analyses specified in Chapter 9.3.4. For those sites that present a greater risk of infiltration system failure, a more detailed method of analysis is required in addition to the simple analysis.

The sections below outline the criteria to be used when determining whether a project is subject to the simplified or the detailed method of analysis. The chosen method of analysis must be approved by the City. Moreover, the City may require that the detailed method of analysis be conducted based on the results of the simple method.

Where the Simple Analysis is appropriate

The simplified analysis is generally applicable to projects with the following characteristics:

- High infiltration capacity soils (NRCS [SCS] soil types A or B)
- Other infiltration facilities are performing successfully at nearby locations
- No septic systems, drinking water wells, or geologically hazardous areas are located within 500 feet
- Low risk of flooding and property damage in the event of clogging or other failure of the infiltration system.

Where the Detailed Analysis is required

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

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

9.3.4 Step 4: Conduct a simple analysis for all proposed infiltration facilities

The following process analyses are required for all proposed infiltration projects.

Conduct Soils Testing

- Test hole or test pit explorations should be conducted during the middle to end of the wet season (December 1 through April 30) to provide accurate groundwater saturation and groundwater information.
- Representative samples shall be collected from each soil type and/or unit to a depth of 6 feet below the proposed base of the infiltration pond. For infiltration ponds, there shall be one test pit

or test hole per 5,000 square feet of pond infiltrating surface with a minimum of two per pond, regardless of pond size. For infiltration trenches, there shall be one test pit or test hole per 50 feet of trench length with a minimum of two required per trench, regardless of length.

- Detailed logs for each test pit or test hole and a map showing the location of the test pits or test holes shall be prepared. Logs must include the depth, soil descriptions, depth to water, evidence of seasonal high groundwater elevation, existing ground surface elevation, proposed pond bottom elevation, and presence of stratification that may impact the infiltration design.
- Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered shall include:
    a. Grain-size distribution (ASTM D422 or equivalent AASHTO specification)
    b. Textural class (USDA) (See Figure 5.1)
    c. Percent clay content (include type of clay, if known)
    d. Color/mottling
    e. Variations and nature of stratification

Determine the Design Infiltration Rate

There are three acceptable methods for estimating design infiltration rates. Each is described in detail in Chapter 9.4 of this volume.

- USDA soil textural classification
- ASTM gradation testing.
- In-situ measurement

Prepare a Geotechnical Report

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

1. A figure showing the following:
    a. topography within 500 feet of the proposed facility
    a. locations of test pits or test holes.
2. Results of soils tests, including detailed soil logs
3. Description of local site geology, including soil or rock units likely to be encountered at soil sampling depths and the seasonal high groundwater elevation
4. A recommended design infiltration rate as well as detailed documentation of the design infiltration rate determination, as specified above
5. A statement as to whether or not the proposed location is suitable for infiltration.

Design the Infiltration Facility

The primary mode of discharge from an infiltration facility is infiltration into the ground. However, when the infiltration capacity of the facility is reached, additional runoff to the facility will cause the facility to overflow.

- Overflows from an infiltration facility must comply with the Minimum Requirement #7 for flow control (see Chapter 2.2.7 in Volume I).

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

- ***On-line*** treatment facilities placed ***upstream or downstream*** of a detention facility must be sized to infiltrate the water quality design volume.
- ***Off-line*** treatment facilities placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the water quality design flow rate to the treatment facility. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).
- ***Off-line*** treatment facilities placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention pond to the treatment facility. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

See Volume I, Chapter 6.5 for flow splitter design details.

To prevent the onset of anaerobic conditions and the release of captured pollutants, an infiltration facility designed for treatment purposes must be designed to drain the water quality design volume within 48 hours. Use the water quality design volume, the surface area of the facility at mid-depth, and the infiltration rate to determine the drawdown time. An infiltration facility designed strictly for flow control purposes has no maximum drawdown time.

9.3.5 Step 5: Conduct a detailed analysis when required.

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

Infiltration Receptor Characterization

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

The geotech report shall be expanded to include a characterization of the infiltration receptor, which shall include the following information:

1. The depth to groundwater and to bedrock/impermeable layers.
2. The seasonal variation of groundwater table based on well water levels and observed mottling of soils.
3. The existing groundwater flow direction and gradient.
4. The volumetric water holding capacity of the infiltration receptor soils. The volumetric water holding capacity is the storage volume in the soil layer directly below the infiltration facility and above the seasonal high groundwater mark, bedrock, hardpan, or other low permeability layer.
5. The horizontal hydraulic conductivity of the saturated zone to assess the aquifer's ability to laterally transport the infiltrated water.
6. An approximation of the lateral extent of infiltration receptor.

7. An evaluation of the impact of the infiltration rate and proposed added volume from the project site on local groundwater mounding, flow direction, and water table determined by hydro-geologic methods.

9.4 Determination of Design Infiltration Rates

Infiltration rates can be determined using either a correlation to grain size distribution from soil samples, textural analysis, or by in-situ field measurements. Short-term infiltration rates up to 2.4 inches/hr represent soils that typically have sufficient treatment properties. Long-term infiltration rates are used for sizing the infiltration facility based on maximum storage level and drawdown time. Long-term infiltration rates up to 2.0 inches per hour can also be considered for treatment if draw down times can be met and the soil has adequate treatment.

For designing the infiltration facility, the site professional shall select one of the three methods described below that will best represent the long-term infiltration rate at the site. The long-term infiltration rate shall be used for routing and sizing the basin/trench for the maximum drawdown time of 48 hours. If the pilot infiltration test (Table 9.3) or hindcast approach (Table 9.2) is selected, corroboration with a textural based infiltration rate (Table 9.1) is also required. Appropriate correction factors must be applied as specified. Verification testing of the completed facility is strongly encouraged. (See Site Suitability Criterion # 7-Verification Testing)

Method 1. USDA Soil Textural Classification

To use the USDA textural analysis approach, a particle size distribution analysis must be conducted in accordance with the USDA test procedure (Soil Survey Laboratory Methods Manual, SSIR No. 42, Version 4, 2004). This manual ***only*** considers soil passing the #10 sieve (2 mm) (U.S. Standard) to determine percentages of sand, silt, and clay for use in Figure 9.1 (USDA Textural Triangle).

Note: Many soil test laboratories use the ASTM soil size distribution test procedure (ASTM D422), which considers the full range of soil particle sizes, to develop soil size distribution curves. Results from the ASTM soil gradation procedure must not be used with Figure 9.1 to determine USDA soil textures.

Table 9.1 provides the correlation between USDA soil texture and infiltration rates for estimating infiltration rates for homogeneous soils based on gradations from soil samples and textural analysis. The correction factors consider the effects of site variability and long-term clogging due to siltation and biomass buildup in the infiltration facility.

These correction factors may be reduced, subject to the approval of the City, under the following conditions:

1. For sites with little soil variability,
2. Where there will be a high degree of long-term facility maintenance.

In no case shall a correction factor less than 2.0 be used.

Correction factors higher than those provided in Table 9.1 shall be considered for situations where long-term maintenance will be difficult to implement or where site conditions are highly variable or uncertain.

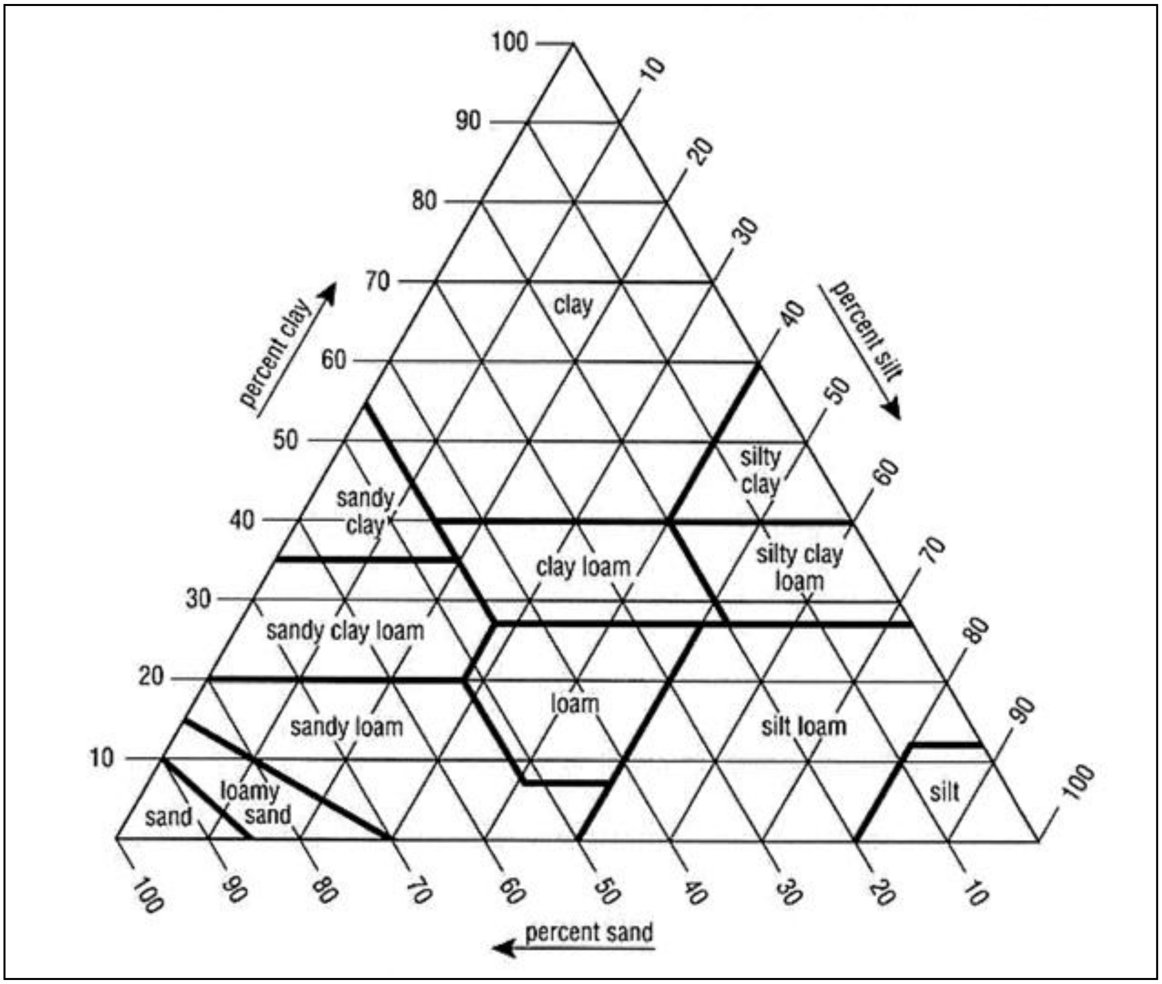


Figure 9.1 USDA Soil Textural Triangle

Table 9.1 Recommended Infiltration Rates based on USDA Soil Textural Classification.

Soil Textural Classification	*Short-Term Infiltration Rate (in./hr)	Correction Factor, CF	Estimated Long-Term (Design) Infiltration Rate (in./hr)
Clean sandy gravels and gravelly sands (i.e., 90% of the total soil sample is retained in the #10 sieve)	20	2	10
Sand	8	4	2
Loamy Sand	2	4	0.5
Sandy Loam	1	4	0.25
Loam	0.5	4	0.13

*From WEF/ASCE, 1998.

Method 2. ASTM Gradation Testing at Full Scale Infiltration Facilities

As an alternative to Table 9.1, recent studies by Massmann and Butchart (2000) were used to develop the correlation provided in Table 9.2. These studies compare infiltration measurements from full-scale infiltration facilities to soil gradation data developed using the ASTM procedure (ASTM D422). The primary source of the data used by Massmann and Butchart was from Wiltsie (1998), who included limited infiltration studies only on Thurston County sites. However, Massmann and Butchart also included limited data from King and Clark County sites in their analysis. This table provides recommended long-term infiltration rates that have been correlated to soil gradation parameters using the ASTM soil gradation procedure.

Table 9.2 can be used to estimate long-term design infiltration rates directly from soil gradation data, subject to the approval of the City. As is true of Table 9.1, the long-term rates provided in Table 9.2 represent average conditions regarding site variability, the degree of long-term maintenance and pretreatment for TSS control. The long-term infiltration rates in Table 9.2 may need to be decreased if the site is highly variable, or if maintenance and influent characteristics are not well controlled. The data that forms the basis for Table 9.2 was from soils that would be classified as sands or sandy gravels. No data was available for finer soils at the time the table was developed. Therefore, Table 9.2 shall not be used for soils with a d_{10} size (10% passing the size listed) less than 0.05 mm (U.S. Standard Sieve).

However, additional data based on recent research (Massmann, et al. 2003) for these finer soils are now available and are shown in Figure 9.2. This figure provides a plot of the relationship between the infiltration rate and the D_{10} of the soil, showing the empirical data upon which it is based. The figure provides an upper and lower bound range for this relationship based on the empirical data. These upper and lower bound ranges can be used to adjust the design infiltration rate to account for site-specific issues and conditions.

Table 9.2 Alternative Recommended Infiltration Rates based on ASTM Gradation Testing

D_{10} Size from ASTM D422 Soil Gradation Test (mm)	Estimated Long-Term (Design) Infiltration Rate (in./hr)
$\geq$ 0.4	9*
0.3	6.5*
0.2	3.5*
0.1	2.0**
0.05	0.8

* Not recommended for treatment
* Refer to SSC-4 and SSC-6 for treatment acceptability criteria

The long-term rates provided in Table 9.2 represent average conditions regarding site variability, the degree of long-term maintenance, and pretreatment for TSS control, and represent a moderate depth to ground water below the pond. The long-term infiltration rates in Table 9.2 may need to be decreased (i.e., toward the lower bound in Figure 9.2) if the site is highly variable, the ground water table is shallow, there is fine layering present that would not be captured by the soil gradation testing, or maintenance and influent characteristics are not well controlled. However, if influent control is good (e.g., water entering the pond is pretreated through a biofiltration swale, pre-sedimentation pond, etc.), a good long-term maintenance plan will be implemented, and the water table is moderate in depth, then an infiltration rate toward the upper bound in the figure could be used.

The infiltration rates provided in Tables 5.1, 5.2, and Figure 9.2 represent rates for homogeneous soil conditions. If more than one soil unit is encountered within 6 feet of the base of the facility or 2.5 times the proposed maximum water design depth, use the lowest infiltration rate determined from each of the soil units as the representative site infiltration rate.

If soil mottling, fine silt or clay layers, which cannot be fully represented in the soil gradation tests, are present below the bottom of the infiltration pond, the infiltration rates provided in the tables will be too high and should be reduced. Based on limited full-scale infiltration data (Massmann and Butchart, 2000; Wiltsie, 1998), it appears that the presence of mottling indicates soil conditions that reduce the infiltration rate for homogeneous conditions by a factor of 3 to 4.

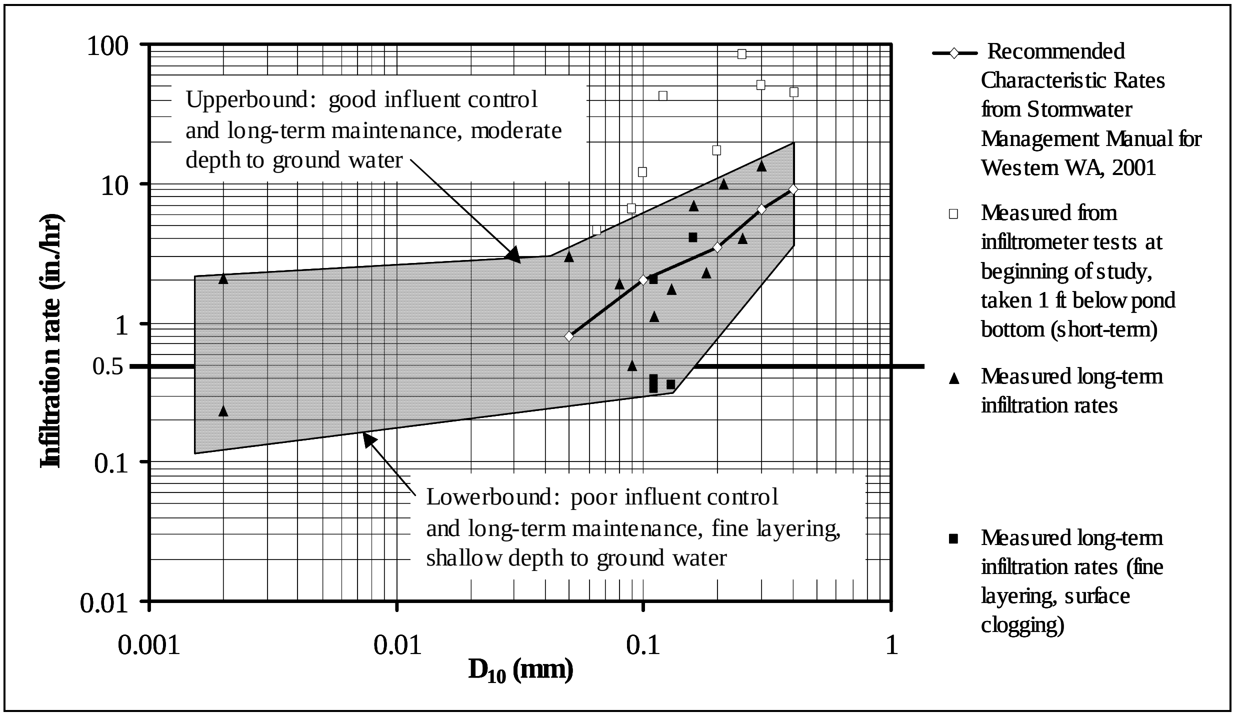


Figure 9.2 Infiltration Rate as a Function of the D_{10} Size of the Soil for Ponds in Western Washington

(the mean values represent low gradient conditions and relatively shallow ponds)

Method 3. In-situ Infiltration Measurements

Where feasible, Ecology encourages in-situ infiltration measurements, using a procedure such as the Pilot Infiltration Test (PIT) described in this section. 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.

Small-scale infiltration tests such as the EPA Falling Head or double ring infiltrometer test (ASTM D3385-88) are not recommended unless modified versions are determined to be acceptable by Ecology or the local jurisdiction. These small-scale infiltration tests tend to seriously overestimate infiltration rates and, based on recent TAC experience, are considered unreliable.

The infiltration rate obtained from the PIT test shall be considered to be a short-term rate. This short-term rate must be reduced through correction factors to account for site variability and number of tests conducted, degree of long-term maintenance and influent pretreatment/control, and potential for long-term clogging due to siltation and bio-buildup.

The typical range of correction factors to account for these issues, based on TAC experience, is summarized in Table 9.3. The range of correction factors is for general guidance only. The specific correction factors used shall be determined based on the professional judgment of the licensed engineer or other site professional considering all issues which may affect the long-term infiltration rate, subject to the approval of the City.

Table 9.3 Correction Factors to be Used With In-Situ Infiltration Measurements to Estimate Long-Term Design Infiltration Rates.

Issue	Partial Correction Factor
Site variability and number of locations tested	CF_v = 1.5 to 6
Degree of long-term maintenance to prevent siltation and bio-buildup	CF_m = 2 to 6
Degree of influent control to prevent siltation and bio-buildup	CF_i = 2 to 6

Total Correction Factor (CF) = $CF_v + CF_m + CF_i$

The following discussions are to provide assistance in determining the partial correction factors to apply in Table 9.3.

Site variability and number of locations tested - The number of locations tested must be capable of producing a picture of the subsurface conditions that represents the conditions throughout the facility site. The partial correction factor used for this issue depends on the level of uncertainty that adverse subsurface conditions may occur. If the range of uncertainty is low - for example, conditions are known to be uniform through previous exploration and site geological factors - one pilot infiltration test may be adequate to justify a partial correction factor at the low end of the range. If the level of uncertainty is high, a partial correction factor near the high end of the range may be appropriate. This might be the case where the site conditions are highly variable due to a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high. A partial correction factor near the high end of the range could be assigned where conditions have a more typical variability, but few explorations and only one pilot infiltration test is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

Degree of long-term maintenance to prevent siltation and bio-buildup . The standard of comparison is the long-term maintenance requirements provided in Appendix F. Full compliance with these requirements would be justification to use a partial correction factor at the low end of the range. If there is a high degree of uncertainty that long-term maintenance will be carried out consistently, or if the maintenance plan is poorly defined, a partial correction factor near the high end of the range may be justified.

Degree of influent control to prevent siltation and biomass buildup - A partial correction factor near the high end of the range may be justified under the following circumstances:

1. If the infiltration facility is located in a shady area where moss buildup or litter buildup from the surrounding vegetation is likely and cannot be easily controlled through long-term maintenance.
2. If there is minimal pre-treatment, and the influent is likely to contain moderately high TSS levels.

If influent into the facility can be well controlled such that the planned long-term maintenance can easily control siltation and biomass buildup, then a partial correction factor near the low end of the range may be justified.

The determination of long-term design infiltration rates from in-situ infiltration test data involves a considerable amount of engineering judgment. Therefore, when reviewing or determining the final long-term design infiltration rate, the City will consider the results of both textural analyses and in-situ infiltration tests results when available.

Infiltration Test Procedure

1. Excavate the test pit to the depth of the bottom of the proposed infiltration facility. Lay back the slopes sufficiently to avoid caving and erosion during the test.
2. 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.
3. Accurately document the size and geometry of the test pit.
4. Install a vertical measuring rod (minimum 5-ft. long) marked in half-inch increments in the center of the pit bottom.
5. 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.
6. 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.
7. 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.
8. 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)
9. 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.

Data Analysis

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

Example

The area of the bottom of the test pit is 8.5-ft. by 11.5-ft.

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 = 600 to 750 gallons per hour = an average of (9.8 + 12.3) / 2 = 11.1 inches per hour.

Applying a correction factor of 5.5 for gravelly sand in Table 9.3 the design long-term infiltration rate becomes 2 inches per hour, anticipating adequate maintenance and pre-treatment.

9.5 Verification of Performance

The project engineer or designee shall inspect infiltration facilities before, during, and after construction as necessary to ensure facilities are built to design specifications, that proper procedures are employed in construction, that the infiltration surface is not compacted, and that protection from sedimentation is in place.

9.6 Infiltration Facilities and Underground Injection Control

The following information on UIC is excerpted from the 2006 Ecology document titled “Guidance for UIC Wells that Manage Stormwater” (Ecology 2006). This document is available online at: <http://www.ecy.wa.gov/biblio/0510067.html>.

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

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

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

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

The two basic requirements of the UIC Program are:

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

UIC wells must either be rule-authorized or covered by a state waste discharge permit to operate. If a UIC well is rule-authorized, a permit is not required. Rule authorization can be rescinded if a UIC well no longer meets the non-endangerment standard. Ecology can also require corrective action or closure of a UIC well that is not in compliance. Additional information on UIC systems can be found online at <http://www.ecy.wa.gov/biblio/0510067.html>.

9.7 Infiltration BMPs

9.7.1 BMP 9.10 Infiltration Basins

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

Design Criteria Specific for Infiltration Basins

1. Access must be provided for vehicles to easily maintain the forebay (presettling basin) area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.
2. The slope of the basin bottom shall not exceed 3 percent in any direction.
3. Lining material – Basins can be open or covered with a 6- to 12-inch layer of filter material such as coarse sand, or a suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. A nonwoven geotextile shall be selected for covers that will function sufficiently without plugging (see geotextile specifications in Chapter 3.1). The filter layer can be replaced or cleaned when and if it becomes clogged.
4. Erosion protection of inflow points to the basin must be provided (e.g., riprap, flow spreaders, energy dissipaters - see Volume I, Chapter 6.6).
5. Vegetation – Open infiltration basins must have sufficient vegetation established on the basin floor and side slopes to prevent erosion and sloughing. The embankment, emergency spillways, basin floor and sideslopes, spoil and borrow areas, and other disturbed areas shall be stabilized and planted, preferably with grass (see Chapter 2.6, Table 2.1).
6. Fertilizers shall be applied only as necessary and in limited amounts to avoid contributing to groundwater pollution.

Construction Criteria for Basins

1. Initial basin excavation shall be conducted to an elevation at least 1 foot higher than the final elevation of the basin floor. Infiltration basins shall not be excavated to final grade until after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation must remove all accumulation of silt in the infiltration basin before putting it in service.
2. Infiltration basins facilities should not be used as temporary sediment traps during construction.
3. Traffic Control – Relatively light-tracked equipment is recommended for construction of infiltration basins to avoid compaction of the basin floor. The use of draglines and trackhoes should be considered.
4. The infiltration facility area shall be clearly identified and protected prior to construction to prevent compaction of underlying soils by vehicle traffic.

9.7.2 BMP 9.20 Infiltration Trenches

Infiltration trenches are generally at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grass-covered area with a surface inlet. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the stormwater in a stone trench.

Note: infiltration trenches for residential roof downspouts are covered in Chapter 12 of this volume.

See Figures 4 - for examples of infiltration trench facilities in various configurations and site settings. Included in the details are infiltration trenches with a grass buffer, as well as an example of a parking lot perimeter infiltration trench design.

Design Criteria for Trenches

1. Due to accessibility and maintenance limitations, infiltration trenches must be carefully designed and constructed.
2. The aggregate material for the infiltration trench must consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Void space for these aggregates must be in the range of 30 to 40 percent.
3. The aggregate fill material shall be completely encased in an engineering geotextile material. Geotextile must surround all of the aggregate fill material except for the top 1 foot, which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging.
4. Overflow paths shall be identified in the case that the infiltration trench becomes plugged. The overflow path shall not be erosive, nor cause flooding of structures.
5. Infiltration trenches may be placed in fill material if the fill is placed and compacted under the direct supervision of a geotechnical engineer or professional civil engineer with geotechnical expertise, and if the measured infiltration rate of the fill is at least 8 inches per hour. Infiltration rates can be tested using the methods described in Chapter 9.4 of this volume. The design of the trench shall be based on the characteristics of the underlying soil.
6. A structure with a sump shall be located upstream of the trench, which provides a minimum of 12 inches of depth below the outlet riser. The outlet riser pipe bottom shall be designed so as to be submerged at all times, and a screening material shall be installed on the pipe outlet.
7. Trenches may be located under pavement if designed by a professional engineer. Trenches must include an overflow at least 1 foot below the pavement, and in a location which can accommodate the overflow without creating a significant adverse impact to downhill properties or drainage systems. This is intended to prevent saturation of the pavement in the event of system failure. The trench depth must be measured from the overflow elevation, not the ground surface elevation.
8. An observation well shall be installed at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. It should consist of a perforated PVC pipe which is 4 to 6 inches in diameter and it should be constructed flush with the ground elevation. For larger trenches a 12- to 36-inch diameter well can be installed to facilitate maintenance operations such as pumping out the sediment. The top of the well should be capped to discourage vandalism and tampering.

Construction Criteria for Trenches

1. Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care must also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic (see Erosion and Sediment Control Criteria in Volume II).
2. The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping, geotextile clogging, and settlement problems.

3. Natural or fill soils must be prevented from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.
4. Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll must overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.
5. Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. Soil piping, geotextile clogging, and possible surface subsidence will be avoided by this remedial process.
6. Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

Chapter 10 - Bioretention Facilities

10.1 Introduction

Bioretention facilities are shallow stormwater retention systems that are designed to mimic forested systems by controlling stormwater through detention, infiltration, and evapotranspiration. Bioretention facilities also provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation. In contrast to traditional stormwater pond designs, these facilities are typically smaller-scale and are integrated into the landscape to better mimic natural hydrologic systems.

For the purposes of this manual, bioretention areas with contributing basins meeting the below criteria are considered to be on-site stormwater management BMPs. These small bioretention areas are referred to as "raingardens" in this manual and can be sized and designed in accordance with Volume V.

Contributing basins for raingardens must meet the following criteria:

- Have a contributing impervious area, x, less than or equal to 2,000 square feet
- Have a contributing pervious area, y, less than or equal to 13,000 square feet
- Have a combination of impervious and pervious square footages such that the following equation holds:

$$6.5x + y \leq 13{,}000 \text{ square feet}$$

For the purposes of this manual, bioretention areas serving contributing basins that do not meet the above criteria are categorized as bioretention facilities and must be sized and designed in accordance with the criteria in this chapter.

Furthermore, bioretention facilities are categorized as either small or large, depending upon the size and nature of the contributing drainage area. For the purpose of this manual, a large bioretention facility has a drainage area that exceeds any of the following thresholds:

a. 5,000 square feet or more of pollution-generating impervious surface (PGIS)

b. 10,000 square feet or more of impervious area

c. Three-fourths of an acre or more of lawn and landscape.

10.2 Applicability

1. A minimum clearance is necessary between the lowest elevation of the bioretention soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer. For small bioretention facilities thresholds, this clearance is 1 foot, for large bioretention facilities, a clearance of 3 feet is required.
2. Bioretention facilities are applicable in parking lots as concaved landscaped areas (i.e., situated lower than the height of the parking lot surface so that stormwater runoff is directed as sheet flow into the bioretention area.). This application, in conjunction with porous surfaces in the parking lot, can greatly attenuate stormwater runoff.
3. Bioretention facilities meet the requirements for basic and enhanced treatment (see Volumes I and III) when the bioretention soil is designed in accordance with the treatment soil requirements outlined in the design criteria below, and it is shown that at least 91 percent of the influent runoff file produced using a continuous simulation model is infiltrated. Applicable drawdown requirements must also be met (i.e., draining within 24 hours).

10.3 Bioretention Facility Design Criteria

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

1. Flow entrance / presettling
2. Cell ponding area
3. Soils
4. Underdrain (if included)
5. Overflow
6. Plant material
7. Mulch layer
8. Modeling and sizing procedure.

Special Considerations

1. Minimizing compaction of the base and sidewalls of bioretention facilities is critical. Excavation, soil placement, or soil amendment shall not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the facility and no heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should be allowed on the bottom of the facility. If machinery must operate in the facility for excavation, light weight, low ground-contact pressure equipment should be used and the base shall be scarified at completion to refracture soil to a minimum of 12 inches.
2. In the event that the downstream pathway of infiltration and interflow can't be maintained, and/or the infiltration capacity is insufficient to handle the contributing area flows (e.g., a facility enclosed in a loop roadway system or a landscape island within a parking lot), an underdrain system can be incorporated into the facility. The underdrain system can then be conveyed to a nearby vegetated channel, another stormwater facility, or dispersed into a natural protection area. Facilities with underdrains may not use the modeling credits outlined in this section. See the underdrain section below for additional information.

Flow Entrance/Presettling

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

Four primary types of flow entrances can be used for surface stormwater facilities:

1. Dispersed, low velocity flow across a grass or landscape area – this is the preferred method of delivering flows to the facility and can provide initial settling of particulates
2. Dispersed flow across pavement or gravel and past wheel stops for parking areas
3. Drainage curb cuts for driveway or parking lot areas – curb cuts shall include rock or other erosion protection material in the channel entrance to dissipate energy
4. Pipe flow entrance – piped entrances shall include rock or other erosion protection material in the facility entrance to dissipate energy and/or provide flow dispersion.

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

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

1. If concentrated flows are entering the facility, engineered flow dissipation (e.g., rock pad or flow dispersion weir) must be incorporated.
2. A minimum 3-inch grade change between the edge of a contributing impervious surface and the vegetated flow entrance is required.
3. Until the upstream catchment area is thoroughly stabilized, flow diversion and erosion control measures must be installed to protect the bioretention area from sedimentation.
4. If the catchment area exceeds 2,000 square feet, a pre-settling facility (e.g., filter strip, pre-settling basin, or vault) may be required. Dispersed flow should not be concentrated for pre-settling purposes.

Cell Ponding Area

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

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

1. The ponding depth shall be a maximum of 12 inches (see alternative design under the overflow section below)
2. The surface pool drawdown time shall be a maximum of 24 hours
3. The maximum planted side slope shall be 3H:1V
4. The bottom width shall be no less than 2 feet
5. The minimum freeboard measured from the invert of the overflow pipe or earthen channel to facility overtopping elevation shall be 6 inches for small bioretention facilities, and 1 foot for large bioretention facilities.
6. If berms are used to achieve the minimum top elevation needed to meet ponding depth and freeboard needs, maximum slope on berm shall be 4H:1V, and minimum top width of design berm shall be 1 foot. Soil used for berms shall be imported bioretention soil or amended native soil and compacted to a minimum of 90 percent dry density.

Overflow

Unless designed for full infiltration of the entire continuous model runoff file, bioretention facilities must include an overflow. Facility overflow can be provided by a drain pipe installed at the designed maximum ponding elevation and connected to a downstream BMP or an approved discharge point.

Overflows shall be designed to convey the 100-year recurrence interval flow. This assumes the facility will be full due to plugged orifices or high inflows. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

It is possible to design additional detention storage above the 12-inch design water surface (to a maximum of 30 inches total) by including an orifice control system within the overflow structure to help attenuate the flows. For example, a Type 1 Catch Basin with removable down-turned elbow (using properly designed orifices) could be used. This would allow the bioretention facility to dewater in a reasonable timeframe (less than 24-hours). If using this design, the plant selection must clearly reflect the additional proposed storage depth.

Soils

For basic and enhanced treatment to be provided, the following criteria must be met:

1. The bioretention soil mix must meet the requirements of Chapter 9.2 of this volume.
2. Minimum depth of treatment soil must be 18 inches.
3. A soils report, prepared and stamped by a geotechnical professional, shall be required that addresses the following for each bioretention or rain garden facility:
    a. A minimum of one soil log or test pit is required at each facility location.
    b. The soil log shall extend a minimum of 4 feet below the bottom of the subgrade (which is the lowest point of excavation where soil is to be amended).
    c. The soil log shall describe the USDA textural class of the soil horizon(s) through the depth of the log and note any evidence of high groundwater level, such as mottling.
    d. As noted above in the applicability section, for most facilities the bottom of the subgrade must be at least 3 feet above the seasonal high groundwater level or other impermeable layer. A minimum of 1 foot of clearance may be acceptable if the contributing area is below the thresholds specified previously.
    e. A primary pathway for stormwater discharge from a bioretention facility with less permeable (Type C) soils can be through interflow in the upper soil structure. The soil investigation should include a detailed description of the condition of the upper soil structure, including the pathway the discharged stormwater will take.
    f. The report shall include recommendations on the degree of soil amendment (see Section 3.14) necessary to reestablish an upper soil profile similar to an undisturbed forested condition that will allow interflow through the upper soil structure.
    g. Where the native soils do not meet the desired soil conditions, the soil shall be improved by amending the soil as discussed in Section 3.14. The depth of the soil amendment should be determined by the designer with deeper amendments, up to 4 feet, allowing a smaller foot print for amended areas. The bottom depth shall also be kept above the seasonal high groundwater level or other impermeable layer as specified previously.
    h. Infiltration rates of the native soil (i.e., the undisturbed soil below the imported and/or amended facility soil) must be used when sizing and modeling bioretention facilities. The native infiltration rate shall be determined using the methods outlined in Chapter 9 of this volume.

Underdrain (Optional)

The area above an underdrain pipe in a bioretention or rain garden provides attenuation and pollutant filtering. Underdrain systems shall be installed only if the bioretention or rain garden is:

- Located where infiltration is not permitted and a liner is used
- In soils with infiltration rates that are not adequate to meet maximum pool drawdown time.

The underdrain pipe diameter will depend on hydraulic capacity required (4 to 8 inches is common). The underdrain can be connected to a downstream BMP such as another bioretention/rain garden facility as part of a connected system, or to an approved discharge point. A geotextile fabric (see Chapter 2 of this volume) must be used between the soil layer and underdrain.

Planting

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

The primary design considerations for plant selection include:

1. Soil moisture conditions – plants should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for the lengths of time anticipated by the facility design.
2. Above and below ground infrastructure in and near the facility – plant size and wind firmness should be considered within the context of the surrounding infrastructure. Rooting depths shall be selected to avoid damage to underground utilities if present. Slotted or perforated pipe shall be 5 feet minimum from tree locations and all side sewer pipes.
3. Adjacent plant communities and potential invasive species control – if adjacent to invasive species, consider planting fast growing, hearty species. Shrubs may be used to help shade-out invasive weeds.
4. Aesthetics – These facilities should be designed to blend into the surrounding landscaping, which will provide a more aesthetically pleasing stormwater facility. In addition, visually pleasing plant designs add value to the property and encourage community and homeowner acceptance.

In general, the predominant plant material utilized in bioretention and rain garden facilities are facultative species adapted to stresses associated with wet and dry conditions. Soil moisture conditions will vary within the facility from saturated (bottom of facility) to relatively dry (rim of facility). Accordingly, wetland plants may be used in the lower areas, if saturated soil conditions exist for appropriate periods, and drought-tolerant species planted on the perimeter of the facility or on mounded areas.

Native plant species, placed appropriately, tolerate local climate and biological stresses and usually require no nutrient or pesticide application in properly designed soil mixes. Natives can be used as the exclusive material in a bioretention or rain garden facility, or in combination with hardy cultivars that are not invasive and do not require chemical inputs. To increase survival rates and ensure quality of plant material, the following guidelines are suggested:

1. As a general guideline, a minimum of three trees, three shrubs, and three herbaceous species should be incorporated to protect against facility failure due to disease and insect infestations of a single species. Grass coverage alone will be acceptable. The planting arrangement should be designed to create a dense coverage of plants, shrubs, and trees.
2. Plants should conform to the standards of the current edition of American Standard for Nursery Stock as approved by the American Standards Institute, Inc., or the 2005 Puget Sound Action Team Low Impact Development Technical Guidance Manual for Puget Sound (PSAT 2005). All plant grades shall be those established in the current edition of American Standards for Nursery Stock (current edition: ANSI Z60.1-2004).
3. All plant materials shall have normal, well-developed branches and root systems, and be free from physical defects, plant diseases, and insect pests.
4. Plant size – small plant material provides several advantages and is recommended. Specifically, small plant material requires less careful handling, less initial irrigation, experiences less transplant shock, is less expensive, adapts more quickly to a site, and transplants more

successfully than larger material. Small trees and shrubs are generally supplied in pots of 3 gallons or less.

5. All plants should be tagged for identification when delivered.
6. Optimum planting time is typically fall (beginning mid October). Winter planting is acceptable; however, extended freezing temperatures shortly after installation can increase plant mortality. Spring is also acceptable, but requires more summer watering than fall plantings. Summer planting is the least desirable and requires regular watering for the dry months immediately following installation.
7. A permanent irrigation system using potable water may be used but is not desirable. An alternative means of irrigation that is a readily available nonpotable source should be considered to maximize efficient use of resources. Any nonpotable sources must be analyzed to ensure that they do not contain chemicals that might harm or kill the vegetation. Any permanent irrigation system that relies on potable water should be designed to apply no more than 0.2 inches of water every 14 days from June through September, after the 2-year establishment period.

Mulch Layer

Bioretention and rain garden facilities shall be designed and maintained with a mulch layer or a dense groundcover. Mulch shall be:

1. Compost in the bottom of facilities (compost is less likely to float than wood chip mulch and is a better source for organic materials)
2. Wood chip mulch composed of shredded or chipped hardwood or softwood on cell slopes
3. Free of weed seeds, soil, roots and other material that is not trunk or branch wood and bark
4. A maximum of 3 inches thick for compost or 4 inches thick for wood chips (thicker applications can inhibit proper oxygen and carbon dioxide cycling between the soil and atmosphere).

Mulch shall not include grass clippings (decomposing grass clippings are a source of nitrogen and are not recommended for mulch in bioretention areas), mineral aggregate, or pure bark (bark is essentially sterile and inhibits plant establishment).

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

Modeling and Sizing

Bioretention facilities are sized by using an approved continuous simulation model and treating the facility as an infiltration facility with appropriate stage-storage and overflow/outflow rates.

When sizing bioretention facilities, the assumptions listed in Table 10.1 shall be applied. It is recommended that bioretention cells be modeled as a layer of soil (with specified infiltration rate) with infiltration to underlying soil, ponding, and overflow. The tributary areas, cell bottom area, and ponding depth should be iteratively sized until the duration curves and/or peak values meet the applicable flow control requirements (see Volume I).

Table 10.1 Continuous Modeling Assumptions for Bioretention Cells.

Variable	Assumption
Computational Time Step	15 minutes
Inflows to Facility	Surface flow and interflow from drainage area routed to facility
Precipitation and Evaporation Applied to Facility	Yes (always activated in WWHM bioretention module)
Bioretention Soil Infiltration Rate	For imported soil, rate is 2.5 inch per hour. For compost amended native soil, rate shall be equal to native soil design infiltration rate.
Bioretention Soil Porosity	40%
Bioretention Soil Depth	Minimum of 18 inches
Native Soil Infiltration Rate	Measured infiltration rate, including applicable safety factors (see Volume III, Appendix III-A)
Infiltration Across Wetted Surface Area	Only if side slopes are 3:1 or flatter
Overflow	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over riser edge or riser notch.

Chapter 11 - Low Impact Development (LID)

11.1 Introduction

Low impact development (LID) BMPs focus on infiltrating, dispersing, evaporating, and reusing stormwater. In contrast to conventional BMPs that typically collect and convey runoff to one location on the site, LID applications treat stormwater in relatively small-scale, dispersed facilities located as close to the source of the runoff as possible.

The City encourages the use of Low Impact Development BMPs where applicable. The following are examples of LID BMPs that may be considered for use in the City of Everett:

1. Bioretention/raingardens – see Chapter 10 (bioretention) and Chapter 12 (raingardens)
2. Alternative Paving Surfaces
3. Rainfall Reuse Systems
4. Vegetated Roofs

Specific criteria for bioretention systems and raingardens are presented in this manual in Chapters 10 and 12 respectively. A general description of alternative paving surfaces, rainfall reuse systems, and vegetated roofs is given later in this chapter.

11.2 Design of LID BMPs

The design of LID BMPs provided in the City of Everett shall be in accordance with Chapter 2 and design criteria suggested and/or required by Ecology. At the time this chapter was written, the Ecology Stormwater Management Manual for Western Washington (February 2005) referred designers to the "Low Impact Development Technical Guidance Manual for Puget Sound", January 2005 edition, published by the Puget Sound Action Team and the Washington State University, Pierce County Extension.

Hydrologic modeling for LID site designs must conform to all applicable minimum requirements outlined in Volume I, and in particular Minimum Requirement #4: Preservation of Natural Drainage System and Outfalls, Minimum Requirement #5: Onsite Stormwater Management, and Minimum Requirement #7: Flow Control (including the applicable predeveloped land-cover assumptions used in hydrologic modeling). At the time this chapter was written, information on hydrologic modeling of LID BMPs, including flow credits that could be obtained, was presented in Appendix III-C of the Ecology Manual.

11.3 Alternative Paving Surfaces

Alternative paving surfaces are designed to accommodate pedestrian, bicycle, and auto traffic while allowing infiltration and storage of stormwater. These following types of surfaces are included:

1. porous asphalt pavement;
2. porous concrete;
3. grid or lattice rigid plastic or paving blocks where the holes are filled with soil, sand, or gravel; and
4. cast-in-place paver systems.

11.4 Rainfall Reuse Systems

Rainfall reuse systems are systems designed to collect stormwater runoff from non-polluting surfaces, such as roofs, and to make use of the collected water. Reuse of the runoff can be for irrigation, potable, and non-potable uses but would require different levels of storage and water quality treatment depending on the intended use.

11.5 Vegetated Roofs

Vegetated roofs are areas of living vegetation installed on top of buildings to provide flow control via detention, attenuation, soil storage, and losses to interception, evaporation, and transpiration. Vegetated roofs are also known as eco-roofs, green roofs, and roof gardens. Vegetated roofs have the additional benefits of providing relaxing green space, reducing temperature within urban centers, and have a longer life span than traditional roofing materials.

A vegetated roof consists of a system in which several materials are layered to achieve the desired vegetative cover and drainage characteristics. Design components vary depending on the vegetated roof type and site constraints, but typically include a waterproofing material, a drain system, a drainage layer, a separation fabric, a growth medium (soil), and vegetation.

Chapter 12 - Onsite Stormwater Management BMPs

12.1 Introduction

Per Minimum Requirement #5, on-site stormwater management is required to infiltrate, retain, and disperse stormwater runoff on-site to the maximum extent feasible without causing flooding or erosion impacts. This chapter outlines the on-site stormwater management strategies and BMPs that must be implemented, where feasible, in order to meet Minimum Requirement #5.

With the exception of Vegetation Protection Areas and Soil Amendments, Quality, and Depth, the BMPs in this chapter are ***not*** applicable in the following situations:

1. within 100 feet of slopes steeper than 20% (5:1)
2. within 200 feet of a landslide hazard area
3. within 10 feet of any structure or property lines
4. if erosion or flooding of downstream properties is likely to occur
5. upstream of the primary and reserve drainfield areas for sites with septic systems

This chapter provides information on the following BMPs:

BMP 12.10 Vegetation Protection Areas

BMP 12.20 Soil Amendments, Quality and Depth

BMP 12.30 Onsite Infiltration Areas

BMP 12.40 Raingardens

BMP 12.40 Downspout Dispersion Systems

BMP 12.50 Concentrated Flow Dispersion

BMP 12.60 Sheet Flow Dispersion

12.2 Downspout Disconnection

As part of meeting Minimum Requirement #5 for on-site stormwater management, the following downspout disconnection methods shall be considered, in the following order:

1. BMP 12.30 On-site infiltration areas
2. BMP 12.40 Raingardens
3. BMP 12.50 Downspout dispersion

Other innovative downspout control BMPs such as rain barrels, ornamental ponds, downspout cisterns, or other downspout water storage devices may also be used to meet Minimum Requirement #5 with prior approval by the City.

12.3 On-site Stormwater Management BMPs

12.3.1 BMP 12.10 Vegetation Protection Areas

The set-aside of vegetation protection areas can greatly mitigate the impacts of development on the site's hydrological cycle. The amount of impervious areas on a site is directly reduced as a result of the protection areas. In addition vegetation protection areas can often be located to receive sheet flow from necessary parking areas, driveways, etc. , which turns these surfaces into ineffective impervious surfaces for the purpose of determining the applicability of the minimum requirements.

The following steps shall be taken for vegetation protection areas formally set-aside as part of meeting the site's stormwater management requirements.

For vegetation protection areas with existing vegetation:

1. The existing vegetation to be protected shall be clearly called out in the project's Stormwater Site Plan, and shall be shown on the Site Development Plan (see Volume I, Chapter 3).
2. The existing vegetation to be protected shall be delineated on the site with silt, construction, or other appropriate fencing to protect soils and vegetation from construction damage.
3. An on-site meeting and site-walk shall be conducted with equipment operators to clarify construction boundaries and the limits of disturbance.
4. The critical root zones of trees to be retained shall be protected.

   The critical root zone usually extends beyond a tree's canopy or drip line and can be approximated by drawing a circle around the tree, with the trunk at the circle's center. The radius of the circle is equal, in feet, to the tree's diameter, in inches, at 4.5 feet above the ground elevation at the trunk (this elevation is called the diameter at breast height, or dbh). For example, a tree with a diameter of 6 inches dbh has a critical root zone that extends 6 feet from the tree in all directions; a 15 inch dbh tree, has a critical root zone that extends 15 feet from the tree.
5. Excavation or changing the grade in the critical root zone of trees that have been designated for protection shall be avoided. If the grade level around a tree is to be raised, a dry rock wall or rock well can be constructed around the tree at the edge of the critical root zone.
6. The installation of any impervious surfaces in critical root zone areas shall be avoided. Where road or sidewalk surfaces are needed under a tree canopy, non-mortared porous pavers or flagstone (rather than concrete or asphalt) or bridging techniques should be used. Tree conservation areas shall be prepared to better withstand the stresses of the construction phase by fertilizing, pruning, and mulching around them well in advance of construction activities.
7. The stockpiling or disposal of excavated or construction materials in the vegetation retention areas shall be prohibited to prevent contaminants from damaging vegetation and soils.
8. Wounds to tree trunks and limbs shall be prevented during the construction phase.

For vegetation protection areas with replanted vegetation:

1. Native plant species adapted to the local environment shall be used.
2. Planting shall occur during seasons that provide best opportunity for survival of vegetation (usually late fall, winter, or early spring months)
3. Excess surface water runoff shall be controlled to prevent erosion, particularly during vegetation establishment.
4. Proper seedbed preparation shall be utilized.
5. Germinating plants shall be protected, as applicable, by fertilizing and mulching.
6. Areas designated for revegetation from soils compaction shall be protected by restricting heavy equipment during construction
7. Proper soil amendments shall be provided where necessary.

8. Over-excavation of cut sections shall be necessary if the cut is in a location that will be utilized for on-site stormwater management. A depth shall be cut that will allow replacement of stockpiled native topsoil to the entire depth that was on the site up to a required maximum of 3 feet.
9. Cut sections where native topsoil replacement is required shall require ripping of any cemented till layers to a depth of 6 inches. Subsequently, the replacement of stockpiled topsoil shall be thoroughly mixed into the ripped till to provide a gradual transition between the cemented till layer and the topsoil.
10. Stockpiled topsoil shall be replaced in lifts no greater than 1 foot deep and compacted by rolling to a density that matches existing conditions.
11. For any soils removed and replaced on site as described above, the soil amendment requirements in BMP 12.20 must also be met.

12.3.2 BMP 12.20 Post-Construction Soil Quality and Depth

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions including: water infiltration; nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions lost, but such landscapes themselves become pollution-generating pervious surfaces due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

Establishing soil quality and depth regains greater stormwater functions in the post development landscape accomplishes the following goals:

1. provides increased treatment of pollutants and sediments that result from development and habitation, and
2. minimizes the need for some landscaping chemicals, thus reducing pollution through prevention.

Applicability

- Soil amendments are required for the disturbed areas of sites subject to Minimum Requirement #5, as outlined in Volume I.
- For sites where Minimum Requirement #5 does not apply, if the site is acceptable for traditional lawn installation, then a compost-amended soil lawn is strongly recommended. A compost-amended lawn will drain equally well, while providing the incidental stormwater retention and detention benefits.
- If the site being considered does not drain well, an alternative to planting a lawn should be considered. If the site is not freely draining, and turf replacement is still being attempted, compost amendment will still provide stormwater benefits but should be incorporated into the soil at a reduced ratio of no more than 30 percent by volume. This upper limit is suggested in the Pacific Northwest because extended saturated winter conditions may create water logging of the lawn.
- Soil amendments shall be used in areas that are to be incorporated into the stormwater drainage system such as runoff dispersion areas, vegetated channels, rain gardens, and bioretention areas and also into the lawn and landscape areas of the development. (Note: See the design criteria

below and under each individual BMP for the application rate for each particular BMP technique.)

- There is the potential that increasing the moisture content within the soil could also increase soil instability in areas with steep slopes. However, the Washington State Department of Transportation (WSDOT) has been incorporating compost-amendment in almost all of its vegetated sites since 1992 and has not experienced problems, even on the steepest sites (33 percent slope), as a result of the increased moisture holding capacity within the soils. (Note: See design criteria below for requirements of steep slope soil amendment.)

Design Criteria

Several options are available for creating the appropriate soil quality and depth and are listed below. There are different desired soil quality and depths depending on the function at the location that is being amended (e.g., either a part of the stormwater drainage system, landscaped area, or lawn). Follow the option that works best with the site and then refer to Table 12.1 for estimating soil depth and height changes when applying soil amendments.

<u>OPTION 1 – Amend Existing Soils in Place:</u>

Scarify or till existing subgrade to 4 inches depth (or to depth needed to achieve a total depth of 12 inches of uncompacted soil after calculated amount of amendment is added, see specific subsections below). Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.

Within *Stormwater Drainage System* locations or *Landscaped Areas (10 percent organic content)* – Place and rototill 3 inches of composted material into 5 inches of soil (a total depth of about 9.5 inches, for a settled depth of 8 inches). As noted previously, subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Rake beds to smooth and remove rocks larger than 2 inches diameter. Mulch areas with 2 inches of organic mulch.

Within *Lawn Areas (5 percent organic content)* – Place and rototill 1.75 inches of composted material into 6.25 inches of soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches). As noted previously, subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Water or roll to compact soil to 85 percent of maximum. Rake to level, and remove surface woody debris and rocks larger than 1 inch in diameter.

<u>OPTION 2 – Stockpile Site Topsoils Prior to Grading for Reapplication:</u>

If placed topsoil plus compost or other organic material will amount to less than 12 inches: scarify or till subgrade to depth needed to achieve 12 inches of loosened soil after topsoil and amendment are placed. Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.

Stockpile and cover soil with weed barrier material that sheds moisture yet allows air transmission, in approved location, prior to grading.

Replace stockpiled topsoil prior to planting.

Within *Stormwater Drainage System* locations or *Landscaped Areas (10 percent organic content)* – Place and rototill 3 inches of composted material into 5 inches of replaced soil (a total depth of about 9.5 inches, for a settled depth of 8 inches). Subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Rake beds to smooth and remove rocks larger than 2 inches in diameter. Mulch areas with 2 inches of organic mulch or stockpiled duff.

Within *Lawn Areas (5 percent organic content)* – Place and rototill 1.75 inches of composted material into 6.25 inches of replaced soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches). Subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Water or roll to compact soil to 85 percent of maximum. Rake to level, and remove surface woody debris and rocks larger than 1 inch in diameter.

<u>OPTION 3 – Import Topsoil Meeting Organic Matter Content Standards:</u>

Scarify or till subgrade in two directions to 6 inches depth. Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.

Within *Stormwater Drainage System* locations or *Landscaped Areas (10 percent organic content)* – Use imported topsoil mix containing 10 percent organic matter (typically around 40 percent compost). Soil portion must be sand or sandy loam as defined by the USDA. Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil. Place 3 inches of topsoil mix on the surface. Rake smooth and remove surface rocks over 2 inches diameter. Mulch planting beds with 2 inches of organic mulch.

Within *Lawn Areas (5 percent organic content)* – Use imported topsoil mix containing 5 percent organic matter (typically around 25 percent compost). Soil portion must be sand or sandy loam as defined by the USDA. Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil. Water or roll to compact soil to 85 percent maximum. Rake to level, and remove surface rocks larger than 1 inch in diameter.

Additional Information on Soil Depth

After determining the elevation to which a site must be graded for drainage and other reasons, estimation of the changes in soil depth and height need to be calculated. A final grade of the soil should range between one-half inch and 2 inches below the elevation of sidewalks, driveways, and other impervious surfaces on the site.

The difference in volume of the dense verses the loose soil condition is determined by the “fluff factor” of the soil. The fluff factor of compacted subsoils in the Puget Sound Area tends to be between 1.3 and 1.4. Rototilling typically penetrates the upper 6 to 8 inches of the existing soil. Assuming only a 6-inch depth is achieved, this depth adjusted by the fluff factor will correspond to a 7.8- to 8.4-inch depth of loose soil. This loose volume would then be amended at a 2:1 ratio of loose soil to compost, corresponding to an imported amendment depth of approximately 4 inches for this example. In the loose state, both the soil and compost have a high percentage of pore spaces (volume of total soil not occupied by solids). The resulting change in elevation must account for compost settling into void spaces of the loose soil (assume 15 percent of the soils’ void spaces become occupied by compost particles). After compost incorporation, the amended site will undergo some degree of compaction by the rolling procedure and the weight of the soil itself. Assume a compression factor of 1.15 for soils with a 1.3 fluff factor and 1.2 for soils with a 1.4 fluff factor (15 to 20 percent of the soils’ void spaces will become occupied by compost particles.) The resulting change in elevation for a site amended to a 6-inch depth will be approximately 3 inches.

Table 12.1 Estimating Soil Depth and Height Changes.

Procedure	Calculation	Relative Elevation Inches
Beginning Elevation		0
Rototill soil to a depth of 6 inches and assuming 1.4-inch fluff factor	Depth achieved by machinery x fluff factor of soil: (6 x 1.4) = 8.4 8.4 – 6 = 2.4	+2.4
Add compost, 2 units soil to 1 unit compost, by loose volume	Depth of soil ÷ 2: 8.4 ÷ 2 = 4.2	+4.2
Filling of pore spaces	Depth of loose soil x percentage of pore space filled by compost addition: 8.4 x (-.15) = -1.3	-1.3
Rototill compost into soil and roll site to compact soil, assuming compression factor of 1.2	(Amended soil depth ÷ compression factor) – amended soil depth:	-2.1
Resulting Elevation Change	Sum	+3.2

Compost Quality

- Compost shall be prepared by the controlled decomposition of organic materials. Acceptable feedstocks include, but are not limited to, yard debris, wood waste, land-clearing debris, brush, branches, manure, biosolids, food residuals, and forest byproducts. The product shall have a uniform, dark, soil-like appearance and an earthy loam-like odor. No ammonia or putrid smells shall be present. Minimum organic matter shall be 35 percent (dry-weight basis). Particles shall be 100 percent passing the 1-inch sieve. pH range shall be between 6.0 and 8.5 for wetlands and streamside locations, and 6.0 and 8.0 for other locations. Foreign material shall be no more than 2 percent on a dry-weight or volume basis, whichever provides the least foreign material. Material shall come from a source that is permitted by (or exempt from) Tacoma-Pierce County Health Department (TPCHD) rules.
- Compost for the approved rates listed above must be Class A compost per Washington State Department of Ecology (Ecology) interim Compost Quality Guidelines ("composted materials" defined in Washington Administrative Code (WAC) Chapter 173-350 Section 220) or topsoil manufactured from these composts plus sand or sandy soil. Products should be identified on the site development plans and recent product test sheets provided showing that they meet additional requirements for organic matter content and a carbon to nitrogen ratio below 25:1. The carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.
- Utilize alternatives to straw mulch, such as composted mulch or wood-based mulch, for construction erosion and sediment control.
- Apply compost on slopes instead of hydromulch.
- Soils amendments should be installed postconstruction, prior to installation of landscaping and turf, unless used as a step in the lot preparation process involving minimal excavation foundation systems.

Steep Slope Areas

Existing Steep Slope Areas – On-site steep slope areas that already have native soils and robust native landscapes should be protected from disturbance as a preference to re-grading and augmenting the disturbed soil with soil amendment. Also, steep slope areas may be subject to critical area protection per the City's Critical Areas Code (EMC 19.37), which outlines criteria for classification of geologically hazardous areas.

Steep slopes that remain on site and that are not subject to the City's Critical Areas Code which are not constructed as part of the development AND where native soils and vegetation is sparse should be amended by planting deep rooting vegetation. Soil amendments shall be applied via a pit application at least twice as wide as the root ball of the vegetation being planted with a mix of 50 percent compost to 50 percent soil mixture.

Constructed Steep Slopes – In lawn and landscaped areas, the slope angle should be minimized to the greatest extent possible for both stability and lawn maintenance concerns and shall be no steeper than the angle of repose of the underlying soils. Terracing is recommended to minimize steep slope angles.

Adequate drainage systems must be installed on constructed steep slope areas where it is determined that retained runoff may cause instability. To provide adequate drainage, a professional engineer must determine the drainage pattern of the slope and design/install controlled drainage at the outfall of these areas. A subsurface collection system should be installed at the base of each terrace to redirect water away from any retaining structures. Subsurface collection systems may also be necessary in low depressions of a non-uniform site, although it is recommended that these areas be left undisturbed so as to serve as natural stormwater retention areas. An appropriate receiving area for the water collected and concentrated by the subsurface drainage system must be provided.

Additional guidelines for this BMP can be found in Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in Ecology Stormwater Management Manual for Western Washington, which is available at www.soilsforsalmon.org under the "How-To" section, or at <www.buildingsoil.org>.

12.3.3 BMP 12.30 On-site Infiltration Areas

On-site infiltration areas are small on-site depressions or infiltration trenches. Only runoff from non-pollutant generating impervious and pervious surfaces may be discharged to on-site infiltration areas designed per this volume. Infiltration for stormwater treatment is covered in Chapter 9.

This section provides pre-sizing of on-site infiltration areas and may be used for the design of small infiltration areas if the contributing basin area meets the following criteria:

1. has a contributing impervious area, x, less than 2,000 square feet; and
2. has a contributing pervious area, y, less than 13,000 square feet; and
3. has a combination of impervious and pervious surfaces such that the "equivalent impervious area", as defined by the following equation, is less than 2,000 square feet:

$$\text{equivalent impervious area} = x + (y \div 6.5)$$

where

x = the square feet of impervious area in the contributing basin

y = the square feet of pervious area in the contributing basin

Infiltration areas with larger contributing basins must be designed in accordance with the criteria in Chapter 9 of this volume.

Sizing Criteria

The feasibility and size of on-site infiltration areas is determined using the 1983 USDA/SCS [now NRCS] Soil Survey of Snohomish County Area Washington. This information can be found by going to the following website:

www://websoilsurvey.nrcs.usda.gov/app/

The size of an on-site infiltration area shall be as follows, based upon the soil map unit found at the location of the proposed on-site infiltration area:

- Alderwood soils – 250 square feet of bottom area per 1,000 square feet of equivalent impervious area
- Everett, Indianola, Lynnwood, Puyallup, and Sumas soils – 150 square feet of bottom area per 1,000 square feet of equivalent impervious area.
- Custer and Winston soils – 60 square feet of bottom area per 1,000 square feet of equivalent impervious area.
- Bellingham, Cathcart, Kitsap, McKenna, Mukilteo, Norma, Pastik, Puget, Snohomish, Tokul, and Urban Land soils – may not be designed using this volume. See Chapter 9 to determine if infiltration is feasible.

Where the project site is located near the edge of a mapping unit, the largest size of system shall be used unless the soil unit is verified on site by a qualified geotechnical engineer.

Design Criteria

The following criteria shall also apply to on-site infiltration trenches:

1. Infiltration trenches shall have the basic cross section shown in Figure .
2. Maximum length of trench must not exceed 100 feet from the inlet sump.
3. Minimum spacing between distribution pipe centerlines must be 6 feet.
4. The aggregate material for infiltration trenches shall consist of 1.5- to three-fourth-inch washed round rock.
5. Geotextile filter fabric shall be wrapped entirely around the system drain rock prior to backfilling EXCEPT that a 6-inch layer of sand below the trench bottom may be used in-lieu of a filter fabric liner on the bottom.
6. Infiltration trenches shall not be placed under pavement or in fill.

12.3.4 BMP 12.40 Raingardens

In this manual, raingardens are small bioretention areas used as on-site stormwater management BMPs. Raingardens may be used to receive runoff from pollutant generating pervious and impervious surfaces, as well as areas where infiltration facilities are not feasible. Raingardens may be integrated into the landscaped areas of the lot.

The contributing basin area restrictions for BMP 12.30 On-site Infiltration Areas are also applicable to raingardens. Bioretention areas with larger contributing basins must be designed in accordance with the criteria in Chapter 10 of this volume.

Sizing Criteria

See sizing criteria for BMP 12.30 Onsite Infiltration Areas

Design Criteria

1. A minimum of 12-inches of bioretention soil shall be provided.
2. A minimum clearance of 1 foot is required between the lowest elevation of the bioretention soil and the seasonal high groundwater elevation or other impermeable layer.
3. Compaction of the base and sidewalls of the rain garden area shall be minimized.
    a. Excavation, soil placement, or soil amendment shall not be allowed during wet or saturated conditions.
    b. Excavation should be performed by machinery operating adjacent to the facility and no heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should be allowed on the bottom of the facility.
    c. If machinery must operate in the facility for excavation, light weight, low ground-contact pressure equipment should be used and the base shall be scarified to a minimum depth of 12 inches at completion to re-fracture the soil.
4. One of the following types of flow entrances shall be used:
    a. dispersed, low velocity flow across a grass or landscape area
    b. dispersed flow across pavement or gravel
    c. pipe flow entrance – piped entrances shall include rock or other erosion protection material in the facility entrance to dissipate energy and/or provide flow dispersion.
5. Woody plants shall not be placed directly in the entrance flow path as they can restrict or concentrate flows and can be damaged by erosion around the root ball.
6. A minimum 3-inch grade change between the edge of a contributing impervious surface and a vegetated flow entrance is required.
7. Raingardens shall not be planted until the upstream basin area is thoroughly stabilized.
8. The ponding depth in a rain garden shall be a maximum of 12 inches
9. Raingardens shall be planted with native plant species or hardy cultivars (see tables for specific guidelines for raingardens.
10. Small trees and shrubs (3 gallon size or less) shall be planted. Optimum planting time is typically fall (beginning mid October). Winter planting is acceptable; however, extended freezing temperatures shortly after installation can increase plant mortality. Spring is also acceptable, but requires more summer watering than fall plantings. Summer planting is the least desirable and requires regular watering for the dry months immediately following installation.
11. Rain gardens shall be designed with a mulch layer. Pure bark mulch shall not be used as bark is essentially sterile and inhibits plant establishment. Mulch shall be:
    a. compost or wood mulch (shredded or chipped).
    b. free of weed seeds, soil, roots and other material that is not trunk or branch wood and bark
    c. a maximum of 3 inches thick for compost or 4 inches thick for wood mulch

  d. free of grass clippings, or mineral aggregate

12. As an alternative to long-term mulching, a dense groundcover may be provided. Mulch is required in conjunction with the groundcover until groundcover is established.

13. The size of a rain garden shall be as follows, based upon the soil map unit found at the location of the proposed on-site infiltration area:

    a. Alderwood soils – 250 square feet of bottom area per 1,000 square feet of equivalent impervious area

    b. Everett, Indianola, Lynnwood, Puyallup, and Sumas soils – 150 square feet of bottom area per 1,000 square feet of equivalent impervious area.

    c. Custer and Winston soils – 60 square feet of bottom area per 1,000 square feet of equivalent impervious area.

    d. Bellingham, Cathcart, Kitsap, McKenna, Mukilteo, Norma, Pastik, Puget, Snohomish, Tokul, and Urban Land soils – may not be designed using this volume. See Volume III to determine if infiltration is feasible.

12.3.5 BMP 12.50 Downspout Dispersion Systems

Downspout dispersion systems are gravel-filled trenches or splash blocks, which serve to spread roof runoff over vegetated pervious areas. Dispersion attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits. General applicability of downspout dispersion is as follows:

- Dispersing roof runoff shall be considered after infiltration and bioretention techniques have been determined infeasible due to soil types or high groundwater.

- The layout of natural resource protection areas adjacent to and down gradient of individual lots can provide opportunities to disperse runoff into the natural resource protection area.

Design Criteria

This section provides design criteria for both dispersion trenches and splash blocks:

1. A vegetated flowpath of at least 25 feet in length must be maintained between the outlet of a trench and any property line; structure; critical area (i.e., stream, wetland), or impervious surface. Natural resource protection areas and critical area buffers may count towards flowpath lengths. However, the area must be permanently protected from modification through a covenant or easement, or a tract dedicated by the proposed project. This does not include steep slopes. See steep slope setbacks are outlined below.

2. Trenches serving up to 700 square feet of roof area may be simple 10-foot long by 2-foot wide gravel filled trenches as shown in Figure 3.3. For roof areas larger than 700 square feet, a dispersion trench with notched grade board as shown in DCSS Drawing #4?? shall be used. The total length of this design must not exceed 50 feet and must provide at least 10 feet of trench per 700 square feet of roof area.

3. A cleanout structure shall be provided prior to discharge into the dispersal area. The structure shall include a lid, 1-foot minimum sump, and T-type outlet with screen as shown in DCSS Drawing #4?? .

4. Splash blocks may be used for downspouts discharging to a vegetated flow path at least 10 feet in width and 50 feet in length as measured from the downspout to the downstream property line; structure; critical areas (i.e., stream, wetland), or other impervious surface. Flow path

measurement may traverse a property line into an adjacent natural resource protection area or critical area buffer-provided that the area is permanently protected through a covenant, easement, or a tract dedicated as part of the proposed project. This **does not** include steep slopes. See steep slope setbacks below.

5. A maximum of 700 square feet of roof area may drain to each splash block. When flow paths of multiple splash blocks are combined the vegetated flow path width shall increase by 50 percent with each additional splashblock.
6. For both trenches and splashblocks, the vegetated flowpath must be covered with well-established vegetation to prevent erosion and promote partial infiltration. Vegetated flowpaths shall consist of undisturbed native landscape area or an area that meets the requirements of Section 3.14.

12.3.6 BMP 12.60 Concentrated Flow Dispersion

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

Applicability

- Any situation where concentrated flow can be dispersed through vegetation.
- Dispersion for driveways will generally only be effective for single-family residences on large lots or those adjacent to a native growth protection area. Typical lots in the City will generally be too small to provide effective dispersion of driveway runoff.

Design Criteria

1. A vegetated flowpath of at least 50 feet must be maintained between the discharge point and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface.
2. A maximum of 700 square feet of impervious area may drain to each concentrated flow dispersion BMP.
3. A pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each discharge point.

12.3.7 BMP 12.70 Sheet Flow Dispersion

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

Applicability

Flat or moderately sloping (less than 15 percent slope) impervious surfaces such as driveways, sport courts, patios, and roofs without gutters; sloping cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture; or any situation where concentration of flows can be avoided.

Design Criteria

1. A 2-foot-wide transition zone to discourage channeling should be provided between the edge of the driveway pavement and the downslope vegetation, or under building eaves. This may be an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material approved by the City.

2. A vegetated buffer width of 10 feet of vegetation must be provided for up to 20 feet of width of paved or impervious surface. An additional 5 feet of width must be added for each additional 20 feet of width or fraction thereof.

3. A vegetated buffer width of 25 feet of vegetation must be provided for up to 150 feet of contributing cleared area (i.e., bare soil, non-native landscaping, lawn, and/or pasture). Slopes within the 25-foot minimum flowpath through vegetation must be no steeper than 8 percent. If this criterion cannot be met due to site constraints, the 25-foot flowpath length must be increased 1.5 feet for each percent increase in slope above 8 percent.

Chapter 13 - Emerging Technologies

This chapter addresses emerging (new) technologies that have not been evaluated in sufficient detail to be acceptable for general usage in new development or redevelopment situations.

13.1 Background

Emerging technologies are new technologies that have not been evaluated using approved protocols, but for which preliminary data indicate that they may provide a desirable level of stormwater pollutant removal. Some emerging technologies have already been installed in Washington as parts of treatment trains or as stand-alone systems for specific applications. In some cases, emerging technologies are necessary to remove metals, hydrocarbons, and nutrients. Emerging technologies can also be used for retrofits and where land availability is unavailable for larger natural systems.

13.2 Evaluation of Emerging Technologies

In the past, Ecology participated in a process to evaluate emerging technologies for permanent and construction site stormwater runoff applications and to convey judgments made by local jurisdictions and others on their acceptance. Based on performance and other pertinent data from vendors and manufacturers and recommendations by the review committees, Ecology assessed levels of developments of emerging technologies and posted relevant decisions and supporting documentation at its stormwater Web site. This process is currently on hold as Ecology evaluates alternative ways to approve emerging technologies. Technologies already submitted will be reviewed, but delays are expected.

13.3 Applicability and Restrictions

The City has chosen, in most instances, to allow the use of new technologies in the City when they achieve a General Use Level Designation (GULD) from Ecology, provided that the design criteria specified by Ecology are used. The City Engineer also has the authority to add additional requirements or conditions to these technologies, beyond those required by Ecology.